



Hopewell Furnace National Historic Site and Valley Forge National Historical Park

Weather of 2009

Natural Resource Data Series NPS/MIDN/NRDS—2010/092



ON THE COVER

Lafayette's Quarters, Valley Forge National Historical Park.
Photograph by: James A. Comiskey, National Park Service.

Hopewell Furnace National Historic Site and Valley Forge National Historical Park

Weather of 2009

Natural Resource Data Series NPS/MIDN/NRDS—2010/092

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September 2010

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Please cite this publication as:

Knight, P., T. Wisniewski, C. Bahrmann, and S. Miller. 2010. Hopewell Furnace National Historic Site and Valley Forge National Historical Park: Weather of 2009. Natural Resource Data Series NPS/MIDN/NRDS—2010/092. National Park Service, Fort Collins, Colorado.

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List of Key Acronyms

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
NADP	National Atmospheric Deposition Program
NARR	North American Regional Reanalysis
NCDC	National Climatic Data Center
NHP	National Historical Park
NHS	National Historic Site
NWS	National Weather Service
PDSI	Palmer Drought Severity Index
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RAWS	Remote Automated Weather Stations
USDM	United States Drought Monitor
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 the 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, 2009, and to place current patterns and trends in an appropriate historical, regional, and global context (Knight et al., in preparation). 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 long-term trends in weather and climate through seasonal and annual summaries of selected parameters (e.g., multiple forms of precipitation, temperature).
- Identify and document extremes and averages of climatic conditions for common parameters (e.g., precipitation, air temperature) and other parameters where sufficient data are available (e.g., wind speed and direction, solar radiation).
- Provide information on near real-time weather parameters, historical climate patterns, and climate station metadata from a single, easy-to-use Internet portal.

To accomplish these objectives, 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 (Knight et al., in preparation). 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 2009's climate summary and trends.

In addition to a suite of summary tables, graphs, and narratives, we specifically identify a series of key climatological 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 (Knight et al., in preparation) and 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, 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/usclimate/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 will direct 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 for the parks typically occurs in early May and the first frosts appear in October.

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, while 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 reaches 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

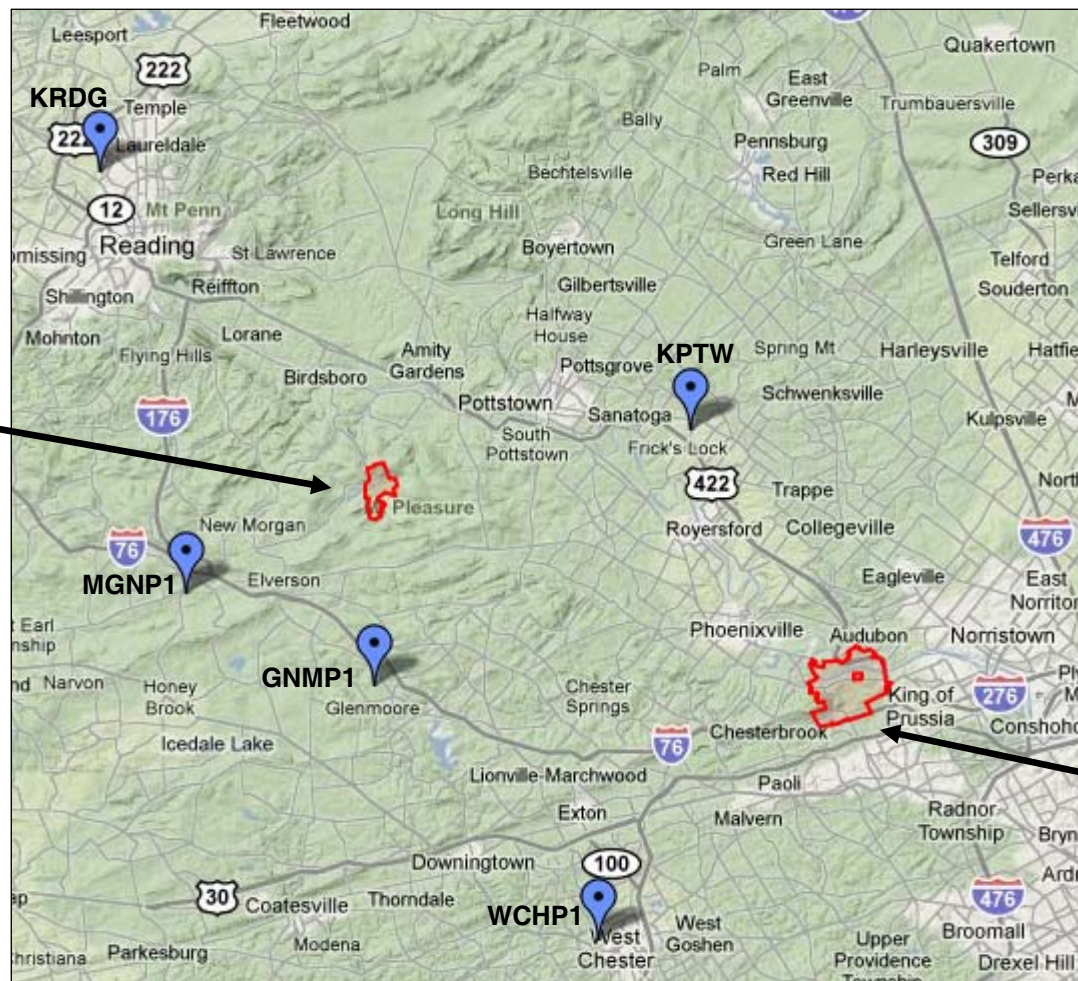
A total of 14 weather observing stations comprised of five weather observing networks were selected around Hopewell Furnace NHS and Valley Forge NHP. Representative stations within a 100-km range of each park were chosen based on several criteria, which include proximity to the parks, the representativeness of the station to the park elevation profile, the type and frequency of observations, the period of record of the data, and data availability (Knight et al., in preparation). A subset of these weather observing networks (GOES and CWOP; seven total stations) are not yet utilized for these reports due to limited data availability and/or lack of data quality assurance (Bureau of Land Management 1997). Moreover, the percentage of time a station reports a particular parameter (e.g., temperature) can influence data inclusion. A total of five stations were ultimately used for this 2009 report: Glenmoore, West Chester, Morgantown, Pottstown, and Reading (Figure 1, Table 1)

Of the five stations, Glenmore, West Chester, and Morgantown have a Period of Record (POR) sufficiently long for a 30-year normal (1971–2000). 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 Glenmore does not report temperature. Glenmore 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 and departures.

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/gmaps/NPS_DEVELOPMENT/interface.php.

**Hopewell
Furnace
National
Historic Site**



**Valley Forge
National
Historical
Park**

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 2009.

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 2009.

Station	Observing Network	Station Name	Period of Record (POR)		Percentage of Time Reporting Temperature for 2009	Percentage of Time Reporting Precipitation for 2009	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	-	99.5
WCHP1	COOP	West Chester	01/01/1893	Present	99.7	99.7	89.7	88..5
MGNP1	COOP	Morgantown	06/01/1951	Present	-	100.0	94.3*	60.7
KPTW	FAA	Pottstown	01/01/1999	Present	98.9	98.9	96.8	96.8
KRDG	FAA	Reading	01/01/1973	Present	98.4	98.4	97.6	29.4

*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 of 2009 in Hopewell Furnace NHS and Valley Forge NHP was cooler than the long-term mean, with annual temperatures 1.1°F (0.7°C) below average (Table 2). Daytime maximum temperatures were consistently lower than normal, with only four months experiencing above average readings at night (Figures 2 and 3)¹.

January, as expected, was the coldest month of the year and also produced the largest negative departures (Figures 2 and 3). Temperatures averaged between 3.4–4.7°F (1.9–2.6°C) below the norm (Tables 3 and 4). The lowest readings of the year occurred at mid-month with a value of -1.0°F (-18.3°C), which is normal (Table 2). Above-average temperatures returned in February which ranged from 0.4–2.4°F (0.2–1.4°C) warmer than normal (Table 4). The number of cold days, where maximum temperatures do not reach 32°F (0°C), was slightly above the long-term average with 23 days compared with an average of 20 (Table 2). Temperatures during March were close to normal, with only a 0.3°F (0.2°C) departure above normal in Pottstown (near Hopewell Furnace NHS) and a 1.8°F (0.7°C) departure below average in West Chester (near Valley Forge NHP) (Table 4). The winter months ranked as the 52nd coolest in 115 years based in the Southeastern Piedmont which encompasses both parks (Table 5).

The spring began mild, with mean temperatures above average in April (Figures 2 and 3). May had cooler-than-average days and milder-than-normal nights, resulting in temperatures that ranged from -0.3 to +1.1°F (-0.2 to +0.6°C) from normal across the region (Table 4). June was decidedly cooler than average. The spring months ranked as the 52nd warmest in 115 years (Table 5).

The summer months were dominated by a very cool July, leading to the 27th coolest in 115 years in the Southeastern Piedmont (Table 5). Readings in July varied from 2.3–3.1 °F (1.3–1.7°C) below average (Table 4), and the number of hot days tallied only nine days compared with an average of 19 occurrences in a typical year (Table 2). August was the warmest month of the year, as mean temperatures ranged from 74.1°F (23.4°C) at Reading to 75.0°F (23.9°C) at West Chester (Table 3). September was another month with cooler-than-average days and milder-than-normal nights (like May 2009) and averaged slightly below the long-term values (Figures 2 and 3). The highest reading of the year was 92.0°F (33.3°C), which is lower than the average of 96.0°F (35.6°C) (Table 2).

Autumn was warmer than average, ranking 44th warmest (Table 5). Temperatures in October varied from 0.1–4.2°F (0–2.3°C) (Table 4) below normal due to chilly days (Figure 2). November brought a complete reversal with the highest positive anomalies of the year. Temperatures averaged 3.5–5.3°F (2–3°C) above the long-term average (Table 4). December was cooler than average with chilly days and mild nights (Figures 2 and 3). The total growing season length was 178 days, or 4 days longer than the 30-year average.

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/>.

Hopewell Furnace National Historic Site
and Valley Forge National Historical Park
Departure from Average Monthly Maximum Temperature
2009 vs. 1971–2000

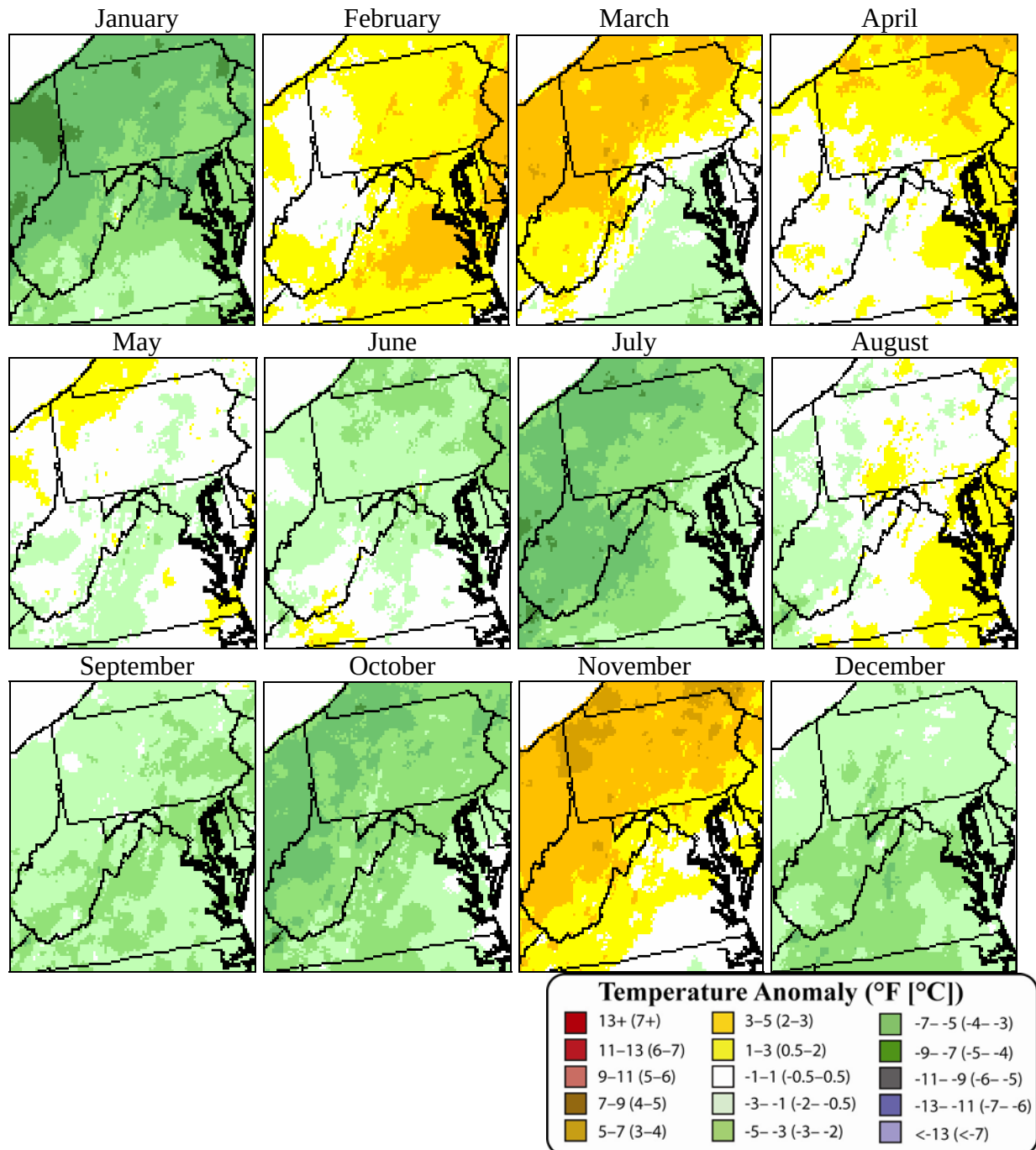


Figure 2. Maps showing departure from average monthly maximum temperature compared to the 30-year normal (1971–2000).

Hopewell Furnace National Historic Site
and Valley Forge National Historical Park
Departure from Average Monthly Minimum Temperature
2009 vs. 1971–2000

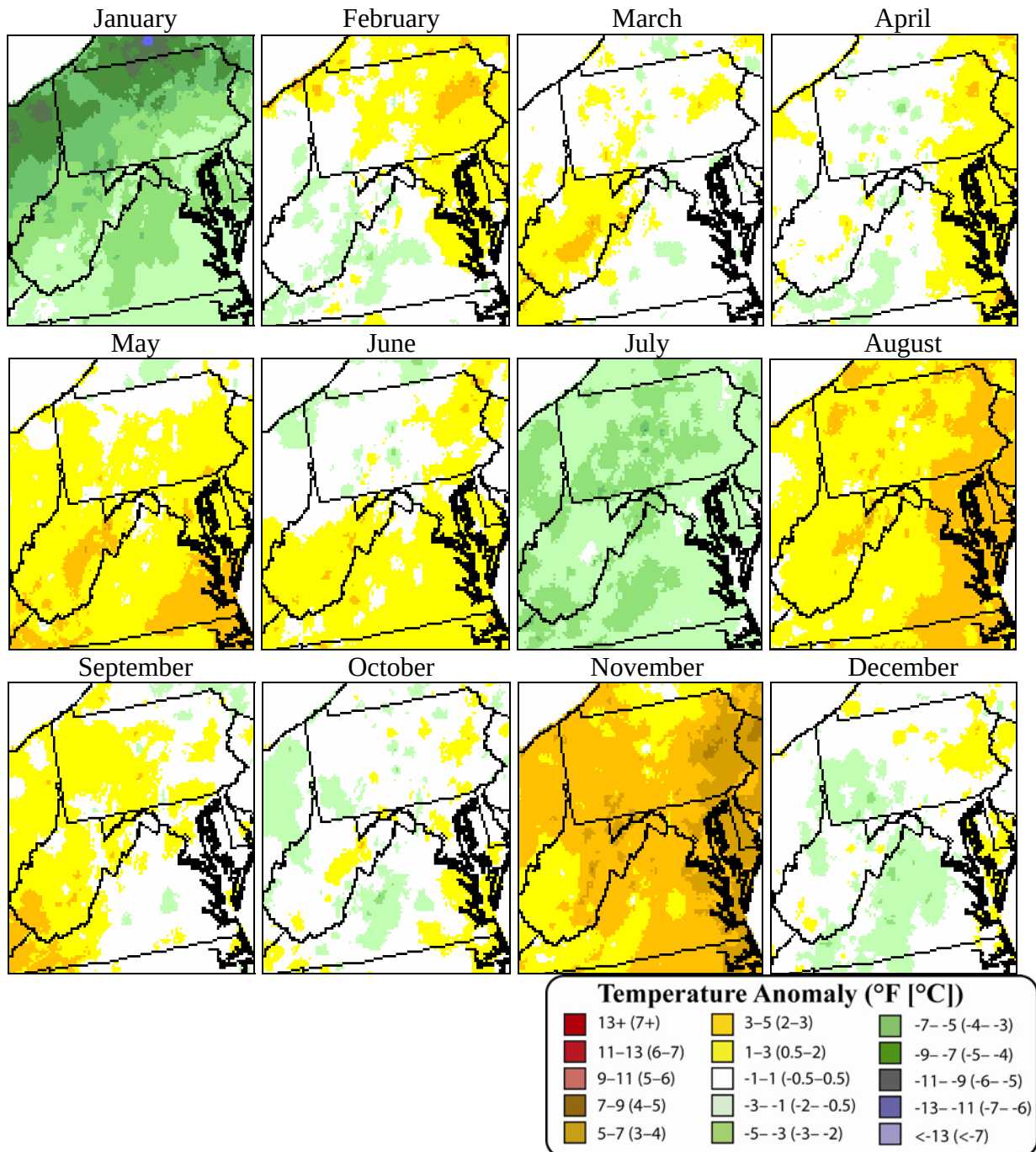


Figure 3. Maps showing departure from average monthly minimum temperature compared to the 30-year normal (1971–2000).

Table 2. Status of 2009 temperature indicators compared to the 30-year normal (1971–2000) at the West Chester (WCHP1) weather observing station.

Temperature Indicator	West Chester, PA 2009	West Chester, PA 1971–2000
Average Annual Temperature	51.7°F 10.9°C	52.8°F 11.6°C
Average Annual Maximum Temperature	62.1°F 16.7°C	63.8°F 17.7°C
Summer Maximum (highest temperature)	92.0°F 33.3°C	96.0°F 35.6°C
Hot Days (days with Tmax≥90°F/32°C)	9	19
Average Annual Minimum Temperature	41.4°F 5.2°C	41.9°F 5.5°C
Winter Minimum (lowest temperature)	-1.0°F -18.3°C	-0.6°F -18.1°C
Cold Days (days with Tmax≤32°F/0°C)	23	20
Sub-freezing Nights (days with Tmin≤32°F/0°C)	124	115
Cold Winter Nights (days with Tmin≤0°F/-17.8°C)	2	2
Growing Season Length (days between last spring 32°F/0°C and first fall 32°F/0°C)	178	174

Table 3. Summary of 2009 monthly average temperatures for selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
West Chester	WCHP1	25.4°F	33.2°F	39.5°F	51.6°F	61.1°F	68.4°F	71.6°F	75.0°F	63.7°F	49.6°F	48.2°F	32.9°F	51.7°F
		-3.7°C	0.6°C	4.1°C	10.9°C	16.2°C	20.2°C	22.0°C	23.9°C	17.6°C	9.8°C	9.0°C	0.5°C	10.9°C
Pottstown	KPTW	26.5°F	34.8°F	42.0°F	54.0°F	62.8°F	68.7°F	72.4°F	74.9°F	65.1°F	54.5°F	49.9°F	35.2°F	53.4°F
		-3.0°C	1.6°C	5.6°C	12.2°C	17.1°C	20.4°C	22.5°C	23.8°C	18.4°C	12.5°C	10.0°C	1.8°C	13.3°C
Reading	KRDG	25.6°F	34.0°F	41.9°F	53.8°F	62.6°F	69.1°F	72.3°F	74.1°F	64.6°F	53.5°F	48.7°F	34.0°F	52.9°F
		-3.5°C	1.1°C	5.5°C	12.1°C	17.0°C	20.6°C	22.4°C	23.4°C	18.1°C	11.9°C	9.3°C	1.1°C	13.0°C

Table 4. Summary of 2009 departure from normal temperature based on 30-year normal (1971–2000) for selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
West Chester	WCHP1	-4.7°F	0.4°F	-1.8°F	0.1°F	-0.3°F	-1.6°F	-3.1°F	2.1°F	-1.6°F	-4.2°F	3.5°F	-2.0°F	-1.1°F
		-2.6°C	0.2°C	-1.0°C	0.0°C	-0.2°C	-0.9°C	-1.7°C	1.2°C	-0.9°C	-2.3°C	2.0°C	-1.1°C	-0.6°C
Pottstown*	KPTW	-3.6°F	1.8°F	0.3°F	2.2°F	0.6°F	-2.1°F	-2.7°F	1.7°F	-0.8°F	-0.1°F	5.3°F	0.3°F	0.3°F
		-2.0°C	1.0°C	0.2°C	1.2°C	0.3°C	-1.2°C	-1.5°C	1.0°C	-0.5°C	0.0°C	3.0°C	0.2°C	0.2°C
Reading*	KRDG	-3.4°F	2.4°F	1.1°F	2.8°F	1.1°F	-0.9°F	-2.3°F	1.2°F	-0.8°F	-0.4°F	4.4°F	-0.3°F	0.4°F
		-1.9°C	1.4°C	0.6°C	1.6°C	0.6°C	-0.5°C	-1.3°C	0.6°C	-0.5°C	-0.2°C	2.4°C	-0.2°C	0.2°C

*Indicates a station's Period of Record is 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 temperature and precipitation rankings over 115 years for the Southeastern Piedmont (NOAA 2010).

Climate Division 3 Rankings Southeastern Piedmont	Jan–Feb–Mar WINTER	Apr–May–Jun SPRING	Jul–Aug–Sep SUMMER	Oct–Nov–Dec AUTUMN
Temperature-2009	63	52	88	44
Precipitation-2009	115	15	14	11

1 = warmest/wettest year and 115 = coldest/driest year

Precipitation Summary

Almost two additional months of average precipitation fell at Hopewell Furnace NHS and Valley Forge NHP in 2009 (Table 6). Three of the four seasons finished with much-above-average precipitation after the driest winter in 115 years (Table 5).

The first three months of 2009 raised concerns about a serious drought (Figure 4). In fact, the Palmer Drought Severity Index (PDSI) dropped precipitously from near-normal to moderate drought levels (-2) by late March (see next section, Figure 5). There were two long dry spells during the winter season. No measurable precipitation was noted from February 5–14 and again from March 4–16 (Table 7). By the end of March, most of the park areas had received less than 40% of normal rainfall (Tables 8 and 9).

Spring became progressively wetter (Figure 4). April brought near normal rainfall, but May turned wet and June was the second wettest month of the year with total rainfall ranging from 4.7 in (119 mm) to 6.1 in (154 mm) (Tables 8 and 9). Overall, this season ranked as the 15th wettest in 115 years of records in the Southeastern Piedmont.

Summer's rainfall was very irregular. Long dry spell ended with excessive precipitation on two occasions. July 4–11 had no measurable rain, but the region was inundated with 2.3 in (58 mm) on July 12. No rain was measured from August 31–September 9, but a total of 1.8 in (46 mm) was registered on September 12. In fact, the wettest day of year occurred August 13 when 3.1 in (78 mm) of rain fell (Table 7). There were no direct or indirect effects from tropical cyclones during the summer of 2009 in southeastern Pennsylvania. The end result was a three month period from July–September ranked as the 14th wettest in 115 years of records, with August being the wettest month of the year (Tables 8 and 9).

Yet another very wet autumn was tallied around Hopewell Furnace NHS and Valley Forge NHP in 2009. Total precipitation during October–November and December exceeded the 30-year mean by 7.1 in (178 mm) at West Chester, PA (Table 6). There were two very wet days during the fall; 2.2 in (56 mm) of rain fell on October 25, and 2.0 in (51 mm) was measured on December 9 (Table 7). Twenty days with more than 1 in (25.4 mm) of rain were noted in 2009; exceeding the long-term mean of 13 days. However, the occurrence of extreme rainfall, more than 2 in (51 mm), was average with two each at both West Chester and Glenmoore (Table 6). The autumn ranked as the 11th wettest for the Southeastern Piedmont (Table 5). Snowfall averaged above the annual normal with an additional 7.5 in (19 cm) tallied at West Chester, much of which fell in December (Table 6). The number of days with measurable snow totaled from 16–18 days, above the average of 12 days, but the occurrence of moderate and heavy snow was average (Table 6).

Table 6. Status of 2009 precipitation indicators compared to the 30-year normal (1971–2000) at the West Chester (WCHP1) and Glenmoore (GNMP1) weather observing stations.

Precipitation Indicator	West Chester, PA 2009	West Chester, PA 1971–2000	Glenmoore, PA 2009	Glenmoore, PA 1971–2000
Annual Precipitation	54.3 in 1,379 mm	47.9 in 1,217 mm	55.9 in 1,420 mm	48.6 in 1,234 mm
Autumn (Oct, Nov, Dec) Precipitation	18.3 in 465 mm	11.2 in 285 mm	15.8 in 401 mm	11.2 in 285 mm
Heavy Rain (days with ≥ 1.0 in (25 mm) rain)	20	13	13	14
Extreme Rain (days with ≥ 2.0 in (51 mm) rain)	2	3	2	2
Micro-drought (strings of 7+ days without rain)	6	8	5	9
Annual Snowfall	34.7 in 88.1 cm	27.2 in 69.1 cm	32.6 in 82.8 cm	27.3 in 69.3 cm
Snow (days with ≥ 0.1 in (0.3 cm) snow)	16	12	18	12
Moderate Snow (days with ≥ 2.0 in (5.0 cm) snow)	6	5	7	5
Heavy Snow (days with ≥ 5.0 in (12.7 cm) snow)	1	1	1	1

Hopewell Furnace National Historic Site
and Valley Forge National Historical Park
Percent of Average Monthly Precipitation
2009 vs. 1971–2000

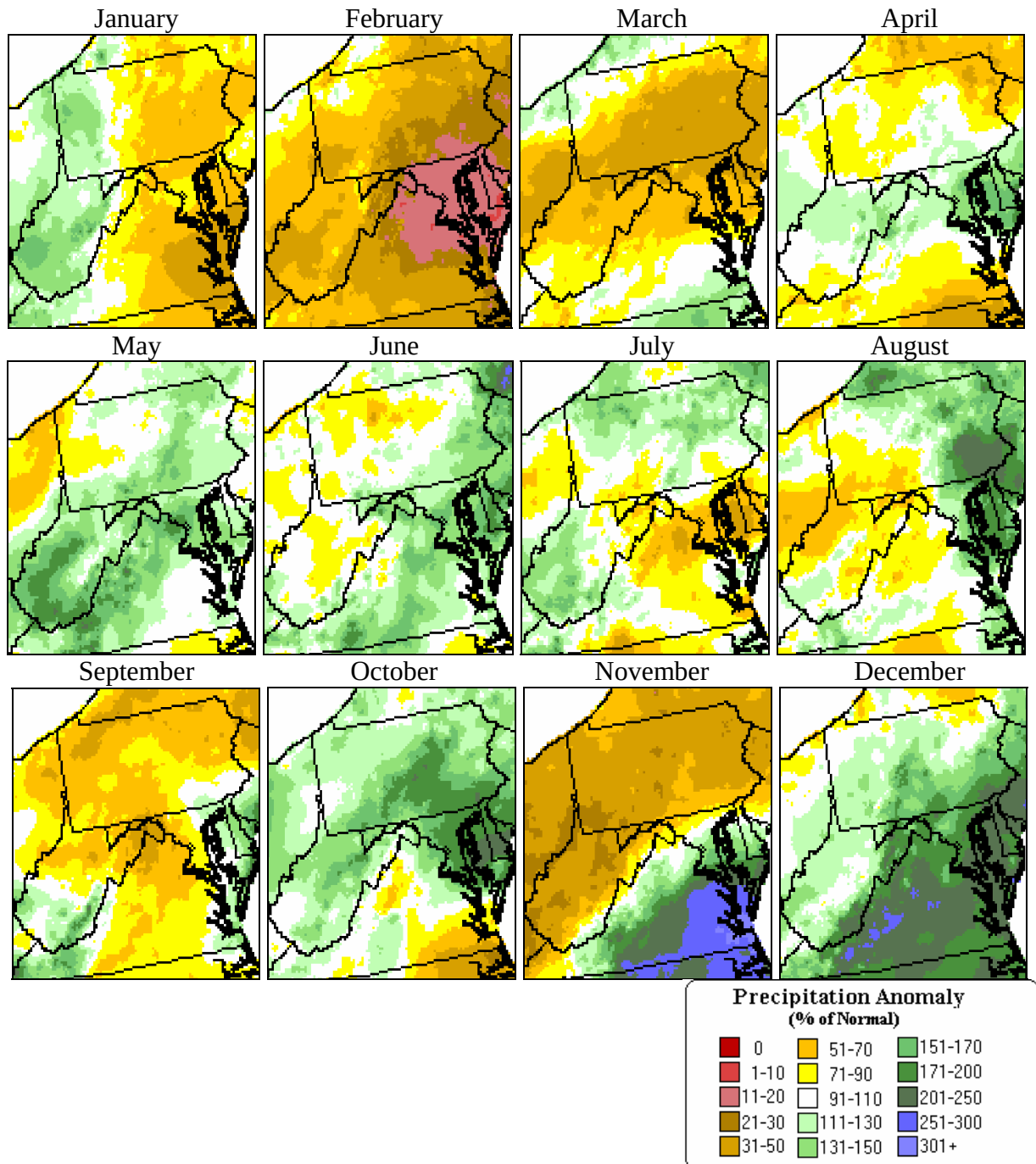


Figure 4. Maps showing percent of average monthly precipitation compared to the 30-year normal (1971–2000).

Table 7. Top five wettest days and top five dry spells (consecutive days with a trace or less of rainfall) during 2009 from weather observing stations at West Chester (WCHP1) and Glenmoore (GNMP1).

Wettest Days in 2009	Dry Spells in 2009
Aug. 13: 3.1 in (78 mm)	Mar. 4–16
Jul. 12: 2.3 in (58 mm)	Aug. 31–Sept. 9
Oct. 25: 2.2 in (56 mm)	Feb. 5–14
Dec. 9: 2.0 in (51 mm)	Jul. 4–11
Sep. 12: 1.8 in (46 mm)	May 18–24

Table 8. Summary of 2009 monthly total precipitation for selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Glenmoore	GNMP1	2.7 in	0.7 in	1.6 in	4.1 in	5.9 in	6.0 in	6.1 in	8.5 in	4.4 in	6.2 in	2.1 in	7.5 in	55.9 in
		70 mm	17 mm	40 mm	104 mm	150 mm	153 mm	156 mm	217 mm	112 mm	157 mm	54 mm	191 mm	1,419 mm
West Chester	WCHP1	2.7 in	0.5 in	1.4 in	4.2 in	6.2 in	4.7 in	2.7 in	9.3 in	4.3 in	7.9 in	1.7 in	8.7 in	54.3 in
		70 mm	13 mm	35 mm	106 mm	156 mm	119 mm	69 mm	236 mm	109 mm	201 mm	44 mm	221 mm	1,378 mm
Morgantown	MGNP1	2.3 in	0.5 in	1.7 in	4.2 in	6.3 in	5.8 in	6.9 in	8.7 in	3.9 in	5.5 in	2.8 in	7.0 in	55.6 in
		58 mm	14 mm	43 mm	106 mm	160 mm	148 mm	174 mm	221 mm	100 mm	141 mm	71 mm	178 mm	1,413 mm
Pottstown	KPTW	2.3 in	0.6 in	1.1 in	3.3 in	5.6 in	6.0 in	4.8 in	7.1 in	4.8 in	5.2 in	1.3 in	5.8 in	47.9 in
		59 mm	15 mm	29 mm	85 mm	141 mm	153 mm	121 mm	180 mm	123 mm	131 mm	34 mm	147 mm	1,217 mm
Reading	KRDG	1.8 in	0.5 in	2.0 in	2.4 in	4.9 in	6.1 in	4.2 in	7.4 in	3.2 in	4.6 in	1.8 in	5.1 in	43.9 in
		46 mm	12 mm	51 mm	61 mm	124 mm	154 mm	107 mm	188 mm	82 mm	116 mm	46 mm	128 mm	1,115 mm

Table 9. Summary of 2009 percent of normal total precipitation based on 30-year normal (1971–2000) for selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Glenmoore	GNMP1	66	21	38	99	131	143	131	211	99	171	55	200	115
West Chester	WCHP1	69	17	34	113	135	110	58	251	90	236	42	229	113
Morgantown	MGNP1	54	17	41	101	140	138	146	216	89	153	73	187	114
Pottstown*	KPTW	66	22	28	95	131	164	115	200	112	168	38	161	109
Reading*	KRDG	49	17	56	65	108	139	103	205	74	139	51	153	98

*Indicates a station's Period of Record is 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.

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 2009 are shown in Figure 5.

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 2010). 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 2009.

According to the USDM, 2009 started with a quickly deepening drought which reached close to moderate drought levels (near -2) by late March (Figure 5). Regular rains returned during April and the remainder of the year was moderately moist to very moist (values between $+2$ and $+4$). When compared to previous years, 2009 had the driest winter, an average spring, a wetter summer, and a very wet autumn.

The DM – Drought Severity Index for Pennsylvania (Figure 6) and the Northeast (Figure 7) shows a pattern similar to the PDSI for the growing season (May through October); with May being the driest.

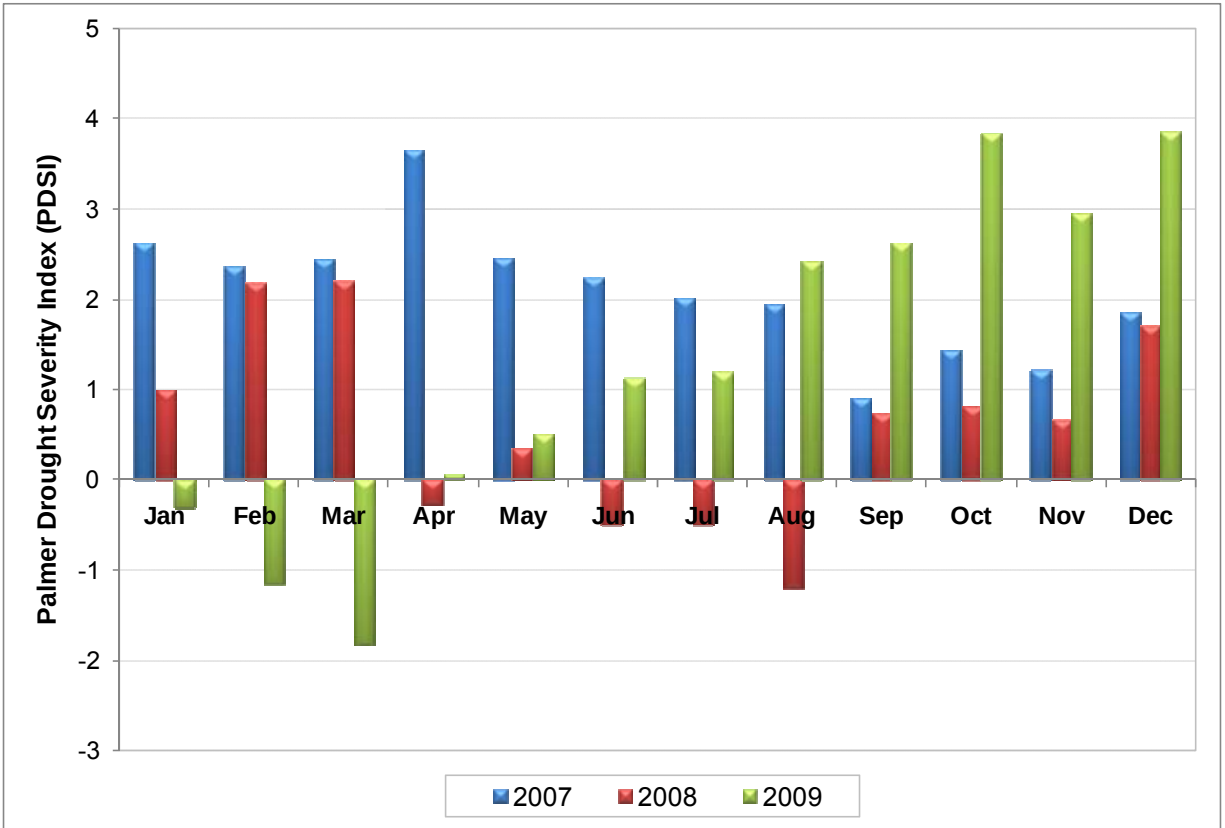


Figure 5. Palmer Drought Severity Index (PDSI) for the Southeastern Piedmont, 2007–2009.

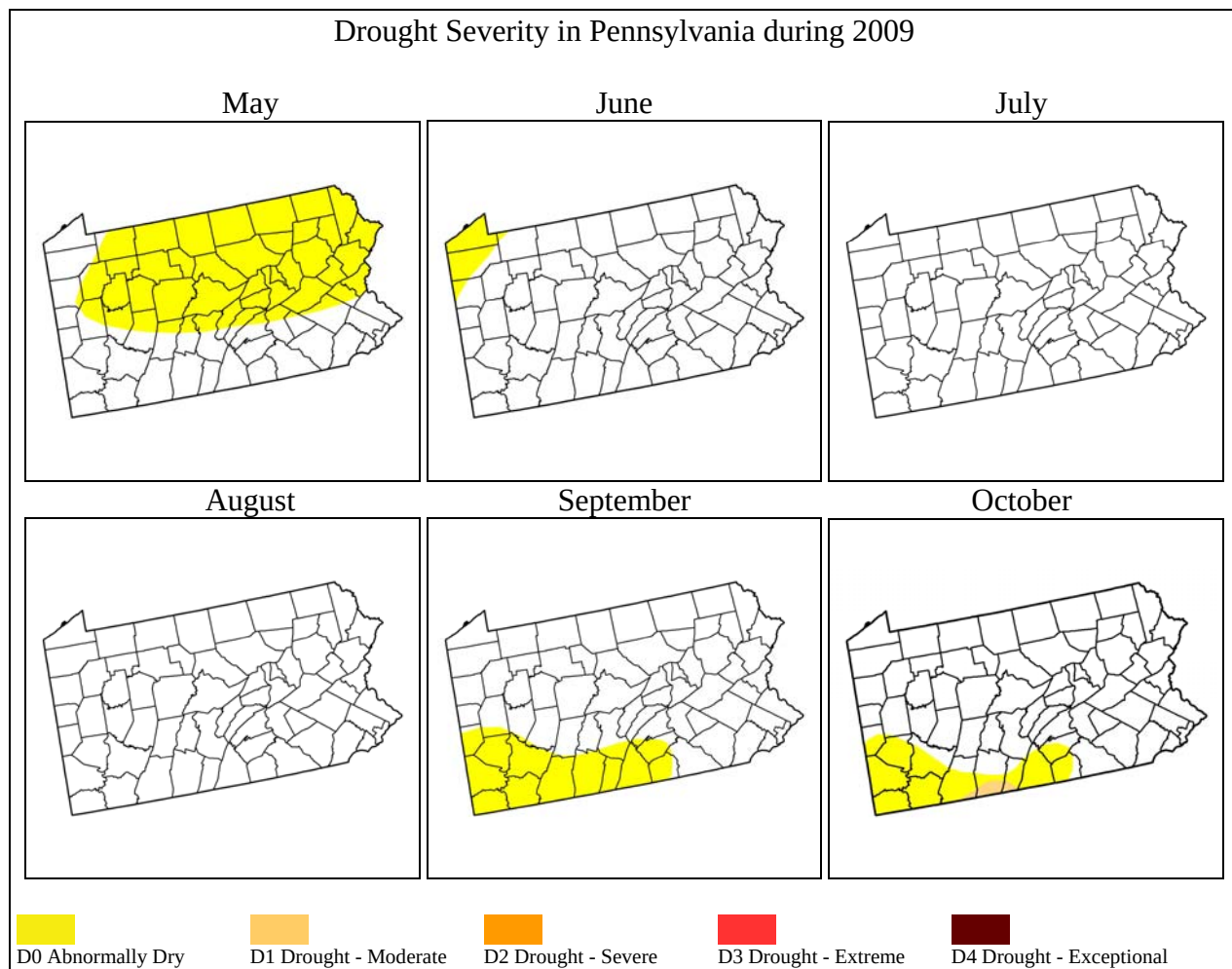


Figure 6. Mid-month values of the Palmer Drought Severity Index for Pennsylvania in 2009.

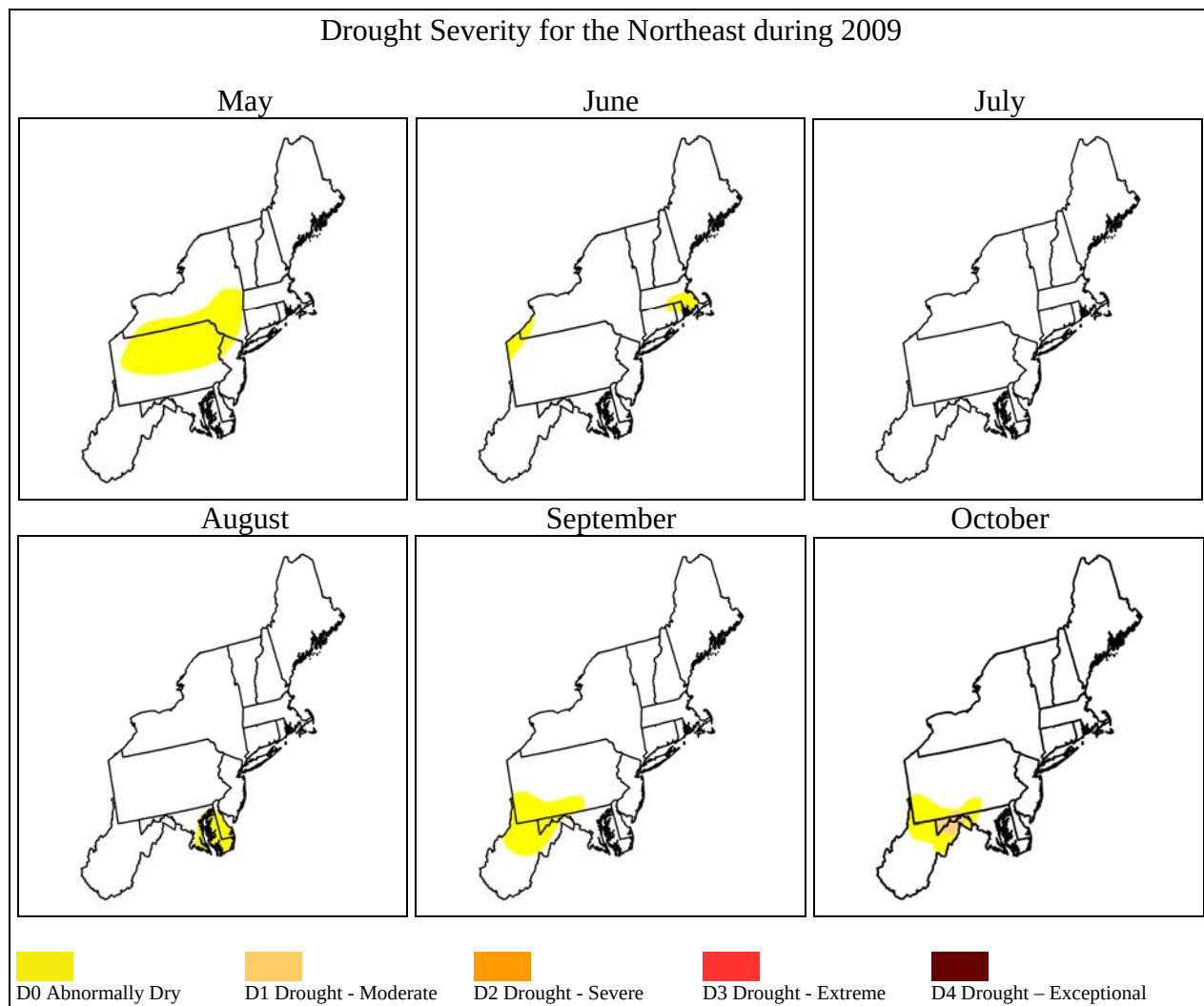


Figure 7. Mid-month values of the Palmer Drought Severity Index (PDSI) for the Northeast in 2009.

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NPS 376/105731, 464/105731, September 2010

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