



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

Mid-Atlantic Network Summary Report for 2011

Natural Resource Data Series NPS/MIDN/NRDS—2012/340



ON THE COVER

National Memorial Arch, Valley Forge National Historical Park.
Photograph by: Abbie Brown.

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Natural Resource Data Series NPS/MIDN/NRDS—2012/340

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

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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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, 2011, 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 2011'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 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/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 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, 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 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 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 (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 2011 report: Glenmoore, West Chester, Morgantown, Pottstown, Reading, and Valley Creek (Figure 1, Table 1)

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 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 will be 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 be the 30-year normal or the pseudo-normal calculated on a shorter time frame

Of the six stations, Glenmoore, West Chester, and Morgantown have a Period of Record (POR) sufficiently long for a 30-year normal (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/gmaps/NPS_DEVELOPMENT/interface.php.

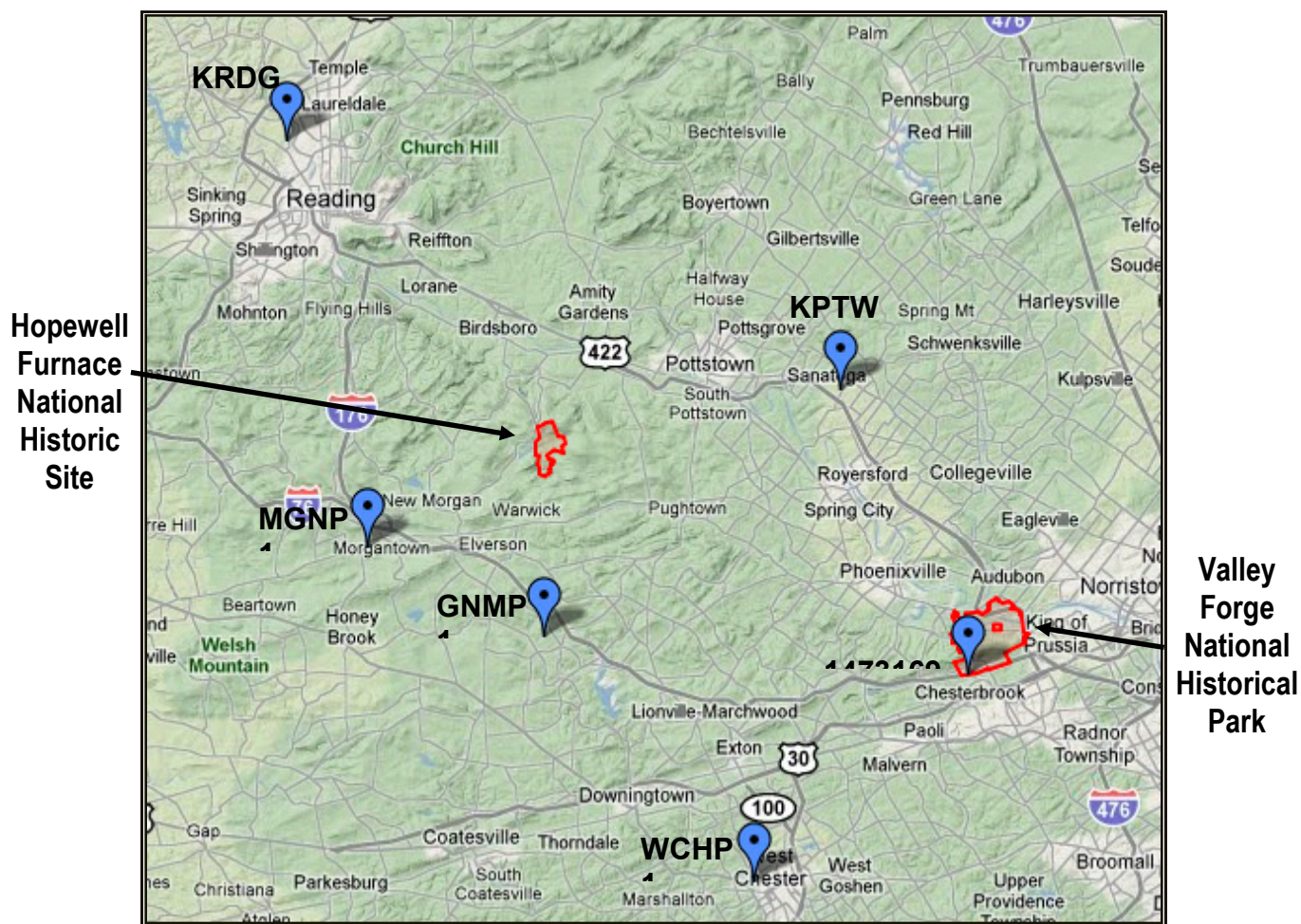


Figure 1. Location of weather observing stations around Hopewell Furnace National Historic Site and Valley Forge National Historical Park selected as most representative of the parks in 2011. See Table 1 for station names.

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 2011.

Station	Observing Network ¹	Name	Period of Record (POR)		Percentage of Time Reporting Temperature for 2011	Percentage of Time Reporting Precipitation for 2011	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	94.5 ²	99.3
WCHP1	COOP	West Chester 2 NW	01/01/1893	Present	98.4	98.6	89.9	88.7
MGNP1	COOP	Morgantown	06/01/1951	Present	-	100.0	86.4 ³	60.6
KPTW	ASOS	(Pottstown) Heritage Field Airport	01/01/1999	Present	96.2	96.2	97.0	97.0
KRDG	ASOS	Reading Regional Airport/Carl A. Spaatz Field	01/01/1973	Present	100.0	100.0	97.8	32.9
1473169	USGS	Valley Creek	10/01/2005	Present	-	100.0	-	98.4

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 2011 for the area around Hopewell Furnace NHS and Valley Forge NHP was notably warmer than the long-term mean, with annual temperatures 2.1°F (1.1°C) above average (Table 2). Daytime maximum temperatures were consistently higher than normal from February through September with only one month, January, experiencing below average readings at night (Figures 2 and 3)¹.

January produced the largest negative departures (Figures 2 and 3) for the early half of 2011. Temperatures averaged between 2.6°F to 3.5°F (1.7°C to 1.9°C) below the norm (Tables 3 and 4). The lowest readings of the year occurred on January 23rd with a value of -2.0°F (-18.9°C), which is slightly below the normal value (Table 2). Above-average temperatures returned in February and March which ranged as much as 2.4°F (1.3°C) warmer than normal (Table 4). The number of cold days, where maximum temperatures do not reach 32°F (0°C), was slightly below the long-term average with 13 days compared with an average of 16 (Table 2). The winter months ranked 63rd warmest in 117 years in the Southeastern Piedmont, which encompasses both parks (Table 5).

The spring was very warm with May tallying the largest positive departures (Figures 2 and 3). April had only somewhat above-normal days and milder-than-normal nights, resulting in temperatures that ranged from 3.2°F to 5.3°F (1.8°C to 2.9°C) from normal across the region (Table 4). June was also warmer than average with a mean temperature of 74.3°F (23.5°C) in Pottstown. The spring months ranked as the 4th warmest in 117 years (Table 5).

The summer months were dominated by a hot July, leading to the 8th warmest in 117 years in the Southeastern Piedmont (Table 5). Readings in July varied from 3.9°F to 6.9°F (2.2°C to 3.4°C) above average (Table 4), and the number of hot days tallied 30 days compared with an average of 21 in a typical year (Table 2). August was not as torrid as July, as mean temperatures ranged from 74.0°F (23.5°C) at Reading to 72.5°F (22.5°C) at West Chester (Table 3). September was another month with above-average daytime readings and milder-than-normal nights and averaged somewhat above the long-term values (Figures 2 and 3). The highest reading of the year was 104.0°F (40.0°C) on July 23rd which is higher than the average of 97.0°F (36.1°C) (Table 2).

Autumn featured a near normal start and a very warm finish, ranking 14th warmest (Table 5). Temperatures in October varied from 0.7°F to 0.9°F (0.4°C to 0.5°C) (Table 4) above normal due to several warm nights (Figure 2). November was much warmer than normal with positive anomalies recorded on 19 of the 30 days. December had the largest positive departures of the autumn (Figures 2 and 3). The monthly anomalies during December ranged from 5.3°F to 5.8°F (2.9°C to 3.2°C) above the long-term average (Table 4). The total growing season length was 198 days, or 24 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
2011 vs. 1981–2010

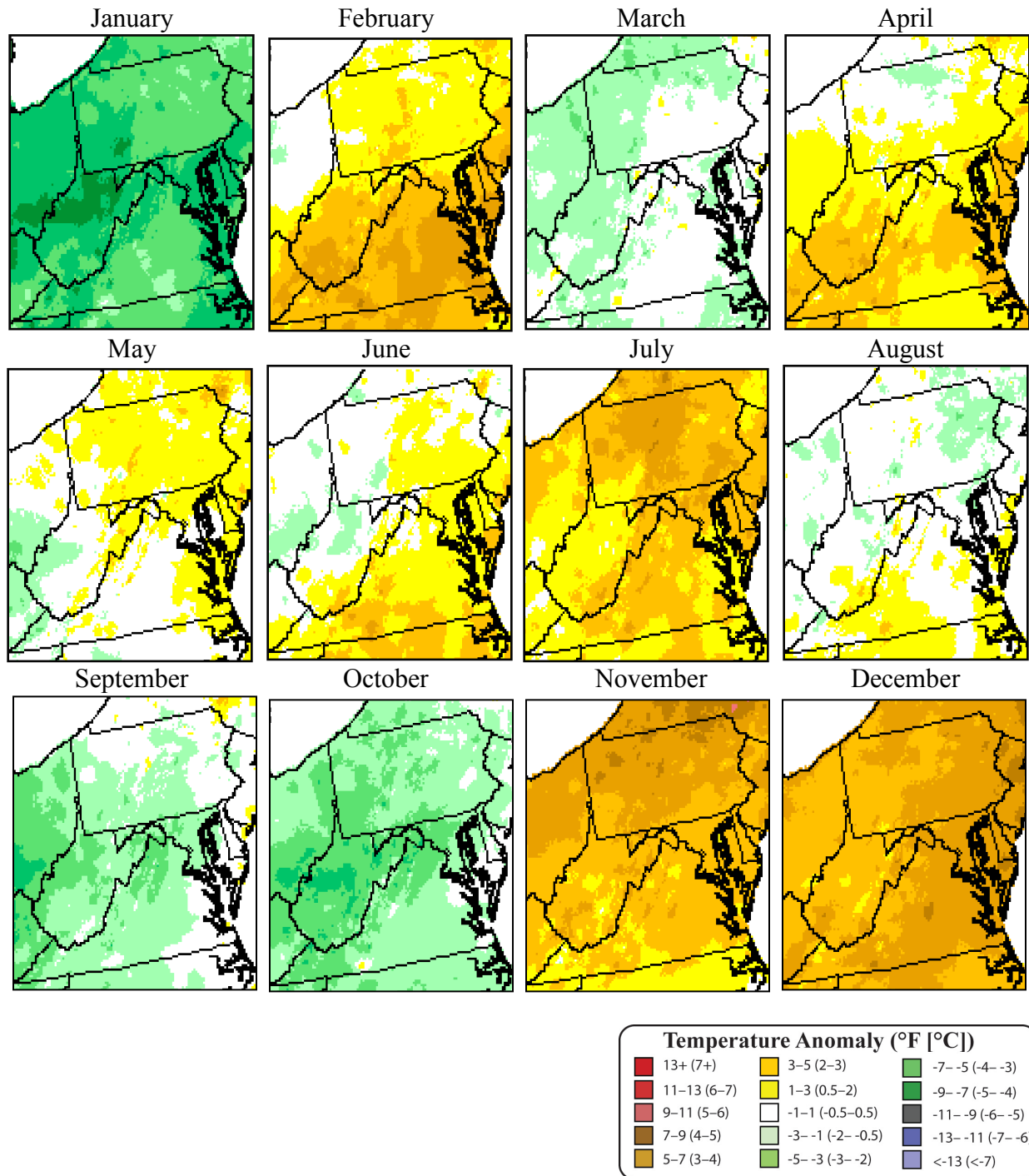


Figure 2. Maps showing departure from average monthly maximum temperature compared to the 30-year normal (1981–2010).

Hopewell Furnace National Historic Site
and Valley Forge National Historical Park
Departure from Average Monthly Minimum Temperature
2011 vs. 1981–2010

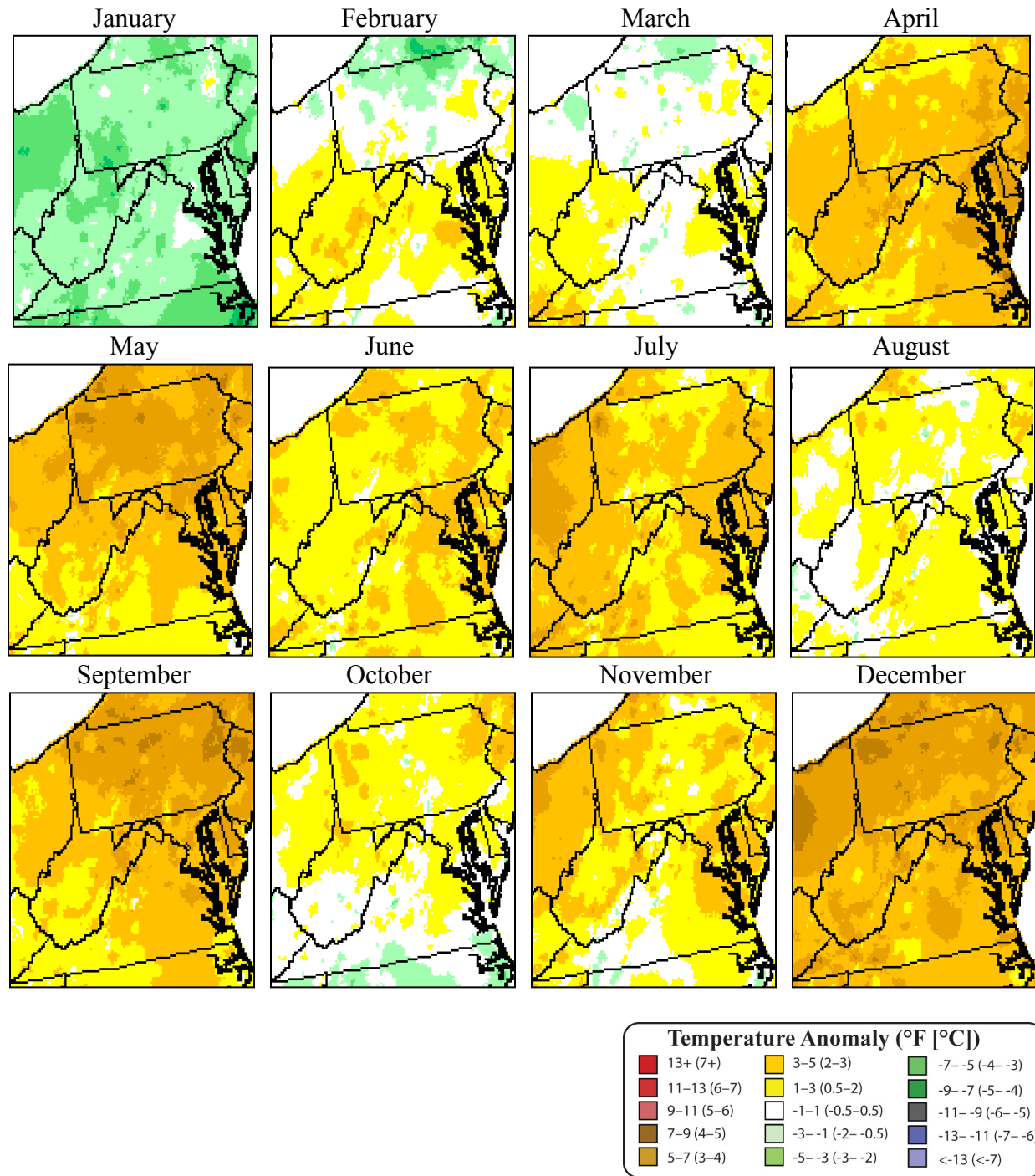


Figure 3. Maps showing departure from average monthly minimum temperature compared to the 30-year normal (1981–2010).

Table 2. Status of 2011 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 2011	West Chester 2 NW 1981–2010
Average Annual Temperature	54.2°F 12.3°C	52.1°F 11.2°C
Average Annual Maximum Temperature	65.3°F 18.5°C	63.8°F 17.7°C
Maximum Temperature	104.0°F 40.0°C	97.0°F 36.1°C
Hot Days (days with Tmax≥90°F/32°C)	30	21
Average Annual Minimum Temperature	43.0°F 6.1°C	40.4°F 4.7°C
Minimum Temperature	-2.0°F -18.9°C	-0.5°F -18.1°C
Cold Days (days with Tmax≤32°F/0°F)	13	16
Sub-freezing Days (days with Tmin≤32°F/0°C)	120	130
Sub-zero Days (days with Tmin≤0°F/-18°C)	3	2
Growing Season Length (days between last spring Tmin 32°F/0°C and first fall Tmin 32°F/0°C)	198	174

Table 3. Summary of 2011 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	25.8 °F	31.9 °F	40.9 °F	53.7 °F	63.8 °F	72.2 °F	78.6 °F	72.5 °F	68.4 °F	54.1 °F	46.6 °F	38.9 °F	54.0 °F
		-3.4 °C	-0.1 °C	4.9 °C	12.1 °C	17.7 °C	22.3 °C	25.9 °C	22.5 °C	20.2 °C	12.3 °C	8.1 °C	3.8 °C	12.2 °C
Pottstown Airport	KPTW	27.5 °F	34.5 °F	43.1 °F	56.6 °F	67.3 °F	74.3 °F	81.3 °F	72.7 °F	67.8 °F	54.6 °F	47.3 °F	39.7 °F	55.6 °F
		-2.5 °C	1.4 °C	6.2 °C	13.7 °C	19.6 °C	23.5 °C	27.4 °C	22.6 °C	19.9 °C	12.6 °C	8.5 °C	4.3 °C	13.1 °C
Reading Airport	KRDG	26.2 °F	33.1 °F	40.8 °F	55.0 °F	65.5 °F	73.2 °F	80.4 °F	74.0 °F	68.5 °F	54.6 °F	48.1 °F	39.7 °F	55.0 °F
		-3.2 °C	0.6 °C	4.9 °C	12.8 °C	18.7 °C	22.9 °C	26.9 °C	23.3 °C	20.3 °C	12.6 °C	8.9 °C	4.3 °C	12.7 °C

Table 4. Summary of 2011 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	-3.1 °F	0.6 °F	1.2 °F	3.2 °F	3.4 °F	2.0 °F	3.9 °F	-0.4 °F	3.3 °F	0.8 °F	3.2 °F	5.6 °F	2.0 °F
		-1.7 °C	0.3 °C	0.7 °C	1.8 °C	1.9 °C	1.1 °C	2.2 °C	-0.2 °C	1.8 °C	0.4 °C	1.8 °C	3.1 °C	1.1 °C
Pottstown Airport ¹	KPTW	-2.6 °F	2.1°F	2.4°F	5.3°F	6.6°F	4.5°F	6.9°F	-0.2°F	2.9°F	0.7°F	3.0°F	5.3°F	3.1°F
		-1.4 °C	1.2°C	1.3°C	2.9°C	3.7°C	2.5°C	3.4°C	-0.1°C	1.6°C	0.4°C	1.7°C	2.9°C	1.7°C
Reading Airport ¹	KRDG	-3.5°F	0.8°F	-0.3°F	3.4°F	4.4°F	2.7°F	5.6°F	1.0°F	3.2°F	0.9°F	4.0°F	5.8°F	2.3°F
		-1.9°C	0.4°C	-0.2°C	1.9°C	2.4°C	1.5°C	3.1°C	0.6°C	1.8°C	0.5°C	2.2°C	3.2°C	1.3°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 2011 over 117 years for the Southeastern Piedmont (NOAA 2011).

	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-2011	63	4	8	14	10
Precipitation-2011	24	22	1	17	1

1 = warmest/wettest year and 117 = coldest/driest year

Precipitation Summary

Precipitation was near record maxima across the Hopewell Furnace NHS and Valley Forge NHP region in 2011 (Table 6). All of the four seasons finished with much-above-average precipitation and the summer was the wettest on record (Table 5).

The first three months of 2011 raised concerns about spring flooding (Figure 4). In fact, the Palmer Drought Severity Index (PDSI) was approaching moderately moist (2) by late March (see next section, Figure 5). While January's rain and snowfall was in the normal range from 56-114 percent of average, whatever small deficit was erased quickly by a snowy February and a very wet March (Table 7 and 8). Surprisingly, only one of the year's wettest days occurred during the cold seasons in 2011, though snowfall was above normal averaging 38.9 in (98.8 cm) compared with a normal value of 27.8 in (70.6 cm) (Tables 6 and 9).

The late spring and early summer became progressively drier with June and July having below normal rainfall (Figure 4 and Table 8). April brought the most rainfall tallies ranging from 5.1 in (130 mm) at West Chester to 7.0 in (178 mm) at Glenmoore, but May had closer to average rainfall (Tables 7 and 8). By June, rain was only 45-81 percent of normal (Table 8). Overall, this season ranked as the 22nd wettest in 117 years of records in the Southeastern Piedmont.

Summer's rainfall was abundant. A few long dry spells marked the beginning of the season and it ended with excessive precipitation on two occasions. June 30-July 7 and July 13-19 had no measurable rain, but the region was inundated with 7.46 in (189 mm) on August 28 due to Hurricane Irene and then 6.02 in (163 mm) on September 6-7 due to the remnants of Tropical Storm Lee. Another wet spell with a total of 2.40 in (61 mm) was registered on September 24 (Table 9). The end result was that the three month rainfall from July–September was highest on record ranking 1st in 117 years of records (Table 5).

Yet another wet autumn was tallied around Hopewell Furnace NHS and Valley Forge NHP in 2011. Total precipitation during October–November and December exceeded the 30-year mean by 3.3 in (84 mm) at West Chester, PA (Table 6). Despite being a wet fall, there was one long dry spell from October 31 to November 8 (Table 9). Seventeen days with more than 1 in (25.4 mm) of rain were noted in 2011; eclipsing the long-term mean of 13 days. The occurrence of extreme rainfall, more than 2 in (51 mm), was well above average with eight days at West Chester (Table 6). The autumn ranked as the 17th wettest for the Southeastern Piedmont (Table 5). The number of days with measurable snow in 2011 totaled 19 days, above the average of 13 days and the occurrences of moderate and heavy snow were also at or above normal (Table 6).

Table 6. Status of 2011 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 2011	West Chester 2 NW 1981–2010	Glenmoore 2011	Glenmoore 1981–2010
Annual Precipitation	69.1 in 1,755 mm	47.8 in 1,214 mm	66.5 in 1,689 mm	49.0 in 1,245 mm
Autumn (Oct, Nov, Dec) Precipitation	15.4 in 391 mm	12.1 in 307 mm	14.9 in 378 mm	12.0 in 305 mm
Heavy Precipitation Days (days with ≥ 1.0 in (25 mm) rain)	17	14	16	14
Extreme Precipitation Days (days with ≥ 2.0 in (51 mm) rain)	8	1	6	2
Micro-drought (strings of 7+ days without rain)	6	6	6	6
Annual Snowfall	M ¹ M ¹	26.5 in 67.3 cm	38.9 in 98.8 cm	27.8 in 70.6 cm
Measurable Snow Days (days with ≥ 0.1 in (0.3 cm) snow)	M ¹	12	19	13
Moderate Snow Days (days with ≥ 3.0 in (7.6 cm) snow)	M ¹	3	5	3
Heavy Snow Days (days with ≥ 5.0 in (12.7 cm) snow)	M ¹	1	1	1

¹West Chester 2 NW (WCHP1) snowfall data was missing for the majority of the year, thus an M is denoted as missing data.

Hopewell Furnace National Historic Site
and Valley Forge National Historical Park
Percent of Average Monthly Precipitation
2011 vs. 1981–2010

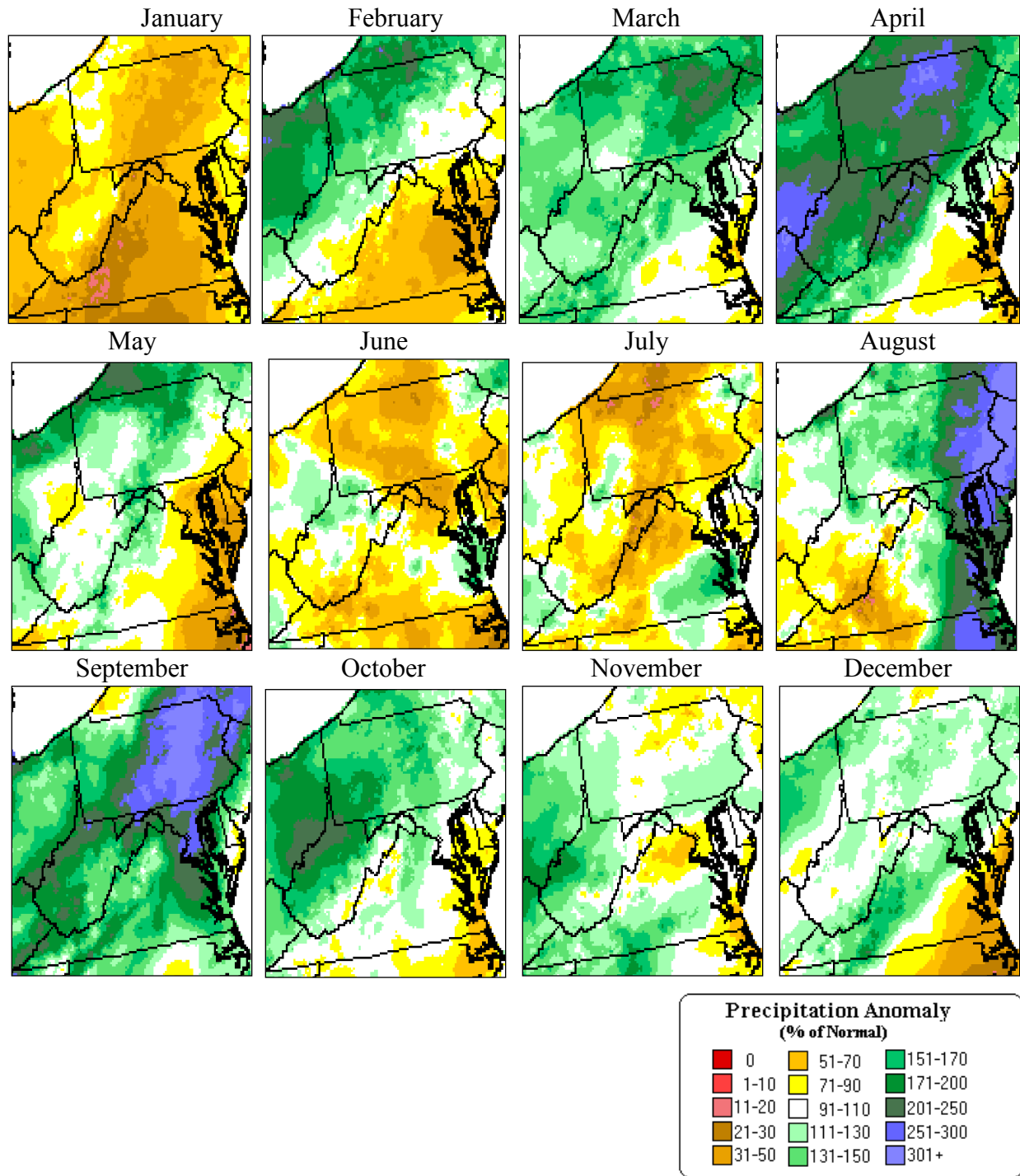


Figure 4. Maps showing percent of average monthly precipitation compared to the 30-year normal (1981–2010).

Table 7. Summary of 2011 monthly total precipitation for selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Glenmoore	GNMP1	3.8 in	3.1 in	6.7 in	7.0 in	4.2 in	2.1 in	1.8 in	13.1 in	9.8 in	4.7 in	5.3 in	4.9 in	66.5 in
		97 mm	79 mm	170 mm	178 mm	107 mm	53 mm	46 mm	333 mm	249 mm	119 mm	135 mm	124 mm	1689 mm
West Chester 2 NW	WCHP1	4.0 in	2.8 in	6.3 in	5.1 in	3.4 in	1.7 in	3.3 in	14.9 in	12.3 in	5.4 in	4.9 in	5.1 in	69.1 in
		102 mm	71 mm	160 mm	130 mm	86 mm	43 mm	84 mm	378 mm	312 mm	137 mm	124 mm	130 mm	1755 mm
Morgantown	MGNP1	3.2 in	2.9 in	6.8 in	5.7 in	2.6 in	M	1.5 in	12.0 in	M	4.4 in	4.7 in	4.3 in	48.0 in
		81 mm	74 mm	173 mm	145 mm	66 mm	M	38 mm	305 mm	M	112 mm	119 mm	109 mm	1219 mm
Pottstown Airport	KPTW	2.2 in	2.4 in	5.3 in	5.8 in	3.8 in	1.9 in	1.5 in	9.8 in	11.4 in	3.8 in	3.6 in	4.2 in	55.7 in
		56 mm	61 mm	135 mm	147 mm	97 mm	48 mm	38 mm	249 mm	290 mm	97 mm	91 mm	107 mm	1415 mm
Reading Airport	KRDG	1.7 in	2.7 in	5.2 in	6.1 in	5.4 in	3.1 in	2.2 in	6.9 in	11.7 in	4.2 in	4.7 in	3.4 in	57.2 in
		43 mm	69 mm	132 mm	155 mm	137 mm	79 mm	56 mm	175 mm	297 mm	107 mm	119 mm	86 mm	1453 mm
Valley Creek	1473169	1.8 in	2.6 in	5.7 in	5.4 in	3.3 in	1.5 in	1.3 in	12.8 in	M	3.2 in	4.0 in	4.4 in	49.7 in
		46 mm	66 mm	144 mm	137 mm	84 mm	38 mm	33 mm	325 mm	M	81 mm	101 mm	112 mm	1167 mm

Table 8. Summary of 2011 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	104	97	162	170	99	52	36	324	215	113	140	121	136
West Chester 2 NW	WCHP1	114	87	145	136	80	45	80	394	240	132	129	122	144
Morgantown	MGNP1	101	98	207	164	68	M	30	300	M	102	127	123	105
Pottstown Airport ¹	KPTW	71	87	145	147	88	47	31	240	241	91	103	113	118
Reading Airport ¹	KRDG	56	110	149	161	126	81	48	190	269	130	136	103	132

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 normals 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 2011 from weather observing stations at West Chester 2 NW (WCHP1) and Glenmoore (GNMP1).

Wettest Days in 2011	Dry Spells in 2011
Aug. 28: 7.46 in (189 mm) ¹	Feb. 10–20
Sept. 7: 3.06 in (78 mm) ²	May 25–Jun. 4
Sept. 6: 2.96 in (75 mm) ²	Oct. 31–Nov. 8
Mar. 11: 2.46 in (62 mm)	Jun. 30–Jul. 7
Sept. 24: 2.40 in (61 mm)	Jul. 13–19

¹ Hurricane Irene

² Tropical Storm Lee

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 2011 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 2011). 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 2011.

According to the USDM, 2011 had bookends of moist conditions with rather dry weather during the first two-thirds of the growing season (Figure 5). The winter was abnormally moist due in large part to heavy snowfall. Then starting in May and continuing into early August was progressively drier (values between 0 and -1.2). Then excessive rains came in late August and continued into October. When compared to previous years, 2011 had the wettest spring, a dry early summer, and an excessively 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 the first half of August being the driest.

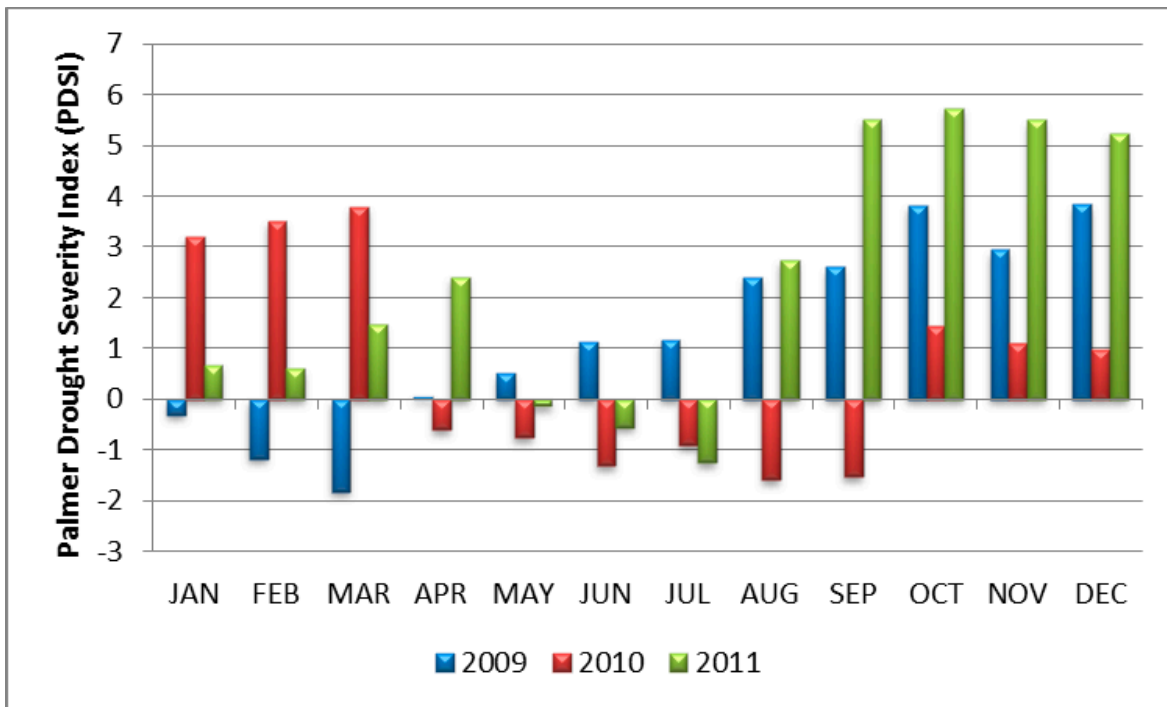


Figure 5. Palmer Drought Severity Index (PDSI) for the Southeastern Piedmont, 2009–2011.

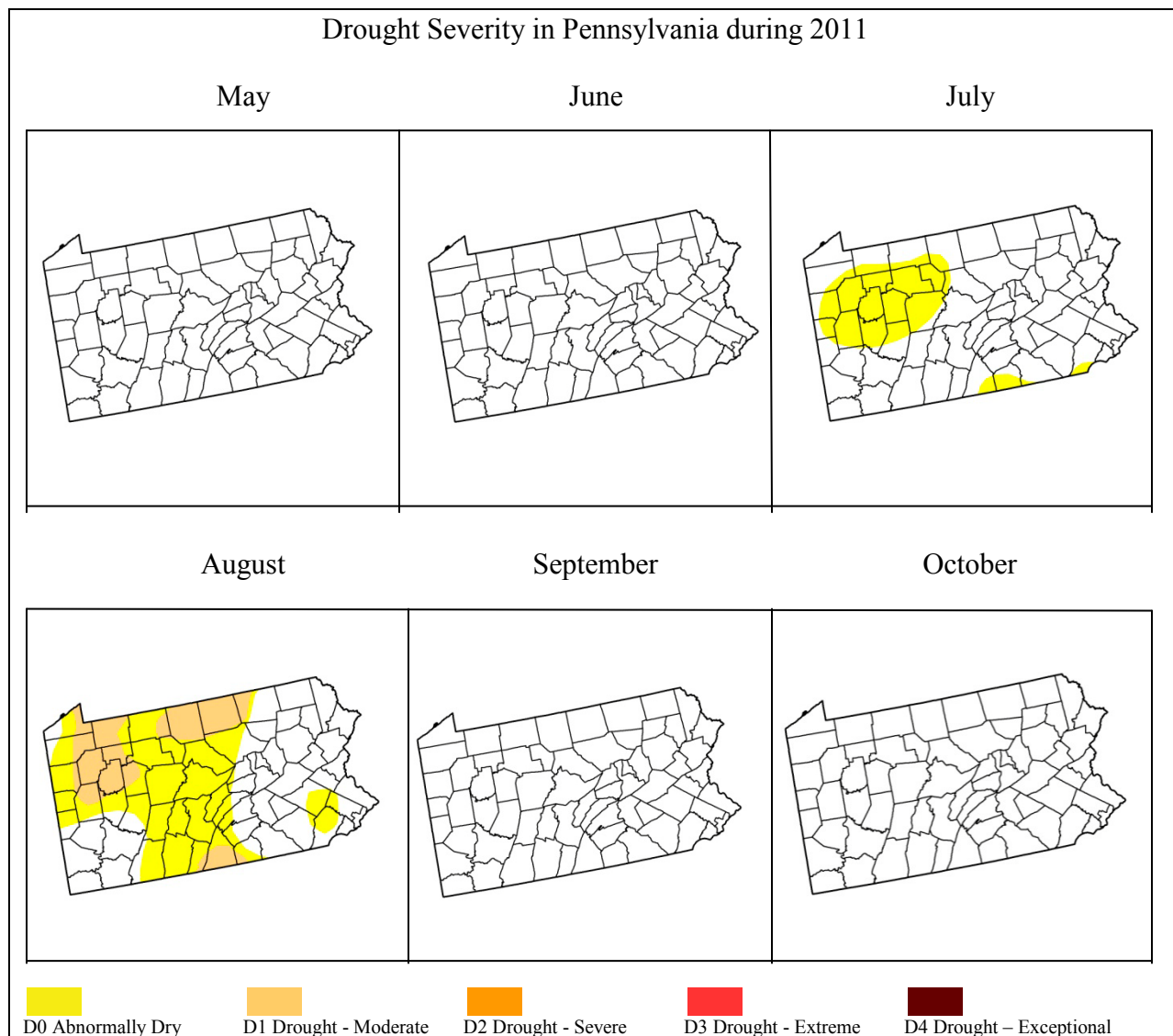


Figure 6. Mid-month values of the United States Drought Monitor (DM) – Drought Intensity Index for Pennsylvania in 2011.

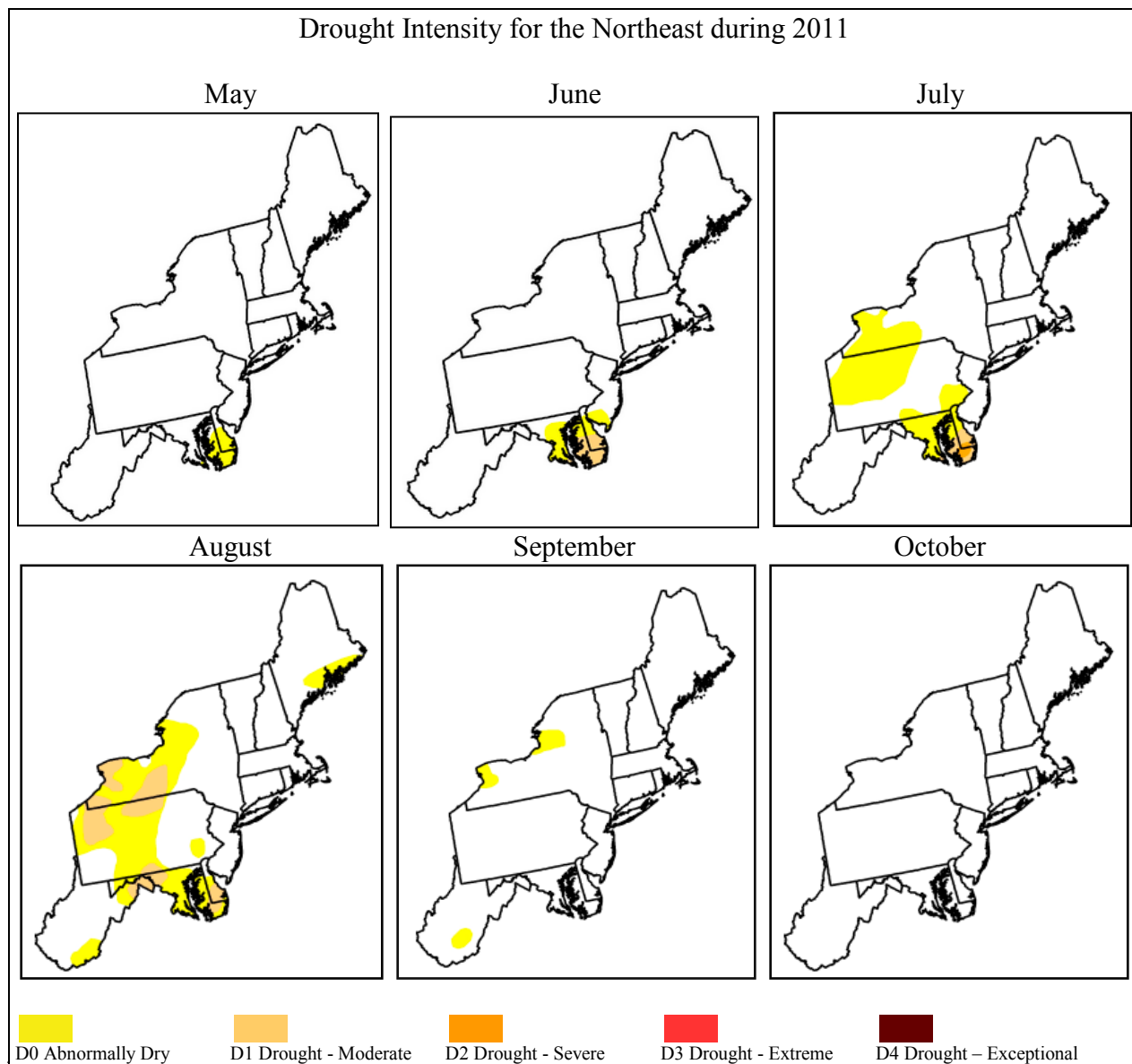


Figure 7. Mid-month values of the United States Drought Monitor (DM) – Drought Intensity Index for the Northeast in 2011.

References

- Comiskey, J. A., and K. K. Callahan. 2008. Mid-Atlantic Network vital signs monitoring plan. Natural Resource Report NPS/MIDN/NRR—2008/071. National Park Service, Fort Collins, CO.
- Daly, C., W. P. Gibson, G. H. Taylor, G. L. Johnson, and P. Pasteris. 2002. A knowledge-based approach to the statistical mapping of climate. *Climate Research* 22:99–113.
- Davey, C. A., K. T. Redmond, and D. B. Simeral. 2006. Weather and Climate Inventory, National Park Service, Mid-Atlantic Network. Natural Resource Technical Report NPS/MIDN/NRTR—2006/013. National Park Service, Fort Collins, CO.
- Gawtry, S., and J. Stenger. 2007. Climate Summary, Shenandoah National Park. Natural Resources Report NPS/NER/NRR—2007/017. National Park Service, Philadelphia, PA
- Kocin, P. J., and L. W. Uccellini. 2004. Northeast Snowstorms Volume 1: Overview. Meteorological Monographs. Vol 32. No 54. American Meteorological Society. Boston, MA.
- Marshall, M., P. Knight, and J. Comiskey. 2012. Weather and climate monitoring protocol: Eastern Rivers and Mountains Network and Mid-Atlantic Network. Natural Resource Report NPS/ERMN-MIDN/NRR-2012/498. National Park Service, Fort Collins, Colorado.
- National Oceanic and Atmospheric Administration (NOAA). 2011. National Climatic Data Center. Climate of 2011 – Annual Review, Global and U.S. Summary. <http://lwf.ncdc.noaa.gov/oa/climate/research/2011/ann/us-summary.html>.
- National Integrated Drought Information System (NIDIS). 2011. National Climate Data Center and United States Department of Agriculture. <http://drought.unl.edu/dm/archive.html>.

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