



Weather of Shenandoah National Park

Mid-Atlantic Network Summary Report for 2015

Natural Resource Report NPS/MIDN/NRR—2016/1327



ON THE COVER

Photograph of Shenandoah National Park.

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Natural Resource Report NPS/MIDN/NRR—2016/1327

Kyle Imhoff and Arthur Person

Pennsylvania State Climate Office
503 Walker Building
Pennsylvania State University
University Park, Pennsylvania

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Abstract

The Mid-Atlantic Network (MIDN) Weather and Climate Monitoring protocol supports the documentation of current status and long-term trends in air temperature and precipitation at multiple temporal and spatial scales in MIDN parks. The purpose of this report is to provide a concise weather and climate summary for Shenandoah National Park (SHEN) for the time period of January 1 to December 31, 2015. SHEN is located in the Western Piedmont, Northern Virginia, and Central Mountain climate divisions of Virginia. In 2015, a total of five weather stations were selected to report park weather and climate conditions, and a large suite of precipitation and temperature metrics were summarized. Ultimately, 2015 was a very warm year and ranked as the 10th warmest on record for the Western Piedmont. In fact, the autumn of 2015 was the warmest autumn since 1895. The year was also very wet, being the 15th wettest on record. No drought conditions were reported during 2015.

List of Key Acronyms

APCO	Appomattox Court House National Historical Park
ASOS	Automated Surface Observation System
BOWA	Booker T. Washington National Monument
CASTNET	Clean Air Status and Trends Network
COOP	National Weather Service Cooperative Observer Program
CWOP	Citizen Weather Observer Program
FAA	Federal Aviation Administration
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
NM	National Monument
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

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). A baseline climate summary has been produced for Shenandoah National Park (Gawtry and Stenger 2007).

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 and regional 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 climate status on an annual basis and climate trends 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 Western Piedmont, Northern Virginia, and Central Mountain Regions of Virginia

Shenandoah National Park (NP) is located in Virginia Climate Division 3 (Western Piedmont), Virginia Climate Division 4 (Northern Virginia), and Virginia Climate Division 5 (Central Mountain). 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>). Virginia is divided into six climate divisions. The Western Piedmont, Northern Virginia, and Central Mountain divisions are generally considered to have a humid, continental type of climate, but the varied physiographic features have a marked effect on the weather and climate of the various parts of the park. The prevailing westerly winds carry most of the weather disturbances that affect the region from the interior of the continent, with the Atlantic Ocean having only an occasional influence on the climate of the area (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 significant effect within this part of Virginia, causing severe floods in some instances. Ice storms along the higher elevations of Shenandoah NP can contribute to significant natural alterations to forest structure.

Temperatures are moderately continental, with the tempering effects due to the higher elevations contributing to cloud production in summer and onshore winds modifying the chill at times during winter (Davey et al. 2006). The lowest readings in 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 Shenandoah Valley. Southwest winds gain additional warmth when descending the crest of the Appalachians. The last freeze and first frost typically occur in late April and October, respectively.

Precipitation is fairly evenly distributed throughout the year. Annual amounts generally range between 34–52 in (864–1,321 mm), though the majority of places receive 39–45 in (991–1,143 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 mountains, due primarily to coastal storms which occasionally frequent the area. For example, the annual average precipitation at Big Meadows is 55 in (1,397 mm), while Luray, to the west and at a much lower elevation, receives an average of 41 in (1,041 mm) per year (Gawtry and Stenger 2007). During the warm season, these coastal storms can bring heavy rain, and in winter, they can result in heavy snow or a mixture of rain and snow.

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, occurring about once every other year, but flash floods and damaging thunderstorm winds affect parts of the park 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 hurricanes and

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 nine weather observing stations comprising four weather observing networks were selected as the most representative weather stations around Shenandoah NP in 2015. Representative stations within a 100-km range of the park were chosen based on several criteria, which include proximity to the park, 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 nine stations were ultimately used for this 2015 report: Luray, Madison, Staunton Water Treatment Plant, Waynesboro Water Treatment Plant, Front Royal, Charlottesville-Albemarle Airport, Headquarters, Sawmill Ridge, and Big Meadows (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 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 2015) normals cover the period 1981–2010. In this report, the 30-year normals established by NCDC are used as the baseline for comparisons (e.g., departures from normal). In cases where data for the 30-year normal period are not available, we use alternative comparisons such as the new pseudo-normals from NCDC or a recent 10-year period. In some cases, sufficient data may simply not be available to calculate normals. For metrics that NCDC may not routinely calculate a normal, such as the number of days with more than 2 in (55 mm) of rain or liquid equivalent, normals are calculated using the same time period (e.g., 1981–2010) as the current NCDC standard. Throughout the report, descriptions of a station’s values as compared to the normals are described as a difference from the “average”, “mean”, “typical”, “long-term value”, as well as “normal”, to improve the readability of the document. However, all of these terms are comparing a value from one year at that station to that station’s normal, whether it is the 30-year normal or the pseudo-normal calculated on a shorter time frame

Of the nine stations, three (Luray, Staunton, and Charlottesville-Albemarle) have a Period of Record (POR) sufficiently long for a 30-year normal (normal calculated from years 1981–2010). However, Charlottesville-Albemarle has a low percentage of time reporting temperature and precipitation over its POR and is therefore not used for the corresponding indicator tables. Madison was also excluded from the monthly deviations from normal for temperature due to gaps in reporting over its POR.

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 weather observing stations along with monthly, seasonal, and annual summaries. The Web interface is accessible through the following link: <http://climate.met.psu.edu/NPS/interface.php>.

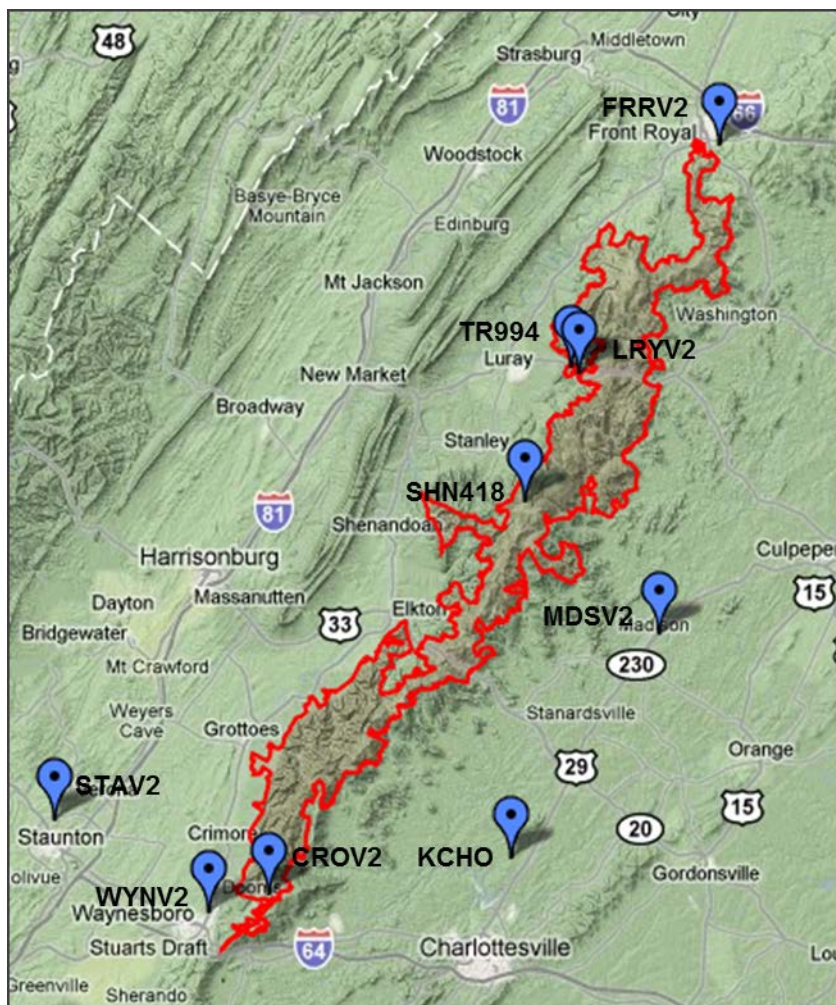


Figure 1. Location of weather observing stations around Shenandoah National Park selected as most representative of the park in 2015. See Table 1 for station names.

Table 1. List of weather observing stations around Shenandoah National Park selected as most representative of the park 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
LRYV2	COOP	Luray 5 E	03/01/1941 - Present	98.4	97.8	92.6	96.9
MDSV2	COOP	Madison	01/01/1996 - Present	92.1	81.4	66.7	66.8
STAV2	COOP	Staunton WTP ³	01/01/1893 - Present	100.0	100.0	95.8	91.8
WYNV2	COOP	Waynesboro WTP ³	10/01/2000 - Present	100.0	100.0	94.9	94.2
FRRV2	COOP	Front Royal	12/01/1995 - Present	98.6	98.1	99.7	99.0
KCHO	ASOS	Charlottesville-Albemarle Airport	01/07/1973 - Present	100.0	100.0	40.5 ²	33.5 ²
SHN418	CASTNET	Big Meadows	07/01/1988 - Present	99.7	99.7	98.5	98.4
TR994	RAWS	Headquarters	11/15/2006 - Present	100.0	100.0	97.5	97.5
CROV2	RAWS	Sawmill Ridge	11/15/2006 - Present	98.6	98.6	89.4	89.4

¹ Observing networks are: COOP — National Weather Service Cooperative Observer Program, ASOS — Automated Surface Observation System, CASTNET — Clean Air Status and Trends Network, and RAWS — Remote Automated Weather Stations.

² The percentage of time reporting temperature and precipitation for KCHO is 99.9 from 2001 through 2010.

³ WTP – Water Treatment Plant

Temperature Summary

Temperatures for 2015 were generally near the long-term average around Shenandoah NP (Table 2) with departures varying from -0.1°F (-0.1°C) to +1.2°F (+0.7°C). The highest maximum temperature of the year and the number of hot days (i.e. days when the temperature exceeds 90°F (32°C)), however, were below normal at both Luray and Staunton (Table 2).

The year started off on a chilly note, with all three winter months of January, February, and March having negative temperature anomalies across all observing stations (Table 3). February was the coldest month of the year with respect to normal (Figures 2 and 3)¹. In February, temperature departures from average ranged from -9.0 to -10.7°F (-5.0 to -5.9°C) across the region (Table 3). Eight of the seventeen days where maximum temperatures did not reach 32°F (0°C) occurred during the month of February at Luray (Table 2). The season, as a whole, ranked between the 10th and 21st coldest across the climate divisions of the Western Piedmont, Northern Virginia, and the Central Mountains out of 121 years of records (Tables 4, 5, and 6).

Spring would turn more seasonable with respect to temperatures and even milder than normal in the month of May (Figures 2 and 3). May departures ranged between 3.2°F and 5.7°F (1.8°C and 3.2°C) above normal (Table 3). The growing season began about a month earlier than normal in Luray (on April 5th compared to the long-term average of May 6th), resulting in a growing season that was about a month longer than normal for the calendar year (Table 2). The highest reading of the year, 93.0°F (33.8°C) occurred on June 24th at Luray (Table 2). Primarily due to the warm May, spring 2015 ranked as the 3rd to 4th warmest since records began in 1895 (Tables 4, 5, and 6).

The summer of 2015 began with varying temperature departures, with July and August averaging cooler than normal at Luray, Staunton, and Front Royal and milder than normal at Charlottesville Airport and Big Meadows (Table 3). September would be slightly warmer than average, as temperatures ranged between 0.3 and 3.6°F (0.2 and 2.0°C) above normal (Table 3). The summer of 2015 tied as the 41st warmest in the Central Mountains and the 30th warmest in Northern Virginia out of 121 years of records (Tables 5 and 6).

The year concluded with very mild weather in November and December (Figures 2 and 3). December brought the largest temperature departures from normal for the entire year and was the warmest December on record at most locations (Table 3). Temperatures during the month averaged 44.1°F (6.7°C) at Big Meadows, which was 12.8°F (7.1°C) above the 1980-2010 normal (Tables 3 and 7). Overall, autumn 2015 was the warmest on record for all three climate divisions encompassing Shenandoah NP (Tables 4, 5, and 6).

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/>.

Table 2. Status of 2015 temperature indicators compared to the 30-year normal (1981–2010) at the Luray 5 E (LRYV2) and Staunton WTP (STAV2) weather observing stations.

Temperature Indicator	Luray 5 E 2015	Luray 5 E 1981–2010	Staunton WTP 2015	Staunton WTP 1981–2010
Average Annual Temperature	54.6°F 12.6°C	54.7°F 12.7°C	54.8°F 12.7°C	53.6°F 12.0°C
Average Annual Maximum Temperature	65.9°F 18.8°C	67.2°F 19.6°C	65.1°F 18.4°C	64.0°F 17.8°C
Maximum Temperature	93.0°F 33.8°C	97.4°F 36.3°C	91.0°F 32.8°C	94.7°F 34.8°C
Hot Days (days with Tmax≥90°F/32°C)	12	25	4	10
Average Annual Minimum Temperature	43.4°F 6.3°C	42.3°F 5.7°C	44.6°F 7.0°C	43.1°F 6.2°C
Minimum Temperature	-3.0°F -19.4°C	-1.9°F -18.8°C	-6.0°F -21.1°C	-1.8°F -18.8°C
Cold Days (days with Tmax≤32°F/0°C)	17	10	17	14
Sub-freezing Days (days with Tmin≤32°F/0°C)	99	111	86	105
Sub-zero Days (days with Tmin≤0°F/-18°C)	2	2	3	1
Growing Season Length (days between last spring Tmin 32°F/0°C and first fall Tmin32°F/0°C)	195	160	202	174

Table 3. Summary of 2015 departure from normal temperature based on 30-year normal (1981–2010) for the selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Luray 5 E	LRYV2	-2.5°F	-9.6°F	-3.2°F	-0.6°F	3.2°F	0.4°F	-1.2°F	-1.4°F	1.1°F	-2.8°F	3.2°F	11.3 °F	-0.1°F
		-1.4°C	-5.3°C	-1.8°C	-0.3°C	1.8°C	0.2°C	-0.7°C	-0.8°C	0.6°C	-1.6°C	1.8°C	6.3°C	-0.1°C
Staunton WTP	STAV2	-1.7°F	-9.2°F	-1.1°F	0.9°F	4.3°F	2.5°F	-0.1°F	-1.1°F	2.0°F	0.5°F	5.2°F	11.4°F	1.3 °F
		-0.9°C	-5.1°C	-0.6°C	0.5°C	2.4°C	1.4°C	-0.1°C	-0.6°C	1.1°C	0.3°C	2.9°C	6.3°C	0.7°C
Front Royal ¹	FRRV2	-3.8°F	-10.7°F	-2.2°F	0.8°F	5.1°F	0.6°F	-1.2°F	-1.7°F	0.3°F	-1.2°F	2.5°F	10.4 °F	0.2°F
		-2.1°C	-5.9°C	-1.2°C	0.4°C	2.8°C	0.3°C	-0.7°C	-0.9°C	0.2°C	-0.7°C	1.4°C	5.8°C	0.1°C
Charlottesville-Albemarle Airport ¹	KCHO	-0.9°F	-9.0°F	-0.8°F	1.6°F	5.6°F	2.6°F	1.1°F	0.9°F	3.6°F	0.9°F	5.5°F	12.7 °F	2.2°F
		-0.5°C	-5.0°C	-0.4°C	0.9°C	3.1°C	1.4°C	0.6°C	0.5°C	2.0°C	0.5°C	3.1°C	7.1°C	1.2°C
Big Meadows ¹	SHN418	-3.4°F	-10.1°F	-0.7°F	1.5°F	5.7°F	4.0°F	3.9°F	1.8°F	3.4°F	0.2°F	3.7°F	12.8 °F	2.1 °F
		-1.9°C	-5.6°C	-0.4°C	0.9°C	3.2°C	2.2°C	2.2°C	1.0°C	1.9°C	0.1°C	2.1°C	7.1°C	1.2°C

¹Indicates a station's Period of Record does not cover the period of 1981-2010 but is ten or more 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. Madison and Waynesboro WTP were not included due to a low percentage of time reporting temperature for the entire Period of Record. Stations with a Period of Record of less than 5 years were not included in this table.

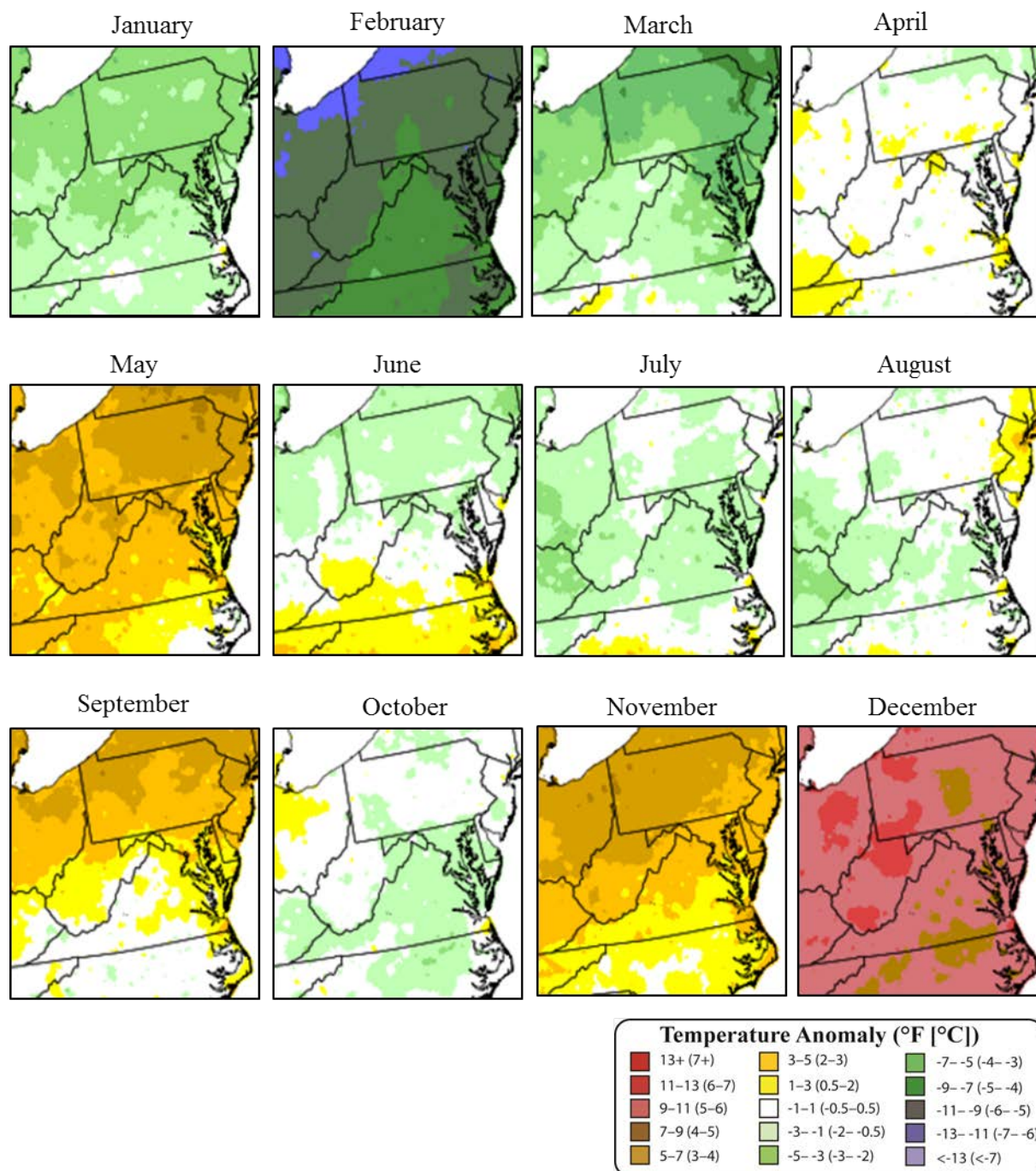


Figure 2. Maps showing departure from average monthly maximum temperature in 2015 compared to the 30-year normal (1981–2010).

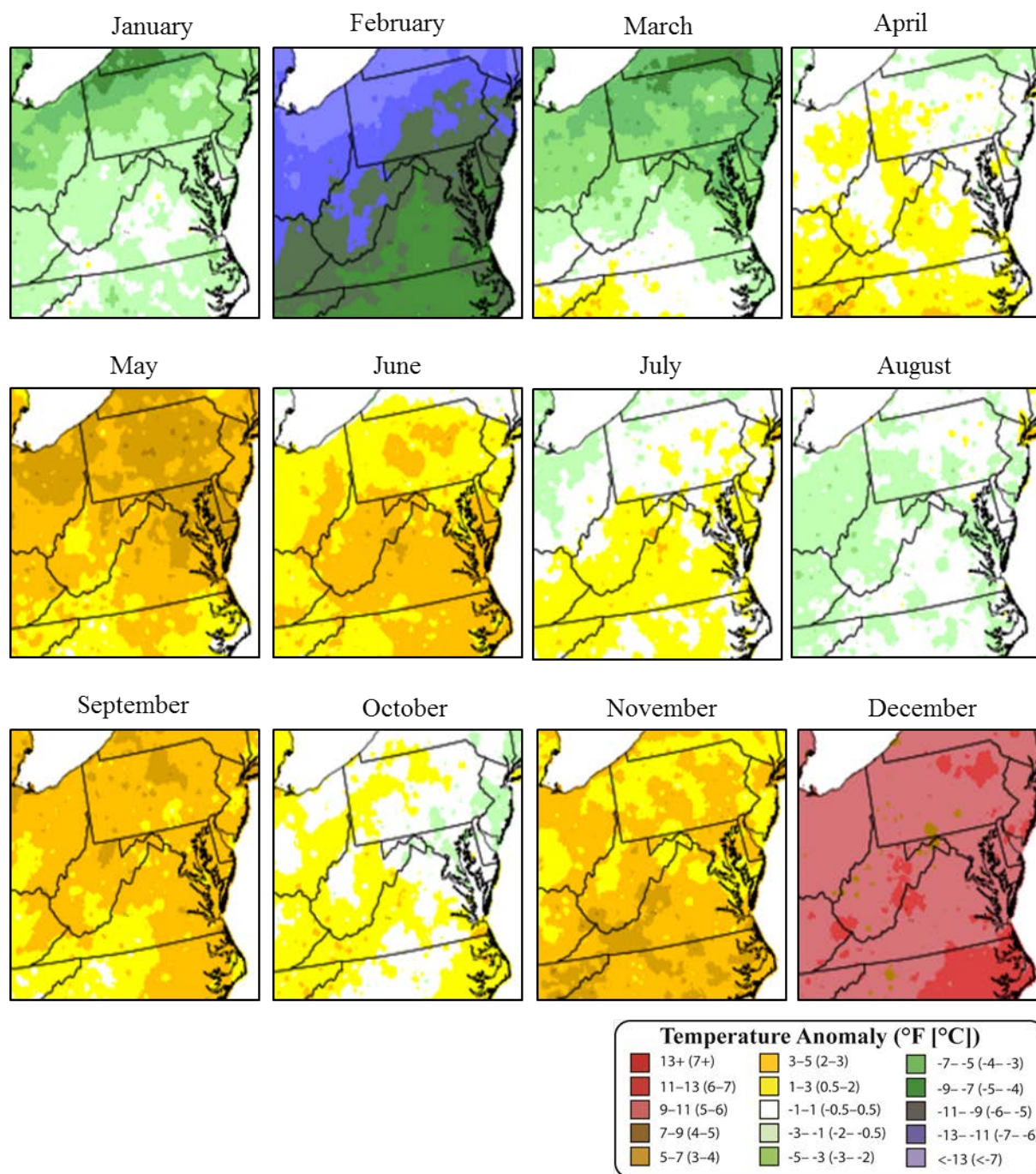


Figure 3. Maps showing departure from average monthly minimum temperature in 2015 compared to the 30-year normal (1981–2010).

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

Climate Division 3 Rankings Western Piedmont	Jan–Feb–Mar WINTER	Apr–May–Jun SPRING	Jul–Aug–Sep SUMMER	Oct–Nov–Dec AUTUMN	Jan–Dec YEAR
Temperature-2015	101-T	3	36-T	1	10
Precipitation-2015	95	44	26	6	15

1 = warmest/wettest year and 121 = coldest/driest year. T = Tie between multiple years.

Table 5. Seasonal and annual temperature and precipitation rankings for 2015 over 121 years for Northern Virginia (NOAA 2015).

Climate Division 4 Rankings Northern Virginia	Jan–Feb–Mar WINTER	Apr–May–Jun SPRING	Jul–Aug–Sep SUMMER	Oct–Nov–Dec AUTUMN	Jan–Dec YEAR
Temperature-2015	112-T	3-T	30-T	1	14-T
Precipitation-2015	84	18	61	36	29

1 = warmest/wettest year and 121 = coldest/driest year. T = Tie between multiple years.

Table 6. Seasonal and annual temperature and precipitation rankings for 2015 over 121 years for the Central Mountains (NOAA 2015).

Climate Division 5 Rankings Central Mountains	Jan–Feb–Mar WINTER	Apr–May–Jun SPRING	Jul–Aug–Sep SUMMER	Oct–Nov–Dec AUTUMN	Jan–Dec YEAR
Temperature-2015	107-T	4	41-T	1	10-T
Precipitation-2015	82	14	24	23	10

1 = warmest/wettest year and 121 = coldest/driest year. T = Tie between multiple years.

Table 7. Summary of monthly average temperatures for 2015 for the selected station

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Luray 5 E	LRYV2	30.4°F	26.9°F	41.1°F	54.0°F	66.0°F	71.3°F	73.3°F	71.7°F	67.6°F	53.7°F	50.1°F	48.2 °F	54.6°F
		-0.9°C	-2.8°C	5.1°C	12.2°C	18.9°C	21.8°C	22.9°C	22.1°C	19.8°C	12.1°C	10.1°C	9.0°C	12.6°C
Madison	MDSV2	36.2°F	32.2°F	44.6	56.6°F	68.1°F	74.2°F	75.1°F	73.6°F	69.7°F	57.0°F	M	M	58.1°F
		2.3°C	0.1°C	7.0	13.7°C	20.1°C	23.4°C	23.9°C	23.1°C	20.9°C	14.6°C	M	M	14.5°C
Staunton WTP	STAV2	30.9°F	26.4°F	42.1°F	53.8°F	65.8°F	72.5°F	73.5°F	71.2°F	67.2°F	54.7°F	50.4°F	47.2°F	54.8°F
		-0.6°C	-3.1°C	5.6°C	12.1°C	18.8°C	22.5°C	23.1°C	21.8°C	19.6°C	12.6°C	10.2°C	8.4°C	12.7°C
Waynesboro WTP	WYNV2	31.9°F	26.5°F	41.4°F	53.3°F	65.5°F	72.5°F	74.1°F	71.7°F	67.1°F	53.9°F	48.1°F	47.0 °F	54.6 °F
		-.1°C	-3.1°C	5.2°C	11.8°C	18.6°C	22.5°C	23.4°C	22.1°C	19.5°C	12.2°C	8.9°C	8.3°C	12.6°C
Front Royal	FRRV2	29.1°F	25.5°F	41.0°F	55.1°F	67.5°F	71.8°F	73.8°F	72.2°F	66.9°F	54.9°F	48.9°F	46.4 °F	54.7°F
		-1.6°C	-3.6°C	5.0°C	12.8°C	19.7°C	22.1°C	23.2°C	22.3°C	19.4°C	12.7°C	9.4°C	8.0°C	12.6°C
Charlottesville-Albemarle Airport	KCHO	34.4°F	29.2°F	45.1°F	56.9°F	68.8°F	74.5°F	76.5°F	74.9°F	70.4°F	56.9°F	52.4°F	50.5°F	57.7°F
		1.3°C	-1.6°C	7.3°C	13.8°C	20.4°C	23.6°C	24.7°C	23.8°C	21.3°C	13.8°C	11.3°C	10.3°C	14.3°C
Big Meadows	SHN418	24.4°F	18.9°F	35.2°F	47.5°F	59.1°F	63.9°F	65.1°F	63.4°F	59.2°F	47.°F	43.0°F	44.1°F	47.8°F
		-4.2°C	-7.3°C	1.8°C	8.6°C	15.1°C	17.7°C	18.4°C	17.5°C	15.1°C	8.8°C	6.1°C	6.7°C	8.8°C
Headquarters	TR994	30.3°F	25.9°F	42.1°F	54.7°F	66°F	71.4°F	73.2°F	71.1°F	66.1°F	52.6°F	48.2°F	46.6 °F	54.0 °F
		-1.0°C	-3.4°C	5.6°C	12.6°C	19.0°C	21.9°C	22.9°C	21.7°C	18.9°C	11.5°C	9.0°C	8.1°C	12.2°C
Sawmill Ridge	CROV2	31.4°F	26.8°F	43.3°F	53.4°F	66.7°F	71.2°F	72.9°F	71.8°F	66.6°F	54.9°F	50.4°F	47.7°F	54.8 °F
		-0.3°C	-2.9°C	6.3°C	12.4°C	19.3°C	21.8°C	22.7°C	22.1°C	19.3°C	12.7°C	10.2°C	8.7°C	12.7°C

M = missing data (monthly statistics are reported as 'M' if greater than 4 days of data are missing).

Precipitation Summary

Precipitation totals in 2015 were generally near to above normal throughout Shenandoah NP (Table 8). Overall, reporting stations in the region tallied annual precipitation between 90% and 136% of normal values (Table 8 and 9).

The year began persistently dry across the region (Figure 4). Although January precipitation was slightly higher than normal at a couple of stations, all stations reported below normal precipitation for both February and March (Table 8). The three climate divisions in which the park resides (Western Piedmont, Northern Mountains, and Central Mountains) reported winter precipitation totals resulting in the 27th to 40th driest winters since 1895 (Tables 4, 5, and 6). Even with the dry start to the year, snowfall was near normal throughout Shenandoah NP (Table 10), due in part to a snowstorm in late February.

Spring 2015 started relatively wet, with precipitation totaling 105 to 178% of normal for the month of April (Table 8). Most places saw near normal precipitation for the remainder of the season, though some places were notably dry in May (Tables 8 and 9). Madison reported only 0.6 in (14 mm) for the month, just 12% of normal (Tables 8 and 9). In the three climate divisions in which the park resides, the three-month period of April through June in 2015 was the 14th to 44th wettest since 1895 (Tables 4, 5, and 6).

The summer months in Shenandoah NP had varied rainfall (Figure 4), with August being a very dry month and September being relatively wet (Tables 8 and 9). Two of the top five longest dry spells of the year occurred during summer, one in late July and the other in late August through early September (Table 11). Conversely, three of the top five wettest days of the year occurred in summer as well (Table 11). The season ranked as the 24th wettest in the Central Mountains and the 61st wettest (mid-point) in Northern Virginia (Tables 5 and 6).

Precipitation for the autumn season of October through December was generally higher than the long-term average throughout Shenandoah NP (Tables 8, 9, and 10). Autumn precipitation was 1.2 in (31 mm) above normal at Luray and 1.3 in (32 mm) above normal at Staunton (Table 10). Even with the relatively wet weather, two dry spells occurred during the season, one in late November and one in early December (Table 11). The final month of the season brought precipitation totals of between 98 and 167% of normal, ending 2015 on a wet note. Ultimately, the autumn season ranked between the 6th to 36th wettest for the climate divisions encompassing Shenandoah National Park (Tables 4, 5, and 6).

Table 8. Summary of 2015 percent of normal total precipitation based on 30-year normal (1981–2010) for selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Luray 5 E	LRYV2	110	43	53	113	67	100	92	38	121	168	79	98	90
Madison	MDSV2	M	65	44	149	12	93	86	39	168	143	M	M	M
Staunton WTP	STAV2	59	89	83	151	103	151	150	72	164	135	92	167	116
Front Royal	FRRV2	126	66	46	105	118	174	145	27	104	200	65	142	110
Charlottesville-Albemarle Airport	KCHO	61	36	96	139	46	221	93	67	153	190	74	122	110
Big Meadows ¹	SHN418 ¹	84	56	93	178	49	126	101	50	251	267	131	126	136

M = missing data (monthly statistics are reported as ' M' if more than 4 days of data are missing).

¹Indicates a station's Period of Record does not cover the period of 1981-2010 but is more than 10 years. In these cases, the departure from normal values was calculated with normals derived from data spanning the length of the station's Period of Record. Waynesboro was not included due to a low percentage of time reporting precipitation for the entire Period of Record. Stations with a Period of Record of less than 5 years were not included in this table.

Table 9. 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
Luray 5 E	LRYV2	3.0 in	1.2 in	2.1 in	3.9 in	2.7 in	3.9 in	3.8 in	1.3 in	5.5 in	5.1 in	2.9 in	3.0 in	38.1 in
		75 mm	29 mm	52 mm	99 mm	68 mm	100 mm	96 mm	32 mm	139 mm	129 mm	72 mm	76 mm	968 mm
Madison	MDSV2	M	1.9 in	1.6 in	4.9 in	0.6 in	4.1 in	3.6 in	1.4 in	7.4 in	4.8 in	M	M	M
		M	48 mm	41 mm	125 mm	14 mm	103 mm	92 mm	36 mm	187 mm	122 mm	M	M	M
Staunton WTP	STAV2	1.6 in	2.3 in	2.7 in	4.8 in	3.9 in	5.5 in	5.9 in	2.6 in	6.2 in	4.0 in	2.8 in	3.2 in	45.3 in
		40 mm	57 mm	68 mm	121 mm	98 mm	139 mm	148 mm	66 mm	158 mm	102 mm	72 mm	81 mm	1151 mm
Waynesboro WTP	WYNV2	2.0 in	1.5 in	3.4 in	5.0 in	1.2 in	5.9 in	2.9 in	1.0 in	10.0 in	7.1 in	2.7 in	3.7 in	46.4 in
		51 mm	39 mm	85 mm	126 mm	30 mm	150 mm	75 mm	26 mm	254 mm	179 mm	69 mm	95 mm	1178 mm
Front Royal	FRRV2	3.1 in	1.7 in	1.7 in	3.4 in	5.0 in	7.0 in	4. in	0.8 in	4.7 in	6.3 in	2.4 in	4.0 in	44.9 in
		78 mm	44 mm	44 mm	87 mm	126 mm	178 mm	121 mm	21 mm	119 mm	160 mm	62 mm	102 mm	1141 mm
Charlottesville-Albemarle Airport	KCHO	1.7 in	1.0 in	3.5 in	4.7 in	1.8 in	8.2 in	4.0 in	2.4 in	6.9 in	5.9 in	2.8 in	3.8 in	46.8 in
		43 mm	24 mm	89 mm	119 mm	46 mm	209 mm	102 mm	62 mm	175 mm	150 mm	72 mm	97 mm	1188 mm
Big Meadows	SHN418	2.1 in	1.1 in	3.4 in	7.2 in	2.1 in	5.4 in	3.9 in	1.8 in	13.9 in	11.1 in	4.8 in	4.1 in	60.9 in
		53 mm	27 mm	86 mm	182 mm	54 mm	138 mm	99 mm	46 mm	352 mm	282 mm	123 mm	103 mm	1546 mm
Headquarters	TR994	3.2 in	1.0 in	2.7 in	4.6 in	2.6 in	3.6 in	3.6 in	1.5 in	5.4 in	5.1 in	3.0 in	2.8 in	3.9 in
		81 mm	25 mm	68 mm	117 mm	66 mm	90 mm	90 mm	39 mm	136 mm	130 mm	76 mm	70 mm	989 mm
Sawmill Ridge	CROV2	1.8 in	1.4 in	3.5 in	4.6 in	2.2 in	4.5 in	2.9 in	2.3 in	7.7 in	6.8 in	3.3 in	3.2 in	44.3 in
		46 mm	36 mm	88 mm	118 mm	55 mm	115 mm	73 mm	59 mm	196 mm	173 mm	84 mm	82 mm	1125 mm

M = missing data (monthly statistics are reported as ' M' if more than 4 days of data are missing).

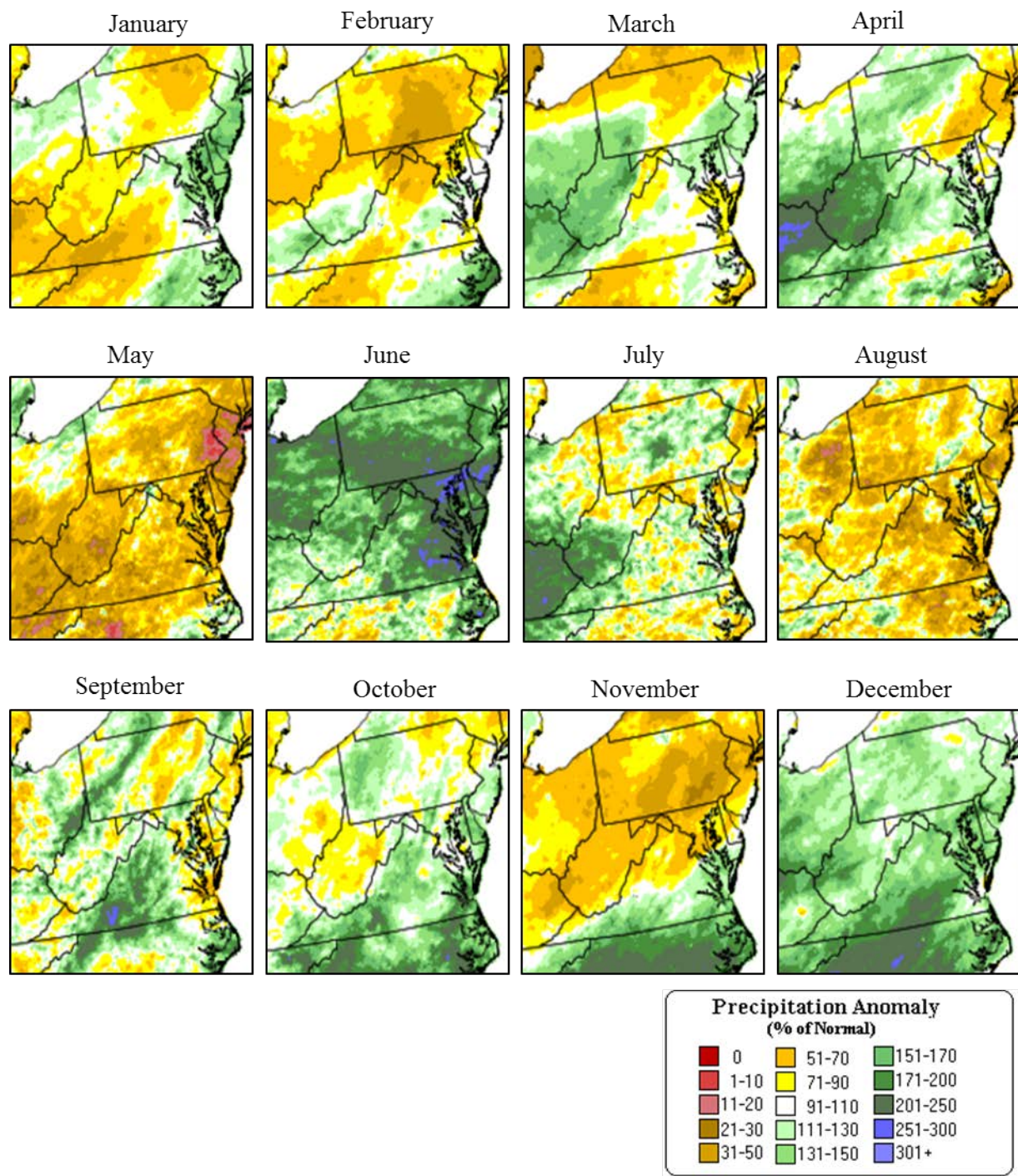


Figure 4. Maps showing percent of average monthly precipitation in 2015 compared to the 30-year normal (1981–2010).

Table 10. Status of 2015 precipitation indicators compared to the 30-year normal (1981–2010) at the Luray 5 E (LRYV2) and Staunton WTP (STAV2) weather observing stations.

Precipitation Indicator	Luray 5 E 2015	Luray 5 E 1981–2010	Staunton WTP 2015	Staunton WTP 1981–2010
Annual Precipitation	38.1 in 968 mm	42.3 in 1,074 mm	45.3 in 1151 mm	39.1 in 993 mm
Autumn (Oct, Nov, Dec) Precipitation	10.9 in 277 mm	9.7 in 246 mm	10.1 in 256 mm	8.8 in 224 mm
Heavy Precipitation Days (days with ≥ 1.0 in (25 mm) rain)	7	11	12	9
Extreme Precipitation Days (days with ≥ 2.0 in (51 mm) rain)	2	2	1	2
Micro-drought (periods of 7+ days without rain)	7	10	10	9
Annual Snowfall	18.4 in 467 cm	17.9 in 45.5 cm	21.5 in 546 cm	22.7 in 57.7 cm
Measurable Snow Days (days with ≥ 0.1 in (0.3 cm) snow)	9	6	5	9
Moderate Snow Days (days with ≥ 3.0 in (7.6 cm) snow)	3	3	3	3
Heavy Snow Days (days with ≥ 5.0 in (15.2 cm) snow)	1	1	2	1

Table 11. 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 Luray 5 E (LRYV2) and Staunton WTP (STAV2).

Wettest Days in 2015	Dry Spells in 2015
Sep 30: 3.34 in (85 mm)	Oct. 10-26
Oct 3: 2.10 in (53 mm)	Aug. 21 - Sep. 2
June 27: 1.68 in (43 mm)	Dec. 4-14
Aug 20: 1.60 in (41 mm)	Nov. 20-28
Jul 29: 1.51 in (38 mm)	Jul. 19-27

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 Western Piedmont in 2015 are shown in Figure 5.

According to the PDSI for the Western Piedmont, 2015 started drier than average as indices remained below 0 through the end of May (Figure 5). The wet June completely reversed the trend and brought index values to above 0 by the end of the 6th month of the year. Increasingly wet weather throughout the summer and autumn seasons brought increasingly positive PDSI values through the remainder of the year, exceeding the moderately wet threshold of $+2.0$ by the end of November. When compared to the previous two years, 2015 was drier in the first half of the year compared to the recent past. The wet weather in the latter half of the year brought the complete opposite trend as compared to 2014, when conditions were relatively wet early and dry later in the year.

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 Virginia (Figure 6) and the Southeast (Figure 7) are shown for 2015. No drought was evident during the growing season.

Based on the DM, although parts of Virginia were abnormally dry during certain seasons, no droughts occurred in the state during 2015 (Figure 6). Nevertheless, within the larger Southeast region some droughts did occur during the year (Figure 7).

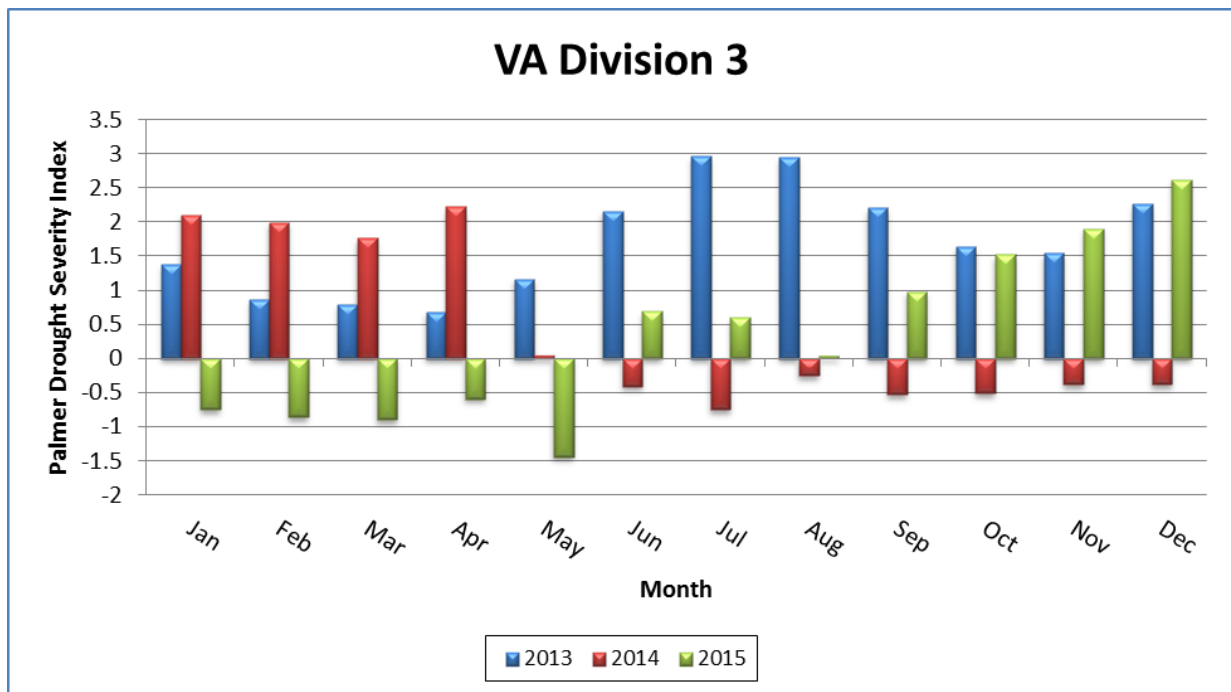


Figure 5. Monthly Palmer Drought Severity Index (PDSI) for the Western Piedmont, 2013–2015.

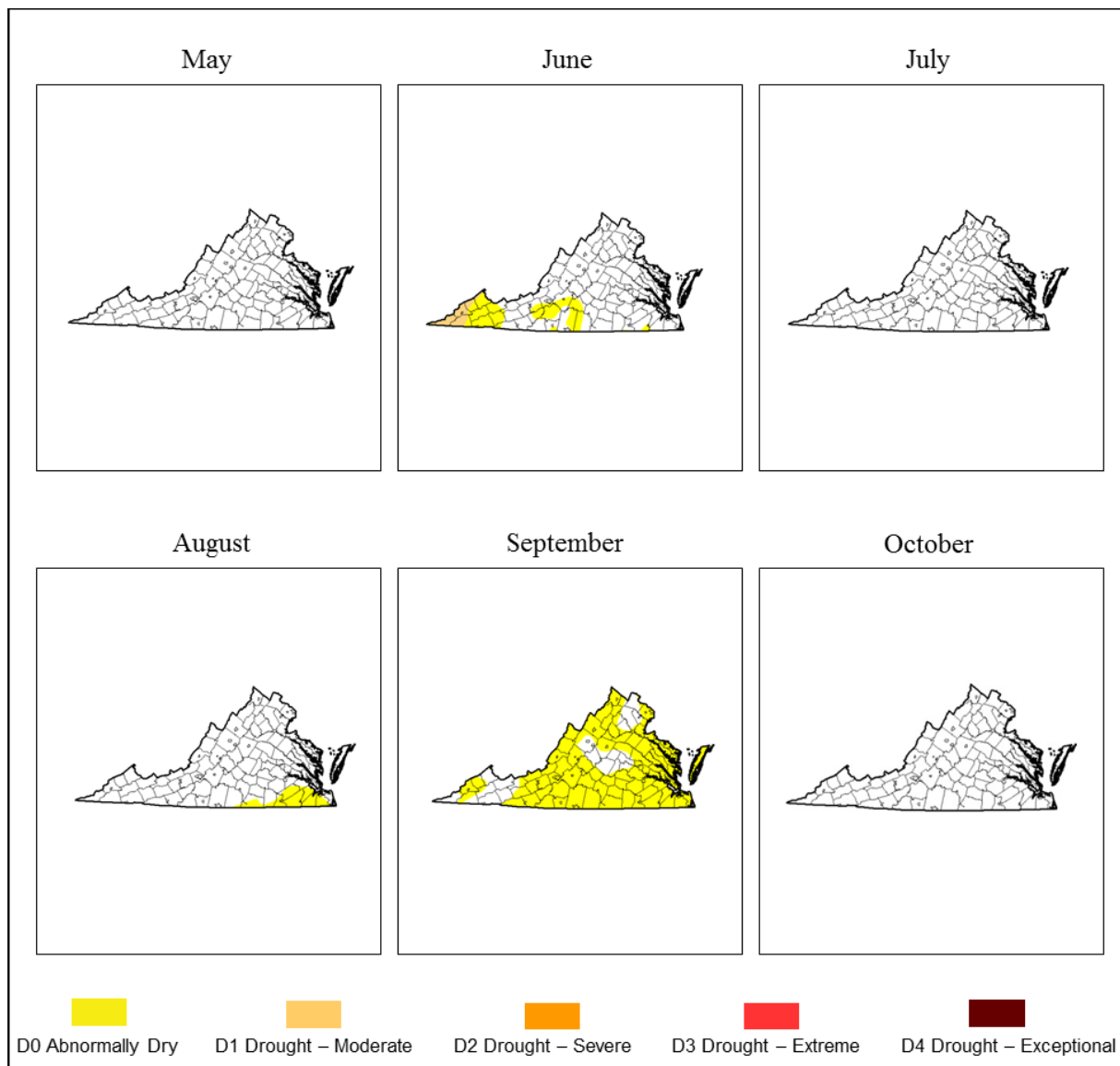


Figure 6. Mid-month values of the United States Drought Monitor (DM) - Drought Intensity Index for Virginia in 2015.

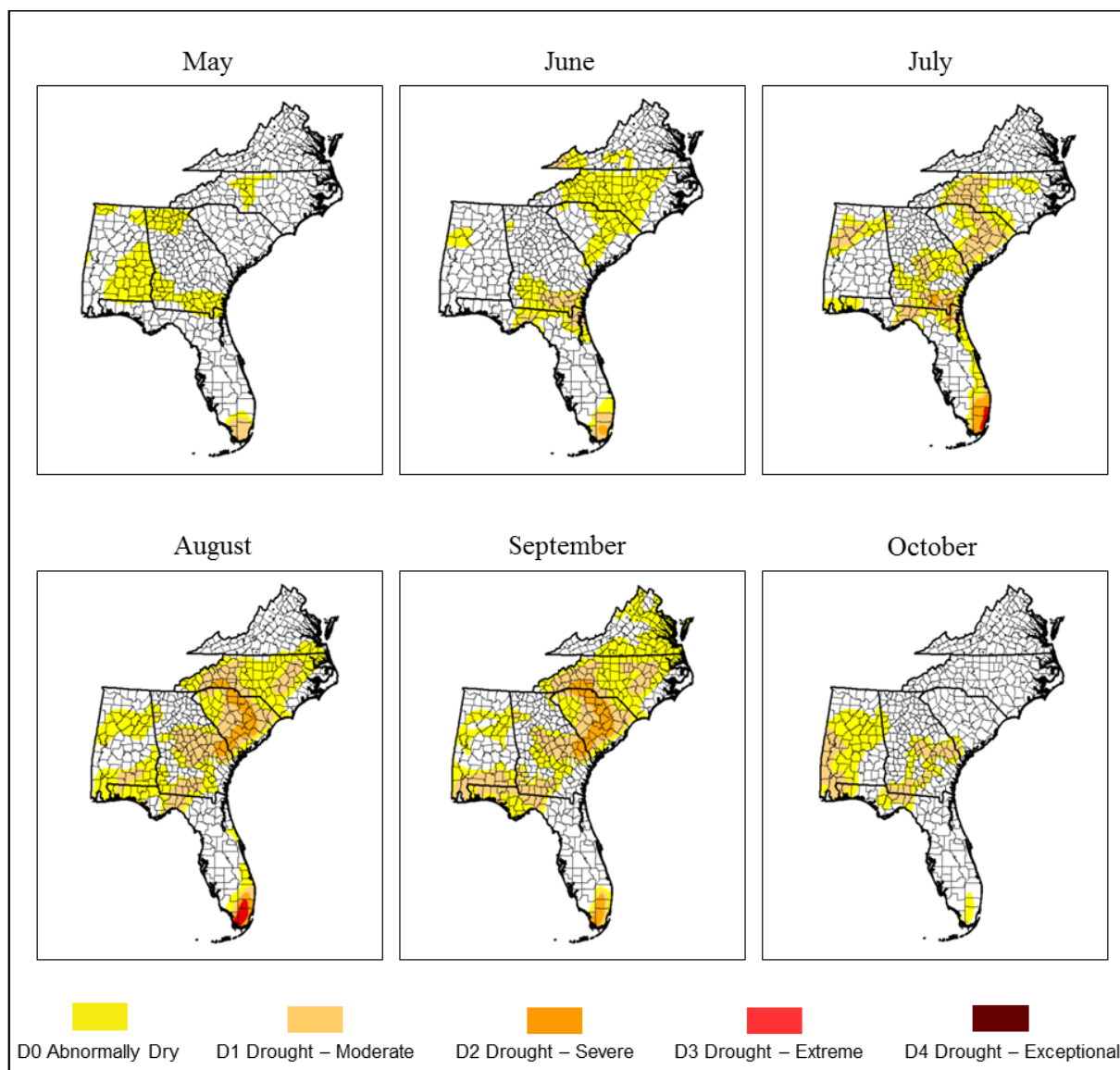


Figure 7. Mid-month values of the United States Drought Monitor (DM) - Drought Intensity Index for the Southeast in 2015.

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