



Shenandoah National Park

Weather of 2009

Natural Resource Data Series NPS/MIDN/NRDS—2010/094



ON THE COVER

View from Skyline Drive, Shenandoah National Park.
Photograph by: National Park Service.

Shenandoah National Park

Weather of 2009

Natural Resource Data Series NPS/MIDN/NRDS—2010/094

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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

COOP	National Weather Service Cooperative Observer Program
CWOP	Citizen Weather Observer Program
FAA	Federal Aviation Administration
IFLOWS	Integrated Flood Observing and Warning System
NADP	National Atmospheric Deposition Program
NARR	North American Regional Reanalysis
NCDC	National Climatic Data Center
NP	National Park
NWS	National Weather Service
PDSI	Palmer Drought Severity Index
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RAWS	Remote Automated Weather Stations
SHEN	Shenandoah National Park
USDM	United States Drought Monitor
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 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). 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, 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.

The Climate of the Western Piedmont, Northern Virginia, and the 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/usclimate/map.html>). Virginia is divided into six climate divisions. The Shenandoah Valley and Mountains 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 damage.

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 typically occurs in late April and first frosts appear in October.

Precipitation is fairly evenly distributed throughout the year. Annual amounts generally range between 34–52 in (864–1,321 mm), while 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, receives an average 41 in (1,041 mm) per year (Gawtry and Stenger 2007). 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.

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, 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

A total of 18 weather observing stations comprising six weather observing networks were selected around Shenandoah NP (Figure 1). 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 (Knight et al., in preparation). A subset of these weather observing networks (IFLOWS, GOES, and CWOP; eight total stations) is 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 seven stations were ultimately used for this 2009 report: Luray, Madison, Staunton Sewage Plant, Waynesboro, Front Royal, Charlottes-Albemarle, and Big Meadows (Figure 1, Table 1).

Of the seven stations, three have a Period of Record (POR) sufficiently long for a 30-year normal (1971–2000). However, Charlottes-Albermale has a low percentage of time reporting temperature and precipitation over its POR and is therefore not used for the 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/gmaps/NPS_DEVELOPMENT/interface.php.

Shenandoah
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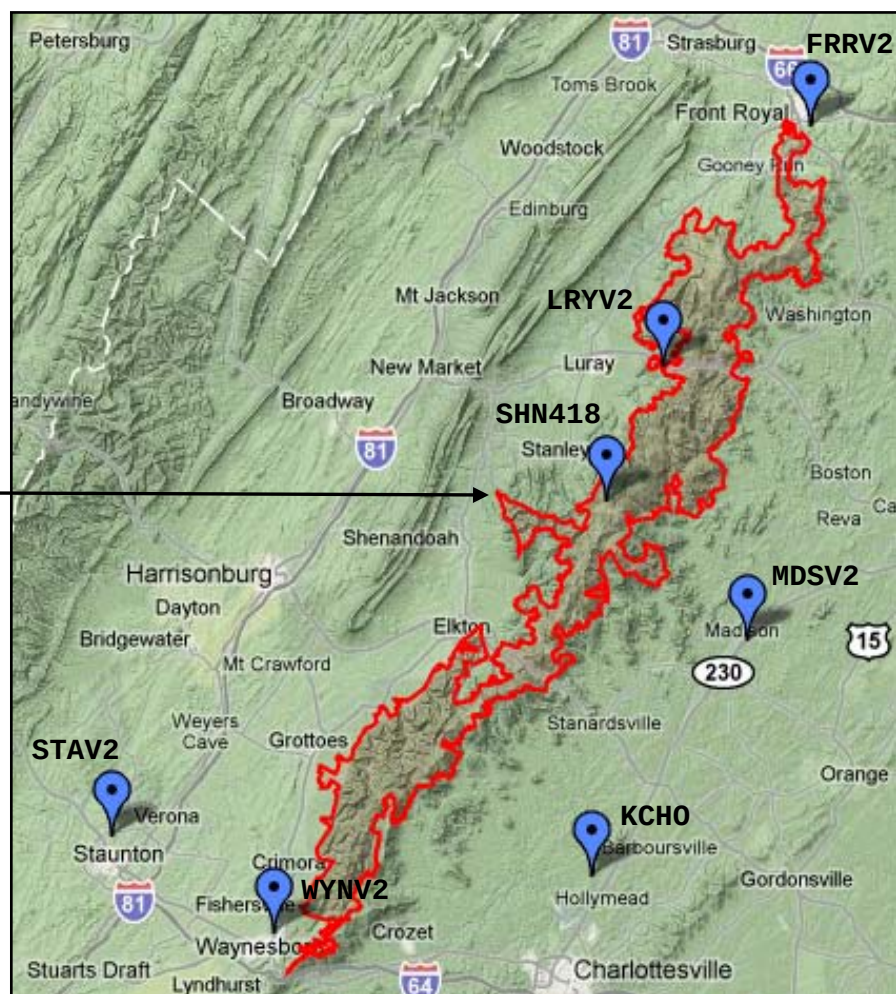


Figure 1. Location of weather observing stations around Shenandoah National Park selected as most representative of the park in 2009.

Table 1. List of weather observing stations around Shenandoah National Park selected as most representative of the parks in 2009.

Station	Observing network	Name	Period of Record		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
LRYV2	COOP	Luray 5 E	03/01/1941	Present	95.9	100.0	92.1	96.9
MDSV2	COOP	Madison	01/01/1996	Present	99.7	100.0	60.0	63.5
STAV2	COOP	Staunton Sewage Plant	01/01/1893	Present	100.0	100.0	93.9	89.5
WYNV2	COOP	Waynesboro	01/01/2001	Present	91.2	90.4	89.7	89.1
FRRV2	COOP	Front Royal	12/01/1995	Present	100.0	100.0	98.6	97.8
KCHO	FAA	Charlottes-Albemarle	01/01/1972	Present	100.0	100.0	33.1*	33.1*
SHN418	CASTNET	Big Meadows	07/01/1988	Present	95.6	95.9	99.8	99.8

* The percentage of time reporting temperature and precipitation for KCHO is 99.5 from 2001 through 2009.

Temperature Summary

Temperatures for the year were slightly above average (Table 2) with a departure near 0.5°F (0.3°C) (Figures 2 and 3)¹. January was quite cold, averaging between 1.3–5.5°F (0.8–3.1°C) below normal across Shenandoah NP (Tables 3 and 4). Noticeably milder daytime temperatures during February (Figure 2) led to above-normal temperatures. The average of the winter months (January through March) was the 54th coolest since records began in 1895 across Northern Virginia, which encompasses the northeastern section of Shenandoah NP (Table 6). The Western Piedmont and Central Mountains of Virginia, which encompass the southern and western sections of the park, averaged the 38th to 50th coolest winter (Tables 5 and 7). The number of cold days was above normal and the lowest readings of the winter, which occurred in mid-January, were several degrees lower than normal (Table 2).

Only April averaged above-normal temperatures across the area (Table 4). Temperatures during the months of May and June varied from somewhat below normal to a bit above, and the result in the three climate divisions was that the spring ranked between the 46th warmest to the 34th coolest (Tables 5, 6 and 7). The growing season started earlier than normal and ended later than in past years so that 2009 had three to four weeks more of frost-free season (Table 2).

The most anomalous season in 2009 was summer. The number of days in which the maximum temperature exceeded 90°F (32.2°C) was below normal (Table 2) and the highest readings of the year were several degrees below the usual values (93°F [33.9°C] and 90°F [32.2°C] in Table 2). In fact, the summer of 2009 ranked as the ninth coolest since 1895 in the Central Mountains Climate Division (Table 7). During July, readings were as much as 6.6°F (3.7°C) below normal in Luray, VA (Table 4). August averaged above-normal readings due to mild nights (Figure 3) and September was very close to normal (Table 4).

The year concluded with alternating cold and warmth. October was cooler than normal in most sections (Figures 2 and 3). However, much warmer conditions returned during November as mean temperatures averaged as much as 4.7°F (2.6°C) above normal at Staunton, VA. The year ended with much below-normal temperatures in December. Overall, autumn 2009 varied from the 51st warmest to the 32nd coolest for the three climate divisions encompassing Shenandoah NP (Tables 5, 6 and 7).

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/>.

Shenandoah National Park
Departure from Average Monthly Maximum Temperature
2009 vs. 1971–2000

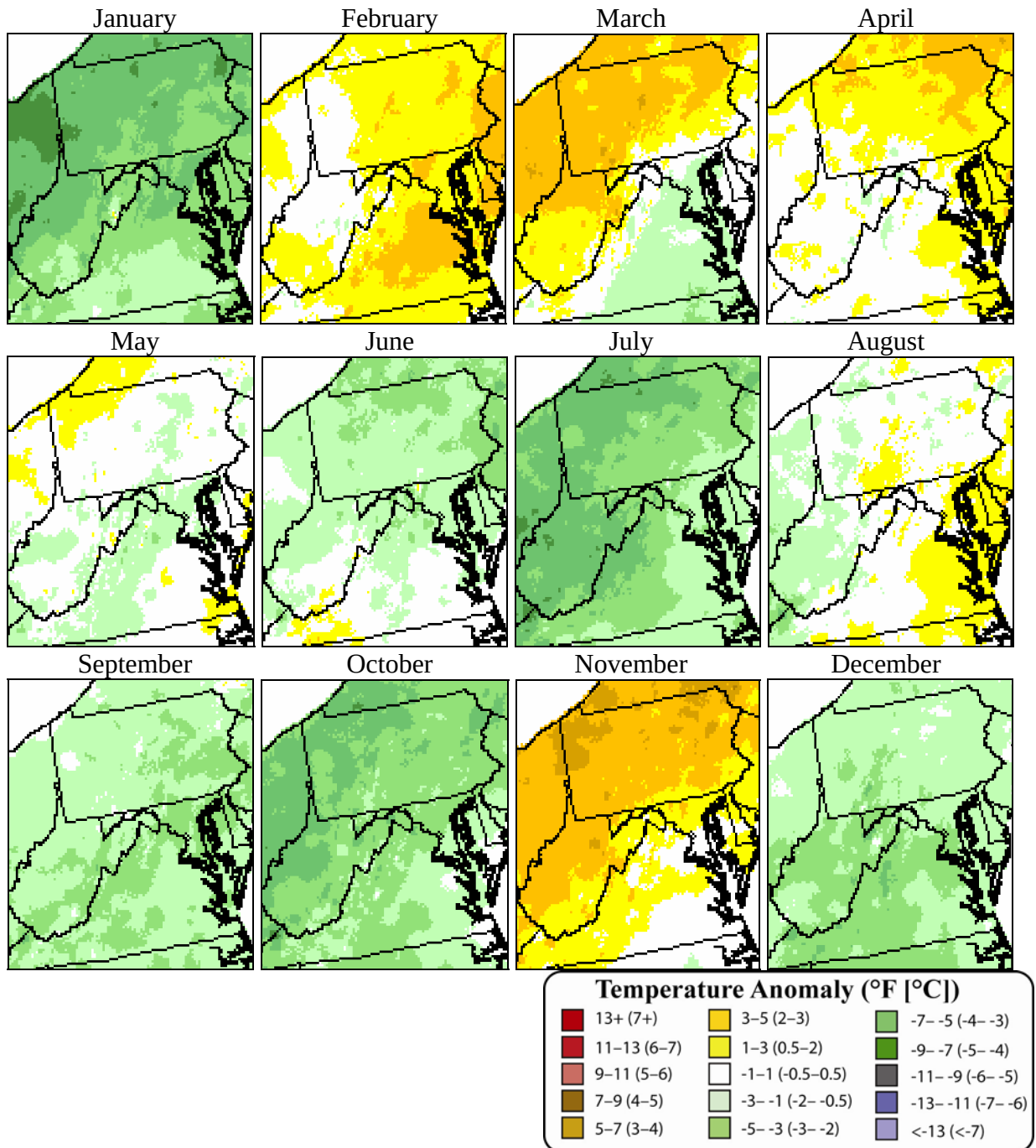


Figure 2. Maps showing departure from average monthly maximum temperature compared to the 30-year normal (1971–2000).

Shenandoah National Park
Departure from Average Monthly Minimum Temperature
2009 vs. 1971–2000

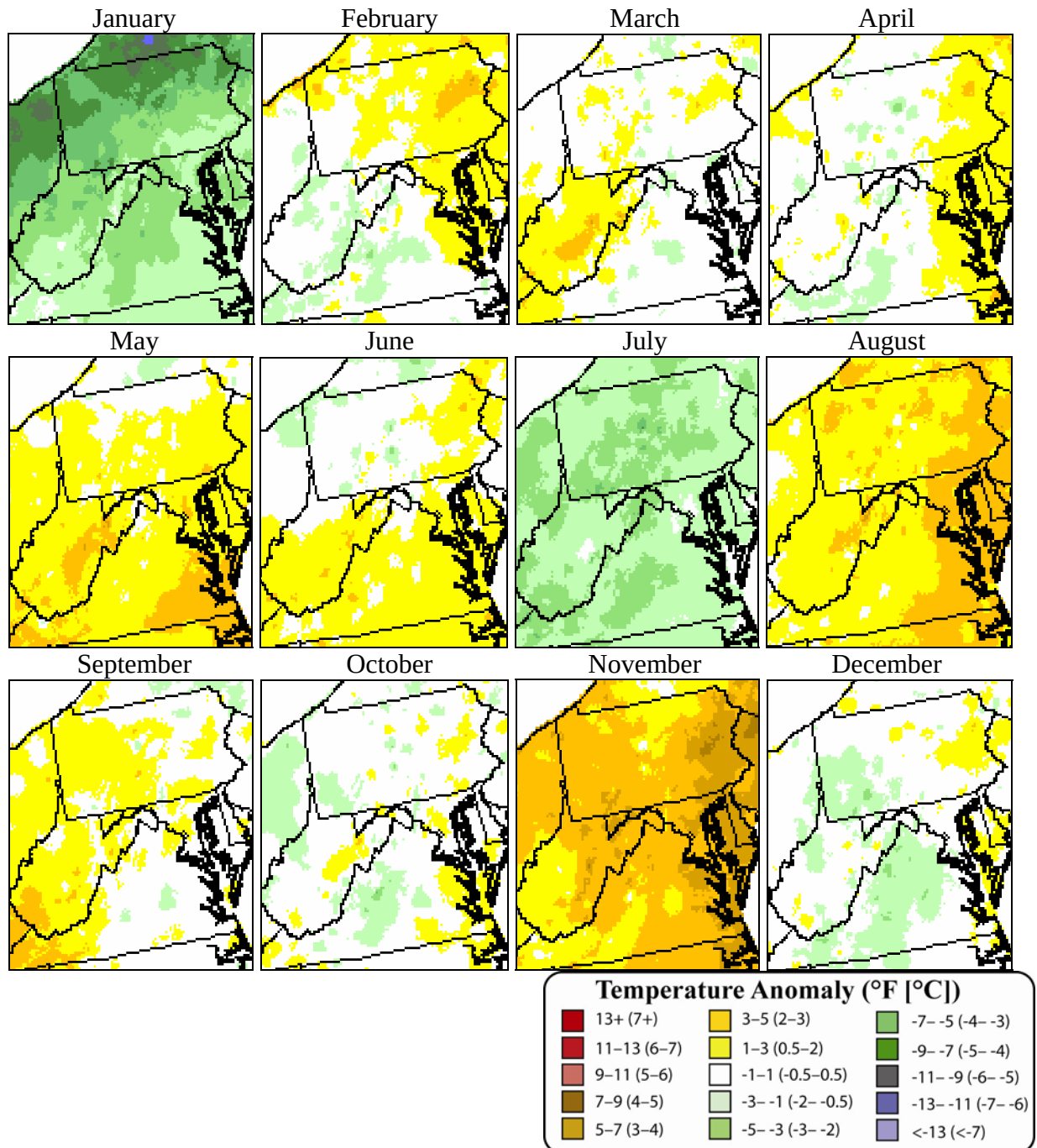


Figure 3. Maps showing departure from average monthly minimum temperature compared to the 30-year normal (1971–2000).

Table 2. Status of 2009 temperature indicators compared to the 30-year normal (1971–2000) at the Luray (LRYV2) and Staunton (STAV2) weather observing stations.

Temperature Indicator	Luray, VA 2009	Luray, VA 1971–2000	Staunton, VA 2009	Staunton, VA 1971–2000
Average Annual Temperature	54.2°F 12.3°C	54.9°F 12.7°C	52.7°F 11.5°C	53.4°F 11.9°C
Average Annual Maximum Temperature	65.4°F 18.6°C	68.8°F 20.4°C	62.5°F 16.9°C	65.7°F 18.7°C
Summer Maximum (highest temperature)	93.0°F 33.9°C	95.8°F 35.4°C	90.0°F 32.2°C	93.9°F 34.4°C
Hot Days (days with Tmax≥90°F/32°C)	12	22	1	12
Average Annual Minimum Temperature	43.0°F 6.1°C	41.1°F 5.1°C	42.9°F 6.1°C	41.1°F 5.1°C
Winter Minimum (lowest temperature)	-4.0°F -20°C	-2.3°F -19.1°C	-2.0°F -18.9°C	1.2°F -17.1°C
Cold Days (days with Tmax≤32°F/0°F)	13	13	20	11
Sub-freezing Nights (days with Tmin≤32°F/0°C)	95	126	104	108
Cold Winter Nights (days with Tmin≤0°F/-17.8°C)	1	2	1	2
Growing Season Length (days between last spring 32°F/0°C and first fall 32°F/0°C)	186	158	185	162

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
Luray 5 E	LRYV2	32.1°F	40.3°F	43.7°F	57.4°F	64.7°F	72.3°F	67.5°F	77.3°F	67.2°F	56.5°F	51.1°F	35.7°F	55.3°F
		0.1°C	4.6°C	6.5°C	14.1°C	18.1°C	22.4°C	19.7°C	25.2°C	19.6°C	13.6°C	10.6°C	2.1°C	13.1°C
Madison	MDSV2	35.3°F	42.3°F	47.1°F	56.9°F	64.6°F	72.6°F	73.3°F	76.1°F	67.3°F	55.9°F	51.6°F	38.6°F	56.8°F
		1.8°C	5.7°C	8.4°C	13.8°C	18.1°C	22.5°C	22.9°C	24.5°C	19.6°C	13.3°C	10.9°C	3.6°C	13.8°C
Staunton on Sewage Plant	STAV2	29.4°F	36.2°F	42.7°F	53.1°F	61.3°F	69.7°F	69.3°F	73.0°F	64.4°F	52.3°F	47.8°F	32.6°F	52.7°F
		-1.5°C	2.3°C	6.0°C	11.7°C	16.3°C	20.9°C	20.7°C	22.8°C	18.0°C	11.3°C	8.8°C	0.3°C	12.6°C
Waynesboro	WYNV2	31.2°F	35.6°F	42.2°F	51.9°F	61.3°F	69.7°F	69.6°F	73.2°F	64.4°F	52.2°F	M	31.7°F	M
		-0.5°C	2.0°C	5.7°C	11.0°C	16.3°C	21.0°C	20.9°C	22.9°C	18.0°C	11.2°C	M	-0.2°C	M
Front Royal	FRRV2	29.4°F	36.8°F	43.2°F	55.1°F	62.9°F	70.6°F	71.6°F	75.6°F	66.6°F	54.4°F	48.9°F	34.8°F	54.2°F
		-1.5°C	2.6°C	6.2°C	12.9°C	17.1°C	21.4°C	22.0°C	24.2°C	19.2°C	12.5°C	9.4°C	1.5°C	13.5°C
Charlottes-Albermarle	KCHO	31.1°F	39.7°F	44.5°F	54.8°F	62.9°F	71.0°F	72.5°F	75.7°F	66.8°F	55.3°F	50.1°F	36.1°F	55.0°F
		-0.5°C	4.3°C	7.0°C	12.7°C	17.2°C	21.7°C	22.5°C	24.3°C	19.3°C	13.0°C	10.0°C	2.3°C	14.0°C
Big Meadows	SHN418	30.1°F	36.3°F	42.8°F	50.9°F	55.5°F	61.9°F	63.7°F	69.8°F	62.0°F	53.5°F	47.8°F	35.6°F	50.8°F
		-1.0°C	2.4°C	6.0°C	10.5°C	13.0°C	16.6°C	17.6°C	21.0°C	16.7°C	11.9°C	8.8°C	2.0°C	10.5°C

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

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
Luray 5 E	LRYV2	-2.2°F	3.0°F	-1.2°F	2.5°F	1.8°F	1.9°F	-6.6°F	4.9°F	0.6°F	0.8°F	4.0°F	-1.8°F	0.5°F
		-1.2°C	1.7°C	-0.7°C	1.4°C	1.0°C	1.0°C	-3.7°C	2.7°C	0.4°C	0.5°C	2.2°C	-1.0°C	0.3°C
Staunton on Sewage Plant	STAV2	-1.3°F	2.6°F	1.0°F	2.3°F	1.5°F	1.8°F	-2.8°F	2.5°F	0.5°F	0.2°F	4.7°F	-1.8°F	0.9°F
		-0.7°C	1.4°C	0.6°C	1.3°C	0.9°C	1.0°C	-1.6°C	1.4°C	0.3°C	0.1°C	2.6°C	-1.0°C	0.5°C
Waynesboro*	WYNV2	-3.2°F	0.8°F	-0.6°F	1.1°F	0.5°F	0.0°F	-2.7°F	0.2°F	-0.7°F	2.4°F	M	-5.3°F	M
		-1.8°C	0.5°C	-0.3°C	0.6°C	0.3°C	0.0°C	-1.5°C	0.1°C	-0.4°C	1.3°C	M	-2.9°C	M
Front Royal*	FRRV2	-5.5°F	0.9°F	0.3°F	1.3°F	0.9°F	-0.5°F	-3.1°F	1.5°F	-0.3°F	-1.4°F	2.7°F	-2.4°F	-0.5°F
		-3.0°C	0.5°C	0.2°C	0.7°C	0.5°C	-0.3°C	-1.7°C	0.8°C	-0.1°C	-0.8°C	1.5°C	-1.3°C	-0.3°C
Charlottes-Albermarle*	KCHO	-3.9°F	1.8°F	-1.6°F	1.6°F	-1.3°F	-1.3°F	-3.5°F	0.6°F	-1.6°F	-2.2°F	1.7°F	-2.7°F	-1.0°F
		-2.2°C	1.0°C	-0.9°C	0.9°C	-0.7°C	-0.7°C	-1.9°C	0.4°C	-0.9°C	-1.2°C	0.9°C	-1.5°C	-0.6°C
Big Meadows*	SHN418	-3.1°F	2.8°F	3.4°F	0.4°F	-2.8°F	0.0°F	-3.3°F	4.6°F	1.4°F	0.8°F	3.7°F	0.1°F	0.7°F
		-1.7°C	1.6°C	1.9°C	0.2°C	-1.5°C	0.0°C	-1.8°C	2.6°C	0.8°C	0.4°C	2.1°C	0.1°C	0.4°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. Madison was not included due to a low percentage of time reporting temperature for the entire Period of Record.

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

Table 5. Seasonal temperature and precipitation rankings over 115 years for the Western Piedmont (NOAA 2010).

Climate Division 3 Rankings Western Piedmont	Jan–Feb–Mar WINTER	Apr–May–Jun SPRING	Jul–Aug–Sep SUMMER	Oct–Nov–Dec AUTUMN
Temperature-2009	77	71	100	83
Precipitation-2009	90	17	84	2

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

Table 6. Seasonal temperature and precipitation rankings over 115 years for Northern Virginia (NOAA 2010).

Climate Division 4 Rankings Northern Virginia	Jan–Feb–Mar WINTER	Apr–May–Jun SPRING	Jul–Aug–Sep SUMMER	Oct–Nov–Dec AUTUMN
Temperature-2009	61	46	73	51
Precipitation-2009	113	6	99	8

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

Table 7. Seasonal temperature and precipitation rankings over 115 years for the Central Mountains (NOAA 2010).

Climate Division 5 Rankings Central Mountains	Jan–Feb–Mar WINTER	Apr–May–Jun SPRING	Jul–Aug–Sep SUMMER	Oct–Nov–Dec AUTUMN
Temperature-2009	65	64	106	76
Precipitation-2009	92	10	50	7

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

Precipitation Summary

Precipitation totals in 2009 averaged slightly below normal in the northern sections of Shenandoah NP and above normal in the southern portion (Table 8). Wet spells were notable in later November and December while dry spells were common in the first three months of the year (Tables 9 and 10). Overall, reporting stations in the region tallied annual precipitation between 94 and 111 percent of normal values (Table 11).

The driest period occurred during January, February, and March. All three climate divisions in which the park resides (Western Piedmont, Northern Mountains, and Central Mountains) reported winter precipitation totals among the 25 driest winters since 1895 (Tables 5, 6, and 7). February was the driest of the three months, with precipitation totals between 15 and 56 percent of average (Table 11). During the first 90 days of 2009, there were three long dry spells totaling 34 days when no measurable precipitation was recorded (Table 9).

In sharp contrast to winter, the spring months of 2009 brought well above-average precipitation, particularly in the months of May and June. In the three climate divisions in which the park resides, that three-month period in 2009 was the 6th–17th wettest since 1895. Twice in early May and once in early June, storms brought a one-day total of ~1.8 in (46 mm) of rain in Luray and Staunton, VA (Table 9). The rainfall in June was less widespread.

The summer months in Shenandoah NP had varied rainfall (Figure 4), with the northern sections ranking as the 16th driest and the southern portion ranking the 50th wettest since 1895 (Tables 5, 6 and 7). No station reported more than 100 percent of normal rainfall in any of the three months (Table 11), and several sites, notably Waynesboro, averaged only 51 percent of normal precipitation. More typical of summer months, there were also two consecutive 7-day periods without rain in Luray from August 30–September 7 and September 29–October 6 (Table 9). There were no effects in Shenandoah NP from tropical storms during 2009.

The remainder of the calendar year was wetter than normal, with Big Meadows reporting 175 percent of their average rainfall for the months of October through December, collectively (Table 11). Two more wet days occurred in November and December with a total of more than 3.5 in (89 mm) (Table 9). Once again, autumn precipitation was above seasonal levels (Table 8). Snowfall in 2009 was above normal, ranging from 125–250 percent higher than the long-term mean (Table 9). Much of the snowfall came when a blizzard buried much of Virginia during December 19–20.

Table 8. Status of 2009 precipitation indicators compared to the 30-year normal (1971–2000) at the Luray (LRYV2) and Staunton (STAV2) weather observing stations.

Precipitation Indicator	Luray, VA 2009	Luray, VA 1971–2000	Staunton, VA 2009	Staunton, VA 1971–2000
Annual Precipitation	40.5 in 1,028 mm	41.6 in 1,057 mm	43 in 1,092 mm	38.9 in 988 mm
Autumn (Oct, Nov, Dec) Precipitation	13.1 in 333 mm	9.5 in 241 mm	12.9 in 328 mm	8.5 in 216 mm
Heavy Rain (days with ≥ 1.0 in (25 mm) rain)	6	10	11	9
Extreme Rain (days with ≥ 2.0 in (51 mm) rain)	0	2	0	1
Micro-drought (strings of 7+ days without rain)	9	9	9	8
Annual Snowfall	33.2 in 84.3 cm	24.6 in 62.5 cm	46.6 in 118.4 cm	18.9 in 48 cm
Snow (days with ≥ 0.1 in (0.3 cm) snow)	8	9	13	7
Moderate Snow (days with ≥ 2.0 in (5.0 cm) snow)	5	5	6	4
Heavy Snow (days with ≥ 5.0 in (15.2 cm) snow)	3	2	2	1

Table 9. 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 Luray (LRYV2) and Staunton (STAV2).

Wettest Days in 2009	Dry Spells in 2009
Nov. 12: 1.8 in (46 mm)	Feb. 12–27
May 8: 1.8 in (46 mm)	Jan. 12–26
Dec. 9: 1.7 in (43 mm)	Mar. 3–12
May 4: 1.7 in (43 mm)	Aug. 30–Sep. 7
Jun. 4: 1.7 in (43 mm)	Sep. 29–Oct. 6

Table 10. 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
Luray	LRYV2	2.3 in	0.4 in	1.8 in	2.2 in	7.9 in	5.9 in	2.4 in	2.7 in	1.7 in	2.7 in	5.8 in	4.7 in	40.5 in
		58 mm	10 mm	46 mm	56 mm	201 mm	150 mm	61 mm	69 mm	43 mm	69 mm	147 mm	119 mm	1,029 mm
Madison	MDSV2	2.1 in	0.6 in	2.4 in	3.8 in	7.7 in	7.0 in	2.8 in	3.8 in	3.0 in	2.4 in	5.4 in	7.2 in	48.2 in
		53 mm	15 mm	61 mm	97 mm	196 mm	178 mm	71 mm	97 mm	76 mm	61 mm	137 mm	183 mm	1,224 mm
Staunton Sewage Plant	STAV2	2.2 in	0.7 in	2.6 in	3.4 in	8.0 in	3.3 in	3.6 in	2.8 in	3.6 in	2.4 in	4.6 in	6.0 in	43.0 in
		56 mm	18 mm	66 mm	86 mm	203 mm	84 mm	91 mm	71 mm	91 mm	61 mm	117 mm	152 mm	1,097 mm
Waynesboro	WYNV2	1.9 in	0.4 in	2.0 in	5.1 in	6.2 in	3.5 in	2.1 in	1.7 in	3.3 in	2.1 in	M	7.4 in	M
		48 mm	10 mm	51 mm	130 mm	157 mm	89 mm	53 mm	43 mm	84 mm	53 mm	M	188 mm	M
Front Royal	FRRV2	2.0 in	0.7 in	2.2 in	4.1 in	6.0 in	4.8 in	2.4 in	3.0 in	1.6 in	3.1 in	4.6 in	7.1 in	41.5 in
		51 mm	18 mm	56 mm	104 mm	152 mm	122 mm	61 mm	76 mm	41 mm	79 mm	117 mm	180 mm	1,057 mm
Charlottes-Albemarle	KCHO	1.6 in	0.5 in	2.3 in	3.1 in	7.0 in	4.2 in	2.4 in	3.6 in	4.2 in	2.3 in	6.6 in	7.7 in	45.5 in
		41 mm	13 mm	58 mm	79 mm	178 mm	107 mm	61 mm	91 mm	107 mm	58 mm	168 mm	196 mm	1,156 mm
Big Meadows	SHN418	2.3 in	1.4 in	2.2 in	6.1 in	7.7 in	3.6 in	2.8 in	4.1 in	3.2 in	3.9 in	9.2 in	5.1 in	51.6 in
		58 mm	36 mm	56 mm	155 mm	196 mm	91 mm	71 mm	104 mm	81 mm	99 mm	234 mm	130 mm	1,311 mm

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

Table 11. Summary of 2009 percent of normal 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
Luray	LRYV2	75	15	53	70	202	148	64	77	39	77	166	165	97
Madison*	MDSV2	60	20	77	106	171	130	62	100	57	73	174	232	104
Staunton Sewage Plant	STAV2	76	28	80	116	210	92	94	80	95	71	156	241	111
Waynesboro*	WYNV2	86	20	65	134	188	80	53	40	63	57	M	264	M
Front Royal*	FRRV2	65	27	65	130	153	121	64	85	37	89	132	249	100
Charlottes-Albemarle*	KCHO	47	16	59	95	148	93	48	88	87	52	166	229	94
Big Meadows*	SHN418	74	56	56	130	157	68	68	91	67	122	224	170	107

*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.

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

Shenandoah National Park
Percent of Average Monthly Precipitation
2009 vs. 1971–2000

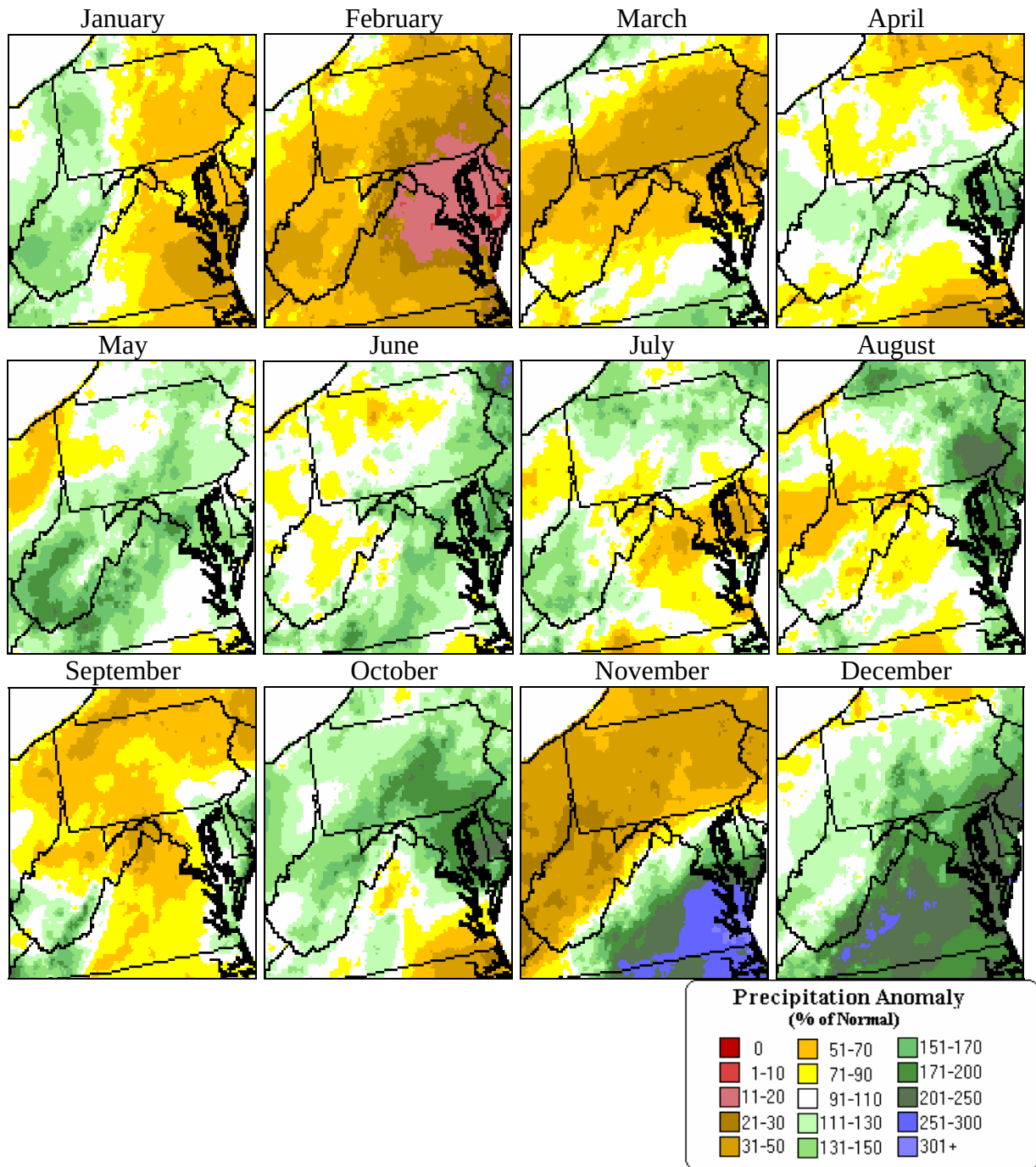


Figure 4. Maps showing percent of average monthly precipitation compared to the 30-year normal (1971–2000).

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 Northern Virginia 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 Virginia (Figure 6) and the Southeast (Figure 7) are shown for 2009.

According to the PDSI, 2009 started below 0, or drier than average. A very dry late winter led to conditions approaching moderate drought (near -2) by late March. However, wet weather during the spring (Figures 5, 6, and 7) brought the index back to positive values and, in fact, by late June, it was approaching moderately-moist conditions. A drier period during the summer kept PDSI values near normal. Wet weather returned late in the autumn and raised the PDSI during the fall. This past year was not as dry as the previous two years, especially in the autumn.

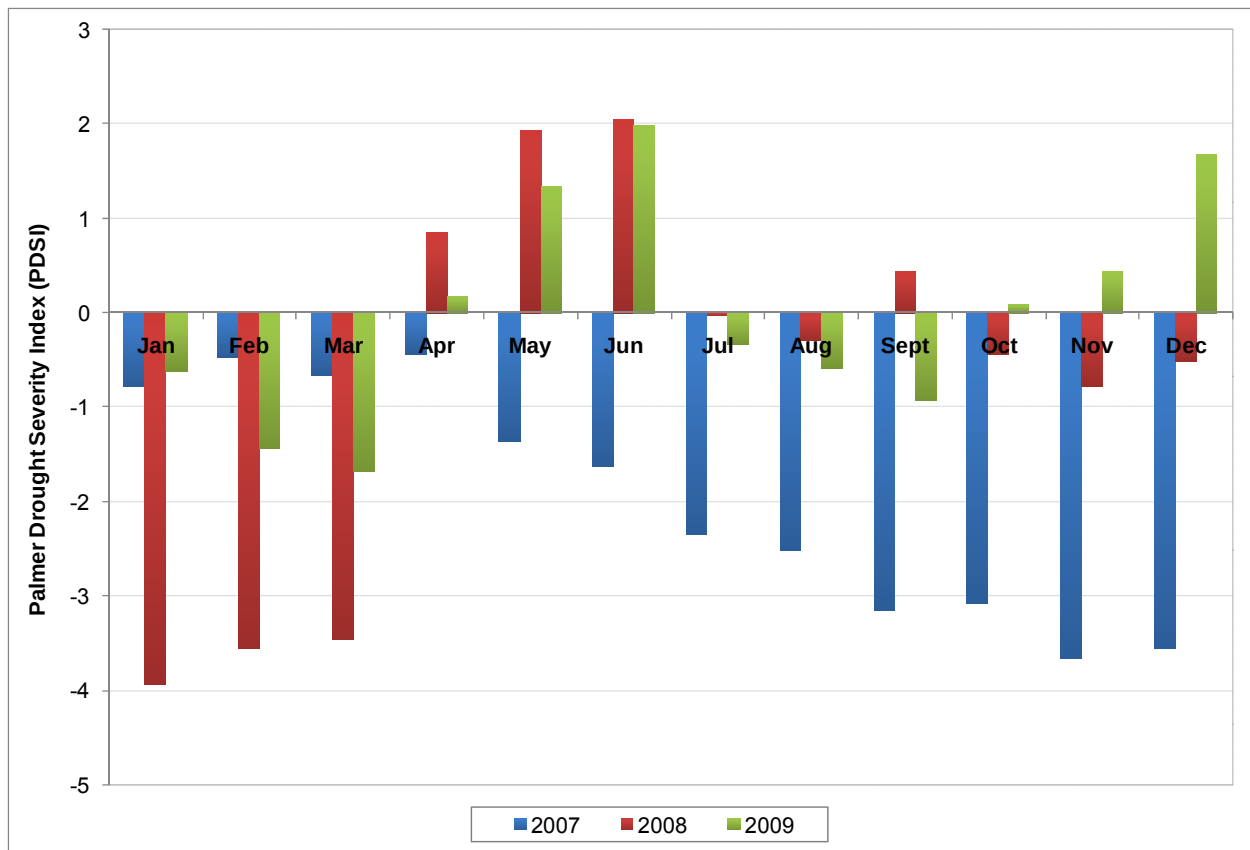


Figure 5. Palmer Drought Severity Index (PDSI) for Northern Virginia, 2007–2009.

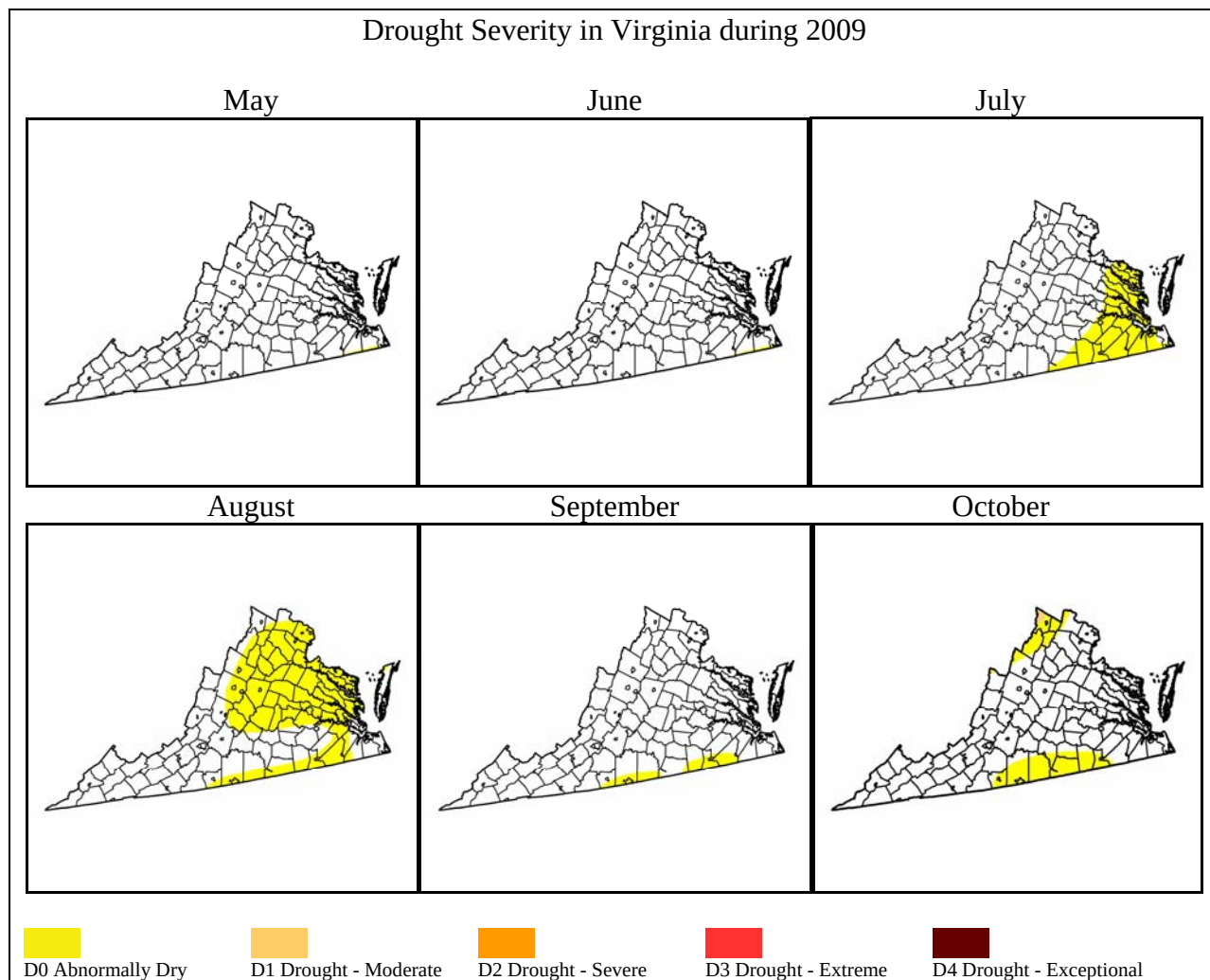


Figure 6. Mid-month values of the Palmer Drought Severity Index for Virginia in 2009.

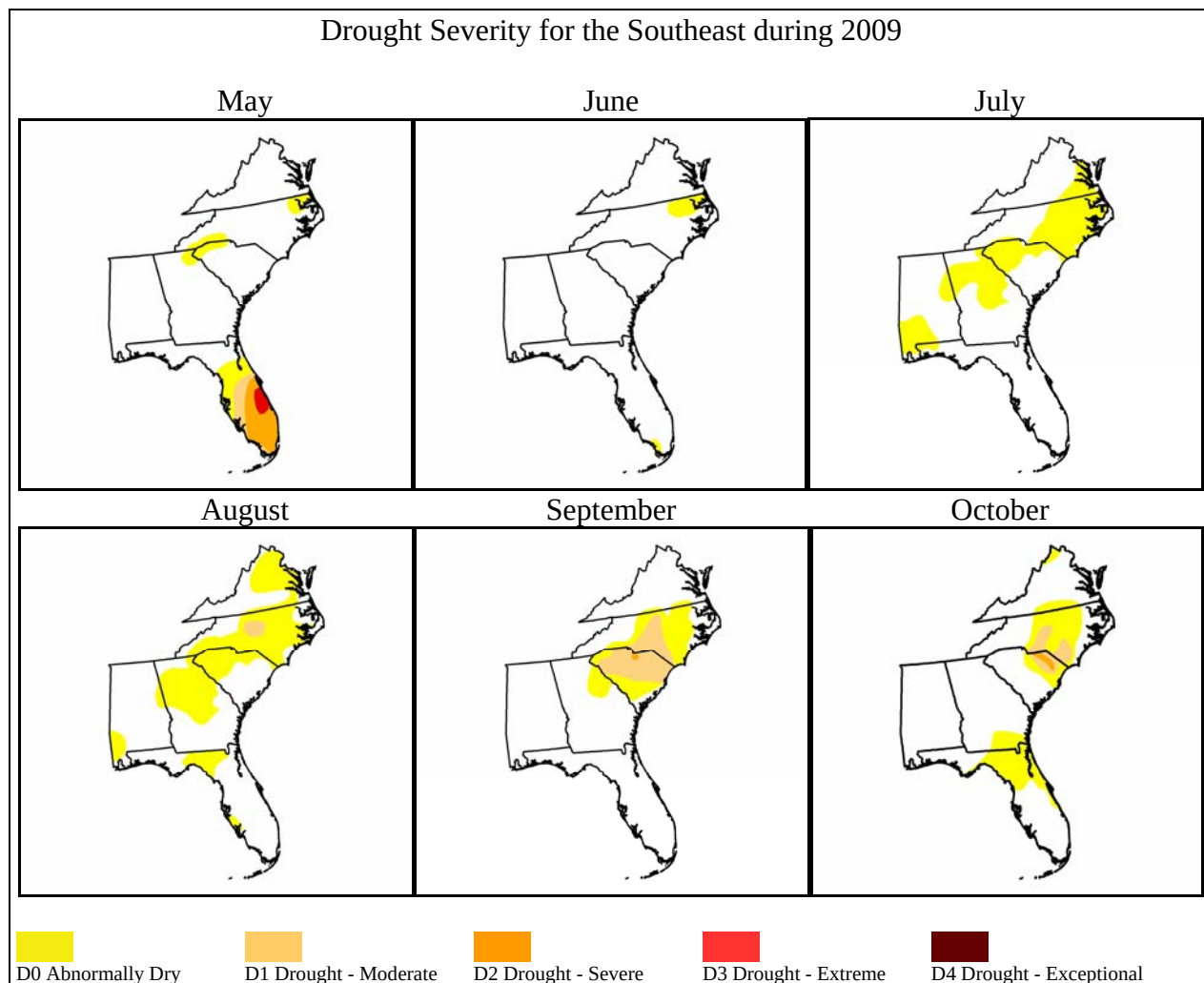


Figure 7. Mid-month values of the Palmer Drought Severity Index for the Southeast in 2009.

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