



Weather of Petersburg National Battlefield and Richmond National Battlefield Park

Mid-Atlantic Network Summary Report for 2015

Natural Resource Report NPS/MIDN/NRR—2016/1328



ON THE COVER

Photograph of Petersburg National Battlefield.
Photograph courtesy of Buddy Secor.

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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 Petersburg National Battlefield (NB) and Richmond National Battlefield Park (NBP) for the time period of January 1 to December 31, 2015. Petersburg NB and Richmond NBP are located in the Tidewater and Eastern Piedmont climate divisions of Virginia. In 2015, a total of four 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 12th warmest on record for the Tidewater. In fact, the autumn of 2015 was the warmest autumn since 1895. The year was also very wet, being the 18th wettest on record. No drought conditions were reported during 2015.

List of Key Acronyms

ASOS	Automated Surface Observation System
CASTNET	Clean Air Status and Trends Network
COOP	National Weather Service Cooperative Observer Program
CWOP	Citizen Weather Observer Program
FAA	Federal Aviation Administration
IFLOWS	Integrated Flood Observing and Warning System
MIDN	Mid-Atlantic Network
NADP	National Atmospheric Deposition Program
NARR	North American Regional Reanalysis
NB	National Battlefield
NBP	National Battlefield Park
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PASC	Pennsylvania State Climatologist
PDSI	Palmer Drought Severity Index
PETE	Petersburg National Battlefield
POR	Period of Record
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RAWS	Remote Automated Weather Stations
RICH	Richmond National Battlefield Park
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).

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 Tidewater and Eastern Piedmont Region of Virginia

Petersburg National Battlefield (NB) and Richmond National Battlefield Park (NBP) lie in VA Climate Division 1 (Tidewater) and VA Climate Division 2 (Eastern Piedmont). A climate division is a region that is reasonably homogenous with respect to climatic and hydrologic characteristics and is frequently used for compiling climate statistics

(<http://www.esrl.noaa.gov/psd/data/usclimdivs/data/map.html>). Virginia is divided into six climate divisions. The Tidewater and Eastern Piedmont divisions of Virginia are generally considered to have a humid, continental type of climate, but the rolling hills and valleys have a marked effect on the weather and climate of the parks. 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.

Temperatures are moderately continental with the tempering effects due to nearby mountains that contribute to cloud production in the summer and onshore winds modifying the chill at times during the winter. 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 directs hot, humid air from the Gulf region into the area. The southwest winds gain additional warmth when descending the crest of the Appalachians. The last freeze and first frost typically occur in mid-April and late October or early November, respectively.

Precipitation is fairly evenly distributed throughout the year. Annual amounts generally range between 38–48 in (965–1,219 mm), though the majority of places receive 40–45 in (1,016–1,143 mm). Greatest amounts usually occur during 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 years with more coastal storms (which occasionally frequent the area). During the warm season, these storms can bring heavy rain, and in winter, heavy snow or a mixture of rain and snow may be produced. On average, annual snowfall amounts tend to be slightly greater in Richmond NBP than Petersburg NB.

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 parks each summer. On average, tornadoes pass through the area about once every three years. The direct effects of an Atlantic hurricane are irregular, 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 and are primarily confined to the months between December and March (Kocin and Uccellini 2004).

Observing Stations and Climate Indicators

A total of four weather observing stations, comprising three weather networks, were selected as the most representative weather stations around Petersburg NB and Richmond NBP in 2015.

Representative stations within a 100-km range of each park were chosen based on several criteria, which include proximity to the park, representativeness of the station to the park elevation profile, 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. The I-295 over Meadow Rd station did not report data for 2015, thus it shows up as missing for the entire year. A total of three stations were ultimately used for the majority of this 2015 report: Richmond, Petersburg, and Hopewell. (Figure 1, Table 1).

The following are the climate indicators selected for each of the parks:

- Average Annual Mean Temperature – A measure of the composite mean temperature (averaging the maximum and minimum on a daily basis) for an entire year
- Average Annual Maximum Temperature – A measure of the average of the daily maximum temperature for an entire year
- Highest Annual Maximum Temperature – A measure of the individual highest maximum temperature each year
- Annual Number of Hot Days (maximum temperature equal to or exceeding 90°F (32°C)) – A measure of warm season heat using a threshold of days with a 90°F (32°C) maxima
- Average Annual Minimum Temperature – A measure of the average of the daily minimum temperature for an entire year
- Lowest Annual Minimum Temperature – A measure of the individual lowest minimum temperature each year
- Annual Number of Cold Days (maximum temperature less than or equal to 32°F (0°C)) – A measure of cold season chill using a threshold of days with a 32°F (0°C) maxima
- Annual Number of Subfreezing Days (minimum temperature less than or equal to 32°F (0°C)) – A measure of cold season chill using a threshold of days with a 32°F (0°C) minima
- Annual Number of Subzero Days (minimum temperature less than or equal to 0°F (-17.8°C)) – A measure of cold season chill using a threshold of days with a 0°F (-17.8°C) minima
- Growing Season Length (number of days between last freeze in spring and first freeze in fall) – A measure of the local growing season as tallied by the total number of days between the last 32°F (0°C) in the spring and the first 32°F (0°C) in the fall
- Annual Precipitation – A measure of total liquid (and its equivalent melted snow) for all days

- Autumn Precipitation (October 1 – December 31) - The three month total precipitation including rain and melted snow
- Annual Number of Heavy Precipitation Days (liquid equal to or greater than 1.0 in (25mm) – A measure of the frequency of heavy precipitation events during each year
- Annual Number of Extreme Precipitation Days (liquid equal to or greater than 2.0 in (50mm)) – A measure of frequency of extreme precipitation events during each year
- Annual Number of Micro-droughts – A measure of micro-droughts for the year as the number of periods of 7+ days without rain
- Annual Snowfall – A measure of total solid precipitation (includes sleet and hail; does not include freezing rain)
- Annual Number of Measureable Snow Days – A measure of the severity of winter precipitation as the number of days receiving more than or equal to 0.1 in (0.3 cm) of solid precipitation (includes sleet and hail; does not include freezing rain)
- Annual Number of Moderate Snow Days– A measure of the severity of winter precipitation as the number of days receiving more than or equal to 3 in (7.6 cm) of solid precipitation (includes sleet and hail; does not include freezing rain)
- Annual Number of Heavy Snow Days– A measure of the severity of winter precipitation as the number of days receiving more than or equal to 5 in (12.7 cm) of solid precipitation (includes sleet and hail; does not include freezing rain)

The average value of a climate element over 30 years is defined as a climatological normal, which are calculated and established by NOAA’s National Climatic Data Center (NCDC). Every ten years, NCDC computes new thirty-year climate normals for selected temperature and precipitation elements for a large number of U.S. climate and weather stations. The current (as of 2013) 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 be the 30-year normal or the pseudo-normal calculated on a shorter time frame

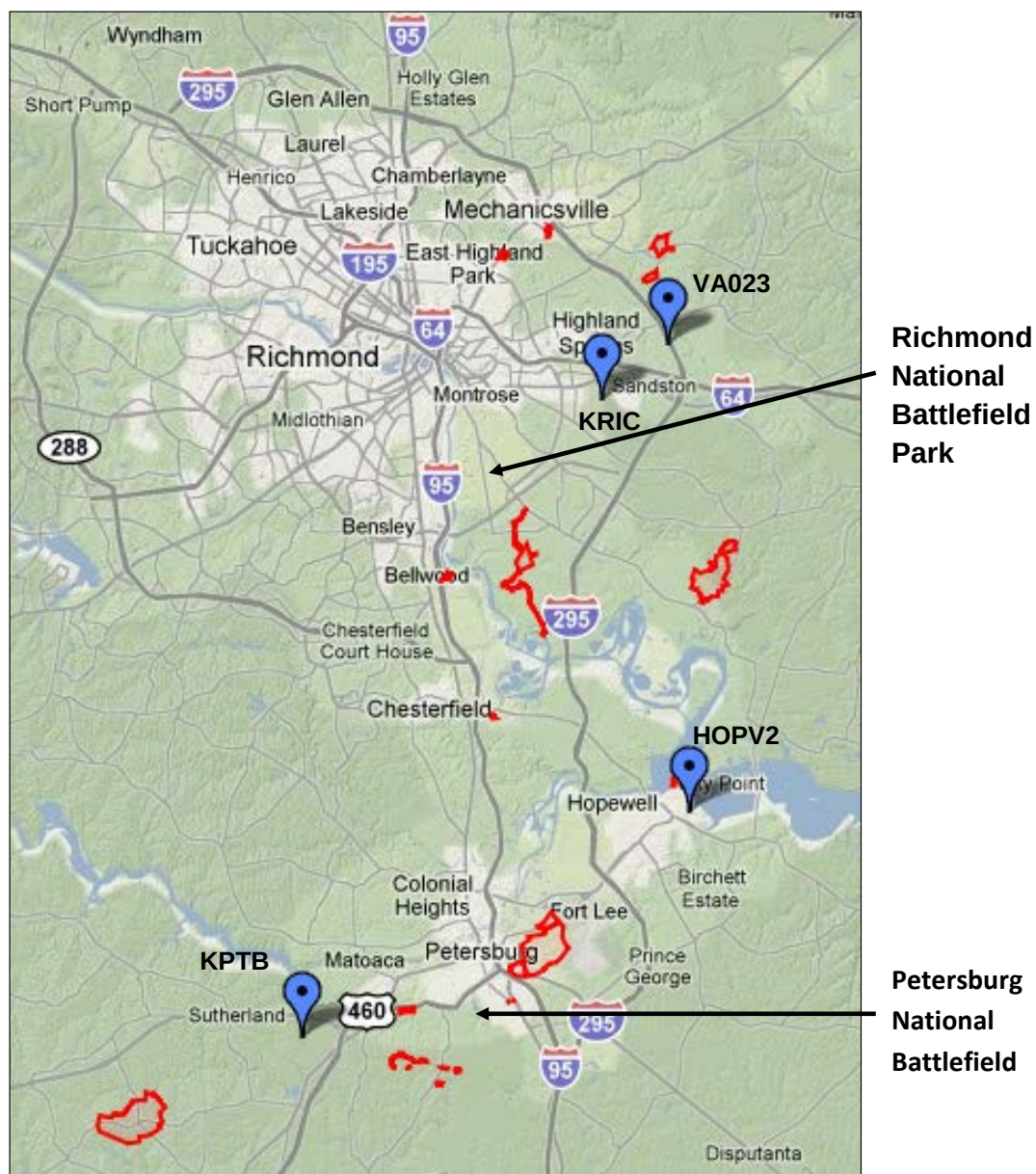


Figure 1. Location of weather observing stations around Petersburg National Battlefield and Richmond National Battlefield Park selected as most representative of the parks in 2015. See Table 1 for station names.

Table 1. List of weather observing stations around Petersburg National Battlefield and Richmond National Battlefield Park selected as most representative of the parks in 2015.

Station	Observing Network ¹	Name	Period of Record (POR)	Percentage of Time Reporting Temperature for 2015	Percentage of Time Reporting Precipitation for 2015	Percentage of Time Reporting Temperature for entire POR	Percentage of Time Reporting Precipitation for entire POR
KRIC	ASOS	Richmond International Airport	02/01/1949 - Present	100.0	100.0	96.2	89.1
KPTB	ASOS	(Petersburg) Dinwiddie County Airport	01/01/1996 - Present	98.1	98.1	82.8	67.1
HOPV2	COOP	Hopewell	01/01/1960 - Present	96.7	97.5	97.5	97.7
VA023	RWIS	I-295 Over Meadow Road	08/24/2005 - Present	-	-	67.5	46.7

¹ Observing networks are: ASOS — Automated Surface Observation System, COOP — National Weather Service Cooperative Observer Program, and RWIS — Road Weather Information System.

Of the four stations, Richmond and Hopewell have a Period of Record (POR) sufficiently long for a 30-year normal (normal calculated from years 1981–2010). A normal was also calculated for Petersburg based on a POR from 1996–2010. Monthly averages and deviations from normal are presented for all stations for precipitation and temperature except for I-295 Over Meadow Road which only has seven years of data.

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>.

Temperature Summary

It was a nearly average year for the area around Petersburg NB and Richmond NBP (Table 2, Figures 2 and 3)¹. May, June, September, November, and December had widespread above normal readings, leaving the remaining seven months near normal or cooler than average (Figure 3).

The year began relatively cool across the region, with January monthly departures ranging from 0.5 to 2.7°F (0.3 to 1.5°C) below normal (Tables 3 and 4). Temperatures took a large swing to the cold side for February. Readings averaged between 8.1 and 9.5°F (4.5 and 5.2°C) below normal, making February the coldest month of the year (Tables 3 and 4). The lowest readings of 2015 occurred on February 20th when minimum temperatures fell to 4°F (-15.6°C) at Richmond and 5°F (-15.0°C) at Hopewell, both several degrees below the long-term average minimum temperature (Table 2). Seven of the ten cold days, when maximum temperatures are below the freezing mark, occurred during the month of February at Richmond Airport (Table 2). Overall, the winter was the 10th coldest in the Tidewater and 15th coldest in the Eastern Piedmont since records began in 1895 (Tables 5 and 6).

After the colder than normal start to the year, spring would turn mild across the region. All reporting stations observed milder than normal temperatures over all three months of April, May, and June, with the exception of Petersburg Airport during April (Table 4). May was the most unusually warm month of the season, with temperature anomalies between 2.8 and 5.1°F (1.5 and 2.8°C) above normal across the region (Table 4). The spring season ranked as the 2nd and 3rd warmest in the Tidewater and in the Eastern Piedmont, respectively, over 121 years of records (Tables 5 and 6).

Summer of 2015 was close to normal for the area around Petersburg NB and Richmond NBP. Cool days and warm nights in July resulted in mean temperatures ranging from -0.1°F to -1.8°F (-0.1°C to -1.0°C) below normal at the stations (Table 4). The moderate temperatures in both July and August resulted in the number of hot days near the long-term averages (slightly above at Richmond and below at Hopewell) for the calendar year 2015 (Table 2). The season ended on a mild note, as average temperatures in September reached 74.4°F (23.6°C) at Richmond Airport, 3.8°F (2.2°C) above the 1981-2010 normal (Tables 3 and 4). The summer season tied as the 28th and 40th warmest in 121 years in the Tidewater and the Eastern Piedmont regions, respectively (Tables 5 and 6).

The autumn began slightly cool in October but would turn anomalously mild by the end of the year (Figures 2 and 3). December 2015 was the warmest on record across the region, with positive temperature anomalies between 10.2 and 11.8°F (5.6 and 6.5°C) for the reporting stations (Tables 3

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/>.

and 4). The autumn season, as a whole, also ranked as the warmest ever recorded for the Tidewater and the Eastern Piedmont since records began in 1895 (Tables 5 and 6).

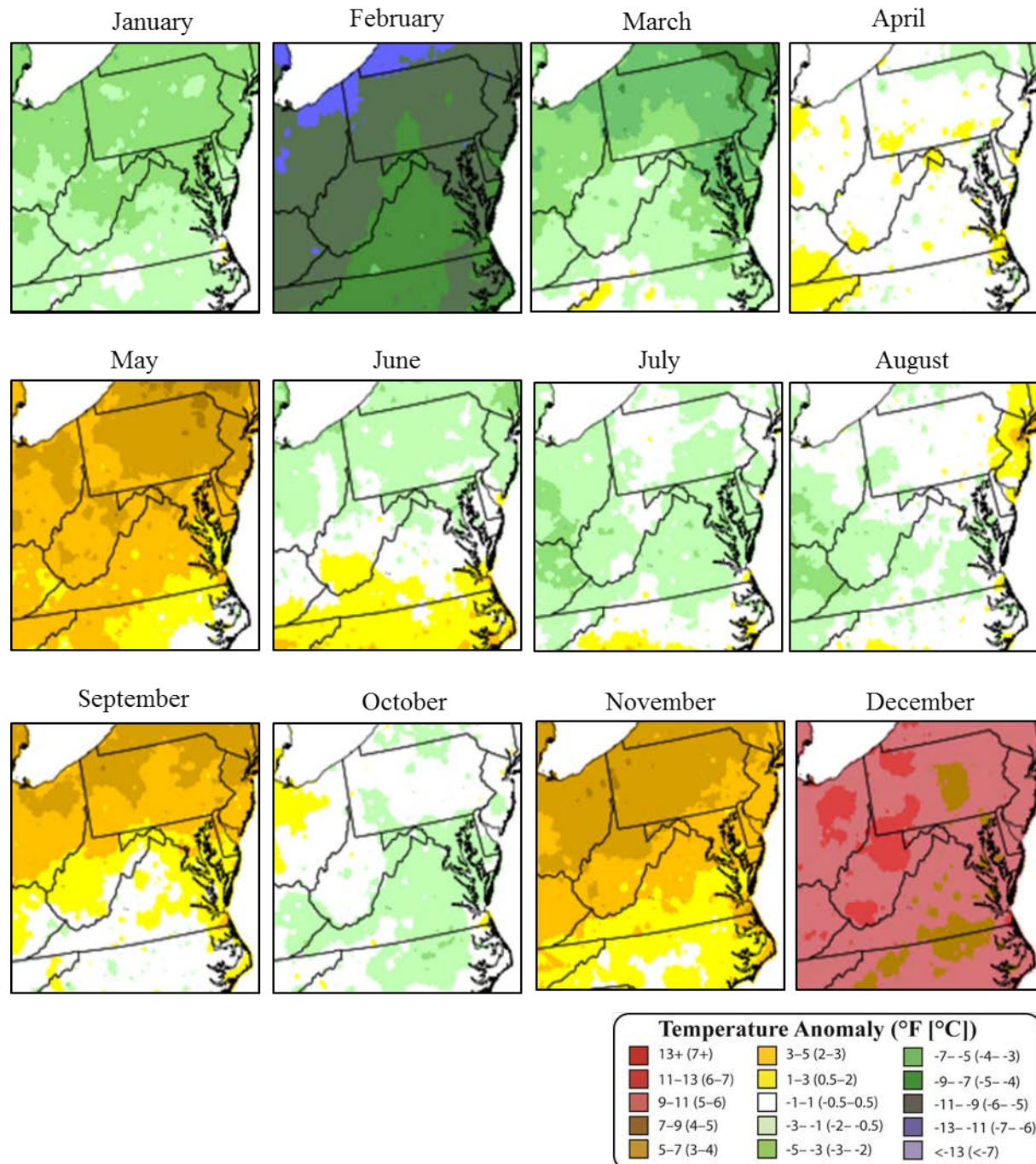


Figure 2. Maps showing departure from average monthly maximum temperature in 2015 compared to the 30-year normal (1981–2010).

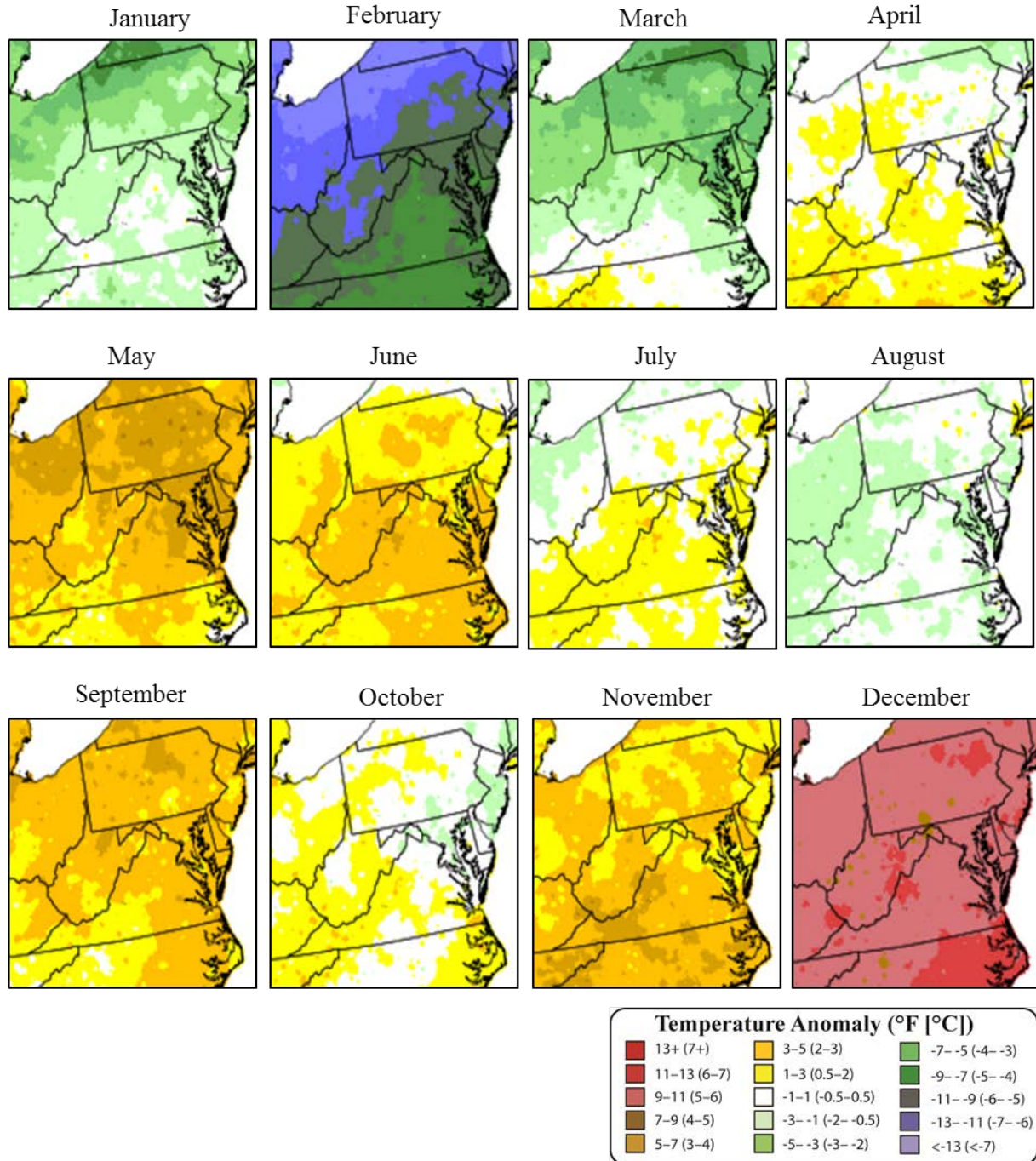


Figure 3. Maps showing departure from average monthly minimum temperature in 2015 compared to the 30-year normal (1981–2010).

Table 2. Status of 2015 temperature indicators compared to the 30-year normal (1981–2010) at the Richmond Airport (KRIC) and Hopewell (HOPV2) weather observing stations.

Temperature Indicator	Richmond Airport 2015	Richmond Airport 1981–2010	Hopewell 2015	Hopewell, 1981–2010
Average Annual Temperature	59.9°F 15.5°C	58.9°F 14.9°C	61.9°F 16.1°C	61.5°F 16.4°C
Average Annual Maximum Temperature	70.1°F 21.2°C	69.6°F 20.9°C	71.6°F 21.4°C	71.6°F 22.0°C
Maximum Temperature	100.0°F 37.8°C	99.8°F 37.7°C	97.0°F 35.0°C	100.3°F 37.9°C
Hot Days (days with Tmax ≥90°F/32°C)	47	42	36	46
Average Annual Minimum Temperature	49.8°F 9.9°C	48.1°F 8.9°C	52.1°F 10.7°C	51.4°F 10.8°C
Minimum Temperature	4.0°F -15.6°C	9.6°F -12.4°C	5.0°F -15.0°C	11.3°F -11.5°C
Cold Days (days with Tmax ≤32°F/0°C)	10	5	3	2
Sub-freezing Days (days with Tmin ≤32°F/0°C)	85	74	49	52
Sub-zero Days (days with Tmin ≤0°F/-18°C)	0	0	0	0
Growing Season Length (days between last spring Tmin 32°F/0°C and first fall Tmin 32°F/0°C)	230	218	230	214

Table 3. Summary of 2015 monthly average temperatures for selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Richmond Airport	KRIC	37.3°F	31.4°F	47.5°F	59.5°F	71.5°F	77.9°F	79.2°F	77.5°F	74.4°F	57.6°F	53.0°F	52.1°F	59.9°F
		2.9°C	-0.3°C	8.6°C	15.3°C	21.9°C	25.5°C	26.2°C	25.3°C	23.6°C	14.2°C	11.7°C	11.2°C	15.5°C
Petersburg Airport	KPTB	36.8°F	32.9°F	47.3°F	59.1°F	70.2°F	76.8°F	77.9°F	75.3°F	72.2°F	58.1°F	53.2°F	52.6°F	59.4°F
		2.7°C	0.5°C	8.5°C	15.1°C	21.2°C	24.9°C	25.5°C	24.1°C	22.3°C	14.5°C	11.8°C	11.4°C	15.2°C
Hopewell	HOPV2	40.7°F	34.9°F	49.7°F	62.3°F	73.6°F	78.7°F	79.0°F	77.4°F	74.3°F	61.3°F	56.4°F	54.2°F	61.9°F
		4.8°C	1.6°C	9.8°C	16.8°C	23.1°C	25.9°C	26.1°C	25.2°C	23.5°C	16.3°C	13.6°C	12.3°C	16.6°C
I-295 Over Meadow Road	VA023	M	M	M	M	M	M	M	M	M	M	M	M	M
		M	M	M	M	M	M	M	M	M	M	M	M	M

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

Table 4. Summary of 2015 departure from normal temperature based on the 30-year normal (1981–2010) for selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Richmond Airport	KRIC	-0.6°F	-9.5°F	-1.1°F	1.3°F	5.1°F	2.6°F	-0.1°F	0°F	3.8°F	-2.1°F	2.6°F	11.1°F	1.1°F
		-0.3°C	-5.2°C	-0.6°C	0.7°C	2.8°C	1.4°C	-0.1°C	0°C	2.2°C	-1.2°C	1.5°C	6.2°C	0.6°C
Petersburg Airport ¹	KPTB	-2.7°F	-8.1°F	-2.3°F	-0.4°F	2.8°F	1.0°F	-0.9°F	-0.8°F	1.8°F	-1.3°F	3.2°F	11.8°F	0.3°F
		-1.5°C	-4.5°C	-1.3°C	-0.2°C	1.5°C	0.5°C	-0.5°C	-0.5°C	1.0°C	-0.7°C	1.8°C	6.5°C	0.2°C
Hopewell	HOPV2	-0.5°F	-9.3°F	-1.9°F	1.2°F	4.6°F	1.5°F	-1.8°F	-1.8°F	1.5°F	-1.1°F	3.1°F	10.2°F	0.5°F
		-0.3°C	-5.2°C	-1.1°C	0.6°C	2.5°C	0.8°C	-1.0°C	-1.0°C	0.8°C	-0.6°C	1.8°C	5.6°C	0.3°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. Stations with a period of record of less than 10 years were not included in this table.

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

Parameter	Climate Division 1 Rankings — Tidewater				
	Jan–Feb–Mar WINTER	Apr–May–Jun SPRING	Jul–Aug–Sep SUMMER	Oct–Nov–Dec AUTUMN	Jan–Dec YEAR
Temperature-2015	112	3	28-T	1	12
Precipitation-2015	50	10	71	10	18

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 Eastern Piedmont (NOAA 2015).

Parameter	Climate Division 2 Rankings — Eastern Piedmont				
	Jan–Feb–Mar WINTER	Apr–May–Jun SPRING	Jul–Aug–Sep SUMMER	Oct–Nov–Dec AUTUMN	Jan–Dec YEAR
Temperature-2015	107	2	36-T	1	10
Precipitation-2015	65	33	70	10	18

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

Precipitation Summary

The year was characterized by notably wetter conditions compared to normal at Petersburg NB and Richmond NBP, as both stations recorded above normal rainfall (+4.3 to +5.0 in (127 – 136 mm)) (Table 7). Snowfall was also above normal for the calendar year, with Hopewell receiving nearly over double its 30-year average (Table 7).

The winter began relatively wet across the region, as January precipitation ranged between 106 to 175% of normal (Table 8). One of the wettest days of the year occurred on January 18th, when 1.70 in (43.2 mm) of precipitation was measured at Hopewell (Table 9). February and March precipitation totals were near normal, with amounts between 76 and 137% of normal for the 2-month period. The winter season ranked as the 50th wettest in the Tidewater and the 65th wettest in the Eastern Piedmont since 1895 (Tables 5 and 6).

The relatively wet weather would persist through the month of April, with 5.3 in (135 mm) of precipitation reported at Richmond Airport, 163% of the long-term mean (Tables 8 and 10). The first rather dry month of the year occurred during May, as monthly totals were just 32 to 54% of normal (Table 8). Two of the top five longest dry spells of the year occurred during the month of May (Table 9). Wet weather would quickly return for the month of June, as the remnants of Tropical Storm Bill near the middle of the month contributed to a monthly sum of 8.1 in (206 mm) of rain measured at Petersburg Airport, 243% of the long-term average (Table 8). The spring months of April, May, and June ranked 10th and 33rd wettest out of 121 years of records at the Tidewater and Eastern Piedmont climate divisions, respectively (Tables 5 and 6).

Summer 2015 was the driest season of the four across the Petersburg NB and Richmond NBP region (Tables 5 and 6, Figure 4). Even with the notably dry weather, however, the wettest day of the year occurred on August 7th. On the 7th, 3.20 in (81.3 mm) of rain fell at Hopewell due to a stalled frontal boundary that brought slow-moving, widespread thunderstorms to the area (Table 9). That single day's rain contributed roughly three-quarters of the month's rainfall at Hopewell (Table 10), illustrating the lack of precipitation during this time. The season, as a whole, ranked as the 51st and 52nd driest in the Tidewater and Eastern Piedmont climate divisions, respectively, since records began in 1895 (Tables 5 and 6).

Autumn would bring a return to wet weather (Figure 4). Precipitation for the season was 3.6 in (92 mm) above normal at Richmond and 3.5 in (89 mm) above normal at Hopewell, which is essentially an extra month's worth of precipitation compared to the long-term average (Table 7). In total, annual precipitation amounts were between 111 and 119% of normal (Table 8). Heavy and extreme precipitation days were near average while the number of micro-droughts were above normal for the year (Table 7).

Table 7. Status of 2015 precipitation indicators compared to the 30-year normal (1981–2010) at the Richmond Airport (KRIC) and Hopewell (HOPV2) weather observing stations.

Precipitation Indicator	Richmond Airport 2015	Richmond Airport 1981–2010	Hopewell 2015	Hopewell 1981–2010
Annual Precipitation	49.1 in 1247 mm	43.8 in 1,111 mm	51.3 in 1303 mm	46.3 in 1,176 mm
Autumn (Oct, Nov, Dec) Precipitation	13.1 in 333 mm	9.5 in 241 mm	13.8 in 351 mm	10.3 in 262 mm
Heavy Precipitation Days (days with ≥ 1.0 in (25 mm) rain)	9	11	13	13
Extreme Precipitation Days (days with ≥ 2.0 in (51 mm) rain)	0	2	4	3
Micro-drought (periods of 7+ days without rain)	11	4	10	8
Annual Snowfall	12.8 in 32.5 cm	10.3 in 26.2 cm	9.1 in 23.1 cm	3.9 in 9.9 cm
Measurable Snow Days (days with ≥ 0.1 in (0.3 cm) snow)	6	6	4	1
Moderate Snow Days (days with ≥ 3.0 in (7.6 cm) snow)	2	1	2	1
Heavy Snow Days (days with ≥ 5.0 in (12.7 cm) snow)	2	1	0	0

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

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Richmond Airport	KRIC	115	137	94	163	43	150	131	59	83	109	121	182	113
Petersburg Airport ¹	KPTB	175	129	121	151	54	180	113	81	87	125	120	73	119
Hopewell	HOPV2	106	76	100	119	32	243	143	86	53	112	117	174	111

¹Indicates a station's Period of Record does not cover the period of 1981-2010 but is 10 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. Stations with a Period of Record of less than 10 years were not included in this table.

Table 9. Top five wettest days and top five dry spells (consecutive days with a trace or less of liquid precipitation) during 2015 from the weather observing stations at Richmond Airport (KRIC) and Hopewell (HOPV2).

Wettest Days in 2015	Dry Spells in 2015
Aug. 7: 3.20 in (81.3 mm)	Oct. 11 – 26
June 27: 2.25 in (57.2 mm)	Aug. 21 – Sept. 3
Nov. 10: 2.00 in (50.8 mm)	Dec. 3 – 13
Dec. 23: 2.00 in (50.8 mm)	May 22 – 31
Jan. 18: 1.70 in (43.2 mm)	May 1 – 9

Table 10. 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
Richmond Airport	KRIC	3.5 in	3.8 in	3.8 in	5.3 in	1.6 in	5.9 in	5.9 in	2.8 in	3.4 in	3.2 in	3.9 in	6.0 in	49.1 in
		89 mm	97 mm	97 mm	135 mm	41 mm	150 mm	150 mm	71 mm	86 mm	81 mm	99 mm	152 mm	1247 mm
Petersburg Airport	KPTB	3.4 in	2.2 in	3.1 in	3.8 in	1.4 in	8.8 in	3.2 in	2.4 in	2.9 in	2.7 in	2.8 in	2.1 in	38.7 in
		86 mm	56 mm	79 mm	97 mm	36 mm	224 mm	81 mm	61 mm	74 mm	69 mm	71 mm	53 mm	983 mm
Hopewell	HOPV2	3.7 in	2.4 in	4.1 in	4.5 in	1.2 in	8.1 in	6.6 in	4.4 in	2.5 in	3.7 in	4.1 in	6.0 in	53.1 in
		94 mm	61 mm	104 mm	114 mm	30 mm	206 mm	168 mm	112 mm	64 mm	94 mm	104 mm	152 mm	1303 mm

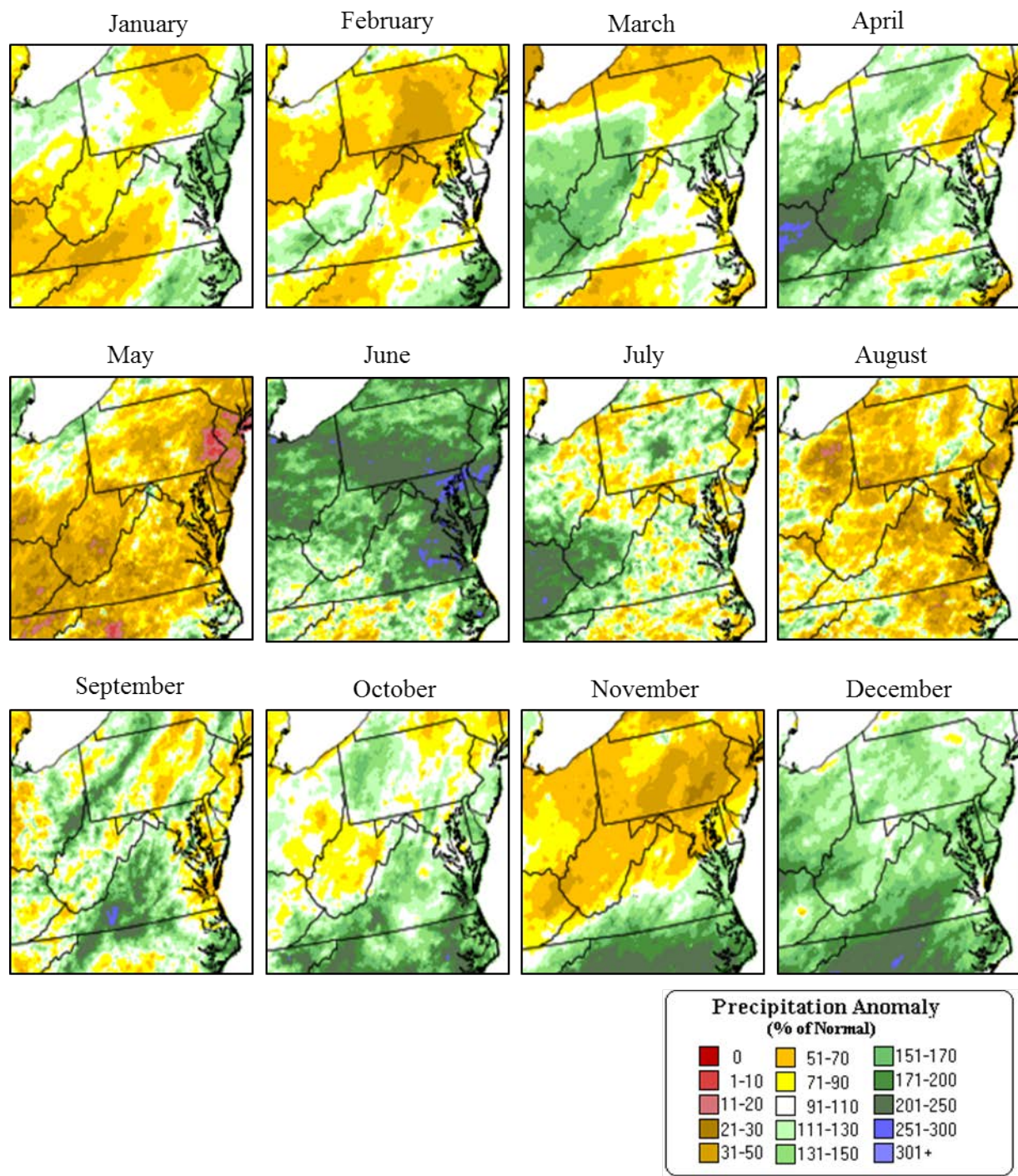


Figure 4. Maps showing percent of average monthly precipitation in 2015 compared to the 30-year normal (1981–2010).

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 Tidewater and the Eastern Piedmont in 2015 are shown in Figures 5 and 6, respectively.

According to the PDSI, 2015 in both the Tidewater and Eastern Piedmont, it was near normal in the early part of the year and became increasingly wetter in the latter half. By May, PDSI values were trending increasingly negative, but a wet June brought the PDSI back to positive territory. The continued wet weather through much of the end of the year brought the PDSI to near $+1.5$ at both divisions by December. Compared to previous years, 2015 was notably wetter than 2014 in the last half of the year and similar to what was observed in 2013, though not nearly as wet in the Eastern Piedmont.

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 7) and the Southeast (Figure 8) are shown for 2015.

Based on the DM, although parts of Virginia were abnormally dry during certain seasons, no widespread droughts occurred in the state during 2015 (Figure 7). Nevertheless, within the larger Southeast region some droughts did occur during the year (Figure 8).

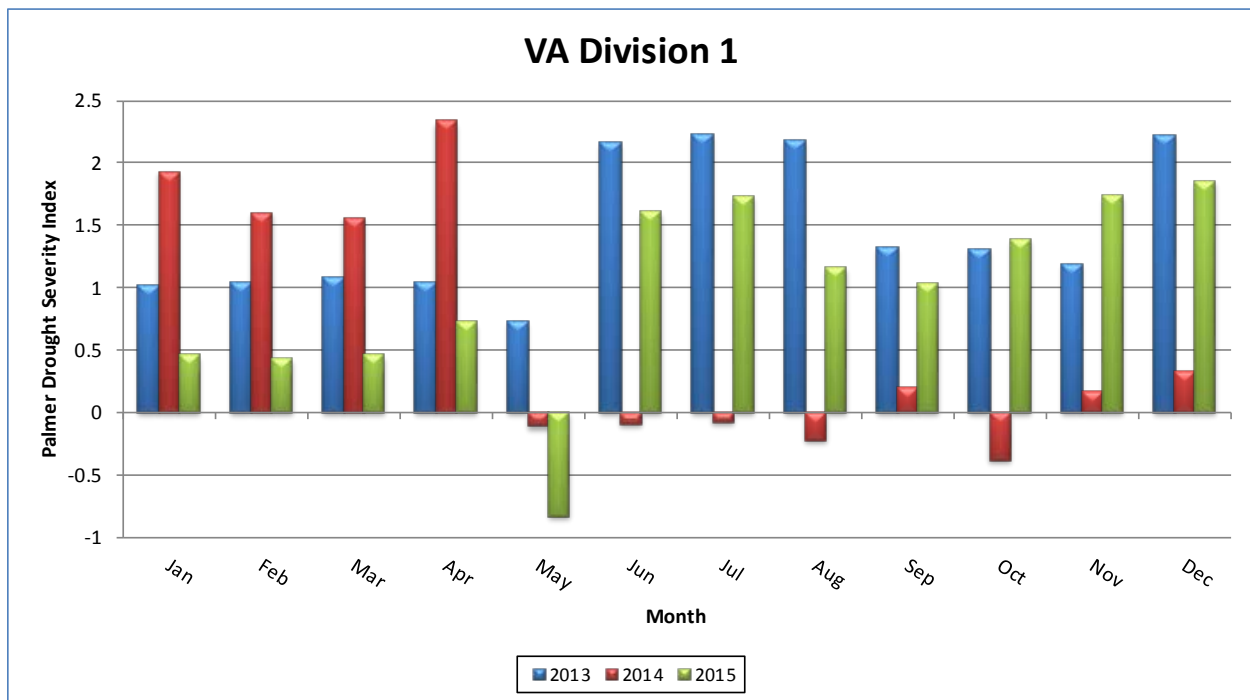


Figure 5. Monthly Palmer Drought Severity Index (PDSI) for the Tidewater, 2013–2015.

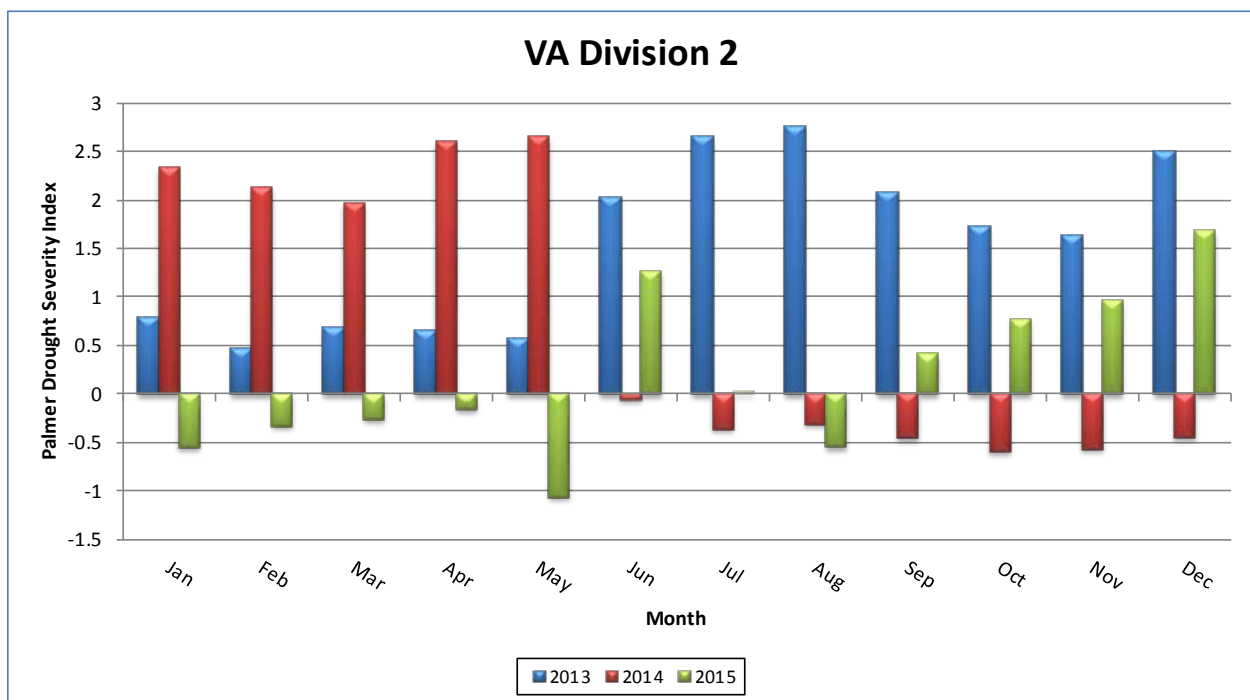


Figure 6. Monthly Palmer Drought Severity Index (PDSI) for the Eastern Piedmont, 2013–2015.

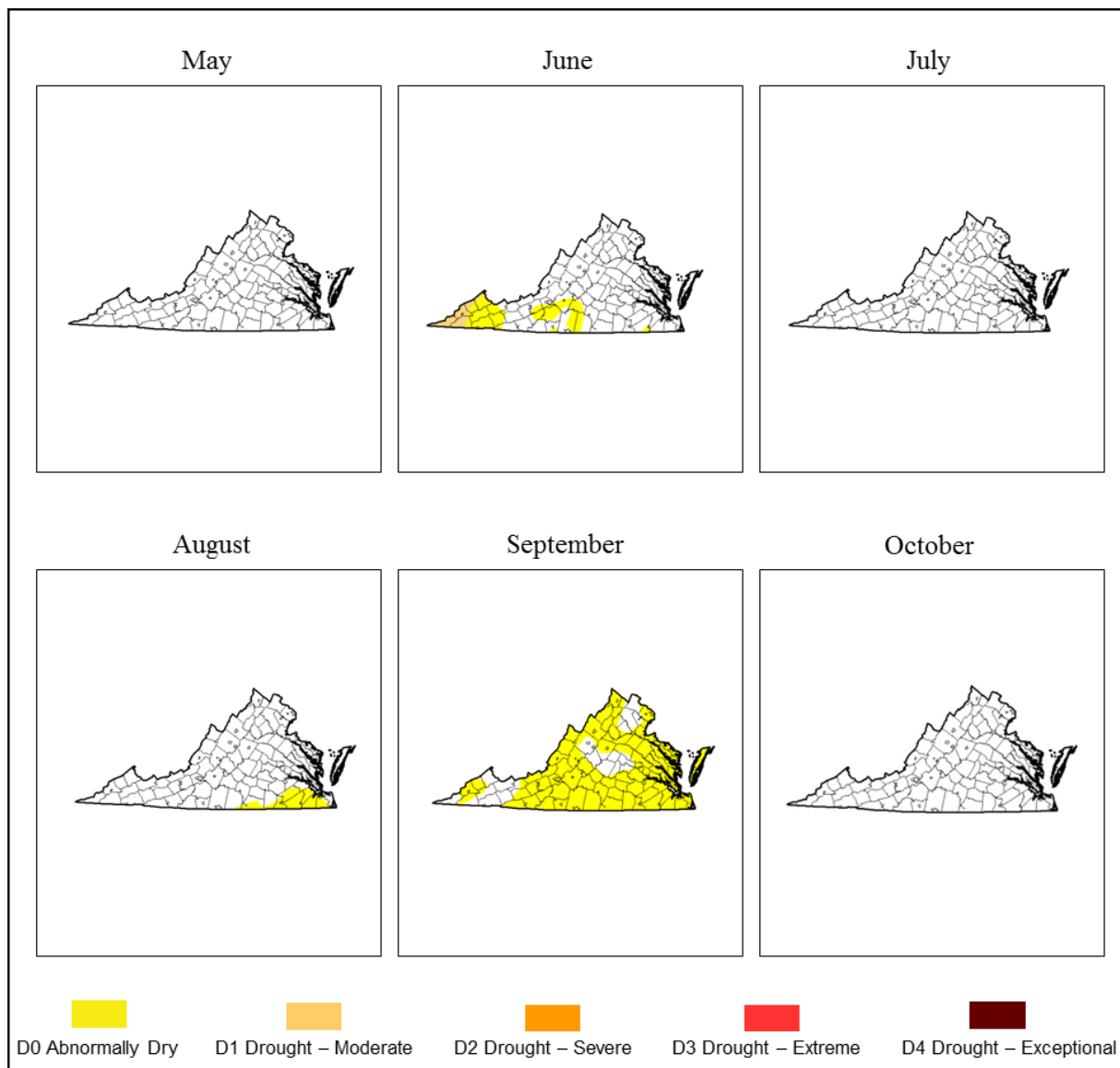


Figure 7. Mid-month values of the United States Drought Monitor (DM) - Drought Intensity Index for Virginia in 2015.

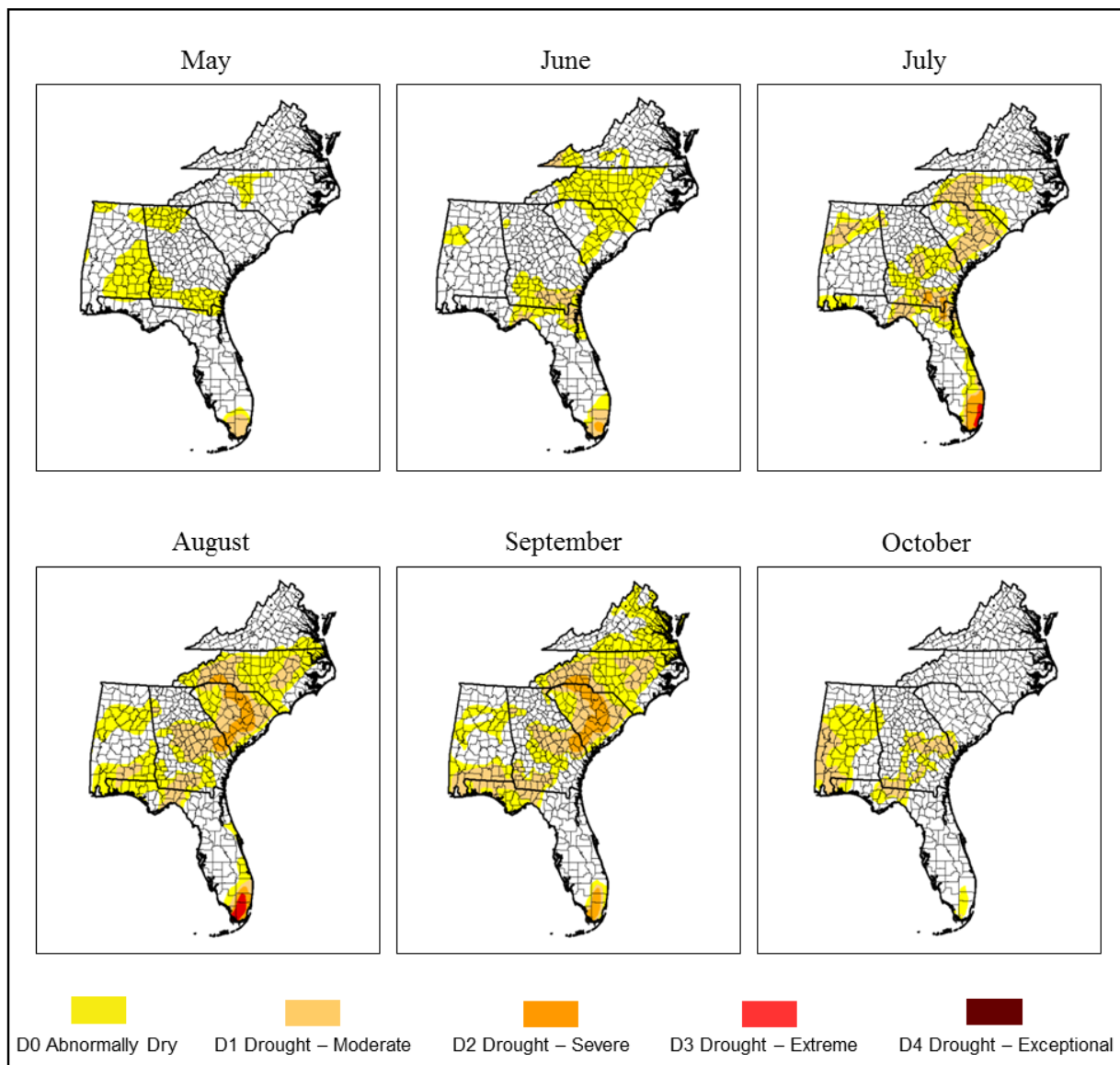


Figure 8. Mid-month values of the United States Drought Monitor (DM) - Drought Intensity Index for the Southeast in 2015.

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, Colorado.
- Gawtry, S., and J. Stenger. 2007. Climate Summary, Shenandoah National Park. Natural Resources Report NPS/NER/NRR—2007/017. National Park Service, Philadelphia, PA.
- Knight, P., K. Imhoff, and A. Person. 2016. Weather of Appomattox Court House National Historical Park and Booker T. Washington National Monument: Mid-Atlantic Network summary report for 2014. Natural Resource Data Series. NPS/MIDN/NRR—2016/1110. National Park Service. Fort Collins, Colorado.
- 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 Assessment Synthesis Team. 2001. *Climate Change Impacts on United States: The Potential Consequences of Climate Variability and Change*. Report for the U.S. Global Change Research Program. Cambridge University Press, Cambridge, UK.
- National Integrated Drought Information System (NIDIS). 2015. National Climate Data Center and United States Department of Agriculture.
<http://droughtmonitor.unl.edu/MapsAndData/MapArchive.aspx> (accessed 12 September 2016).
- National Oceanic and Atmospheric Administration (NOAA). 2015. National Centers for Environmental Information Climatological Rankings. Available at:
<http://www.ncdc.noaa.gov/temp-and-precip/climatological-rankings/> (accessed 12 September 2016).

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