



Weather of Petersburg National Battlefield and Richmond National Battlefield Park

Mid-Atlantic Network Summary Report for 2016

Natural Resource Data Series NPS/MIDN/NRDS—2017/1105



ON THE COVER

“Fort Stedman, Petersburg” – Petersburg National Battlefield

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Natural Resource Data Series NPS/MIDN/NRDS—2017/1105

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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 (PETE) and Richmond National Battlefield Park (RICH) for the time period of January 1 to December 31, 2016. PETE and RICH are located in the Tidewater and Eastern Piedmont climate divisions of Virginia. In 2016, 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, 2016 was a very warm year and ranked as the 4th and 6th warmest on record for the Tidewater and the Eastern Piedmont, respectively. Three of the four seasons were warmer than normal, particularly the summer, which ranked as the second warmest on record for both climate divisions. The year was also wetter than normal, being the 14th (Tidewater) and 43th (Eastern Piedmont) wettest out of 122 years of records. No drought conditions were reported near the parks during 2016.

List of Acronyms

ASOS	Automated Surface Observation System
CASTNET	Clean Air Status and Trends Network
COOP	National Weather Service Cooperative Observer Program
MIDN	Mid-Atlantic Network
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PDSI	Palmer Drought Severity Index
PETE	Petersburg National Battlefield
POR	Period of Record
RAWS	Remote Automated Weather Stations
RICH	Richmond National Battlefield Park
RWIS	Road Weather Information System
USDM	United States Drought Monitor

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, 2016, 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 2016'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 status and trends on an annual basis and 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.

Methods

Observing Stations

A total of four weather observing stations, comprising three weather networks, were selected as the most representative weather stations around Petersburg National Battlefield (PETE) and Richmond National Battlefield Park (RICH) in 2016 (Figure 1, Table 1). 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.

Petersburg National Battlefield and Richmond National Battlefield Park 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>).

Climate Indicators and Climatological Normals

A suite of indicators were identified to provide a summary of weather and climate conditions (Marshall et al. 2012). 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 2016) 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-normal 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.

Of the four stations, only Richmond and Hopewell have a Period of Record (POR) sufficiently long for a 30-year normal (normal calculated from years 1981–2010). Complete temperature and precipitation metrics are only calculated for Richmond, as Hopewell was missing many weeks of

data in 2016. Precipitation data from Petersburg (Dinwiddie County airport) was excluded in 2016 due to major inconsistencies between this station's reported precipitation versus surrounding stations. Monthly averages are calculated for all four stations (with the exclusion of precipitation from Petersburg) and deviations from monthly normals are presented for Hopewell, Petersburg, and Richmond. Because the Petersburg station does not have a full 30 yr. period of record, the Petersburg normal was calculated using data from 1996-2010. The I-295 over Meadow Road station is excluded from a normal calculation because of its very short period of record and generally low reporting percentages.

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). Positive values indicate periods of above normal precipitation (0 to 2: near normal; 2 to 3: moderate moisture; >3 : very moist) and negative values indicate periods of drought (0 to -2: near normal; -2 to -3: moderate drought; <-3 : severe to extreme drought).

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 2017). 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).

Data Processing and Quality Assurance

Data from selected stations are downloaded from relevant data streams (ASOS, RAWS, CASTNET, etc). Variables are calculated using simple statistics (e.g. mean, minimum, maximum, etc.).

Each data stream has varying levels of associated quality assurance (from none to extensive). ASOS, RAWS, and CASTNet data have rigorous and extensive quality assurance beginning at the point of gather (data-logger on site) and at additional levels as described in the respective user's manuals and specification documents

The COOP data quality control is now much more extensive in real-time as the electronically submitted data passes through several levels of quality assurance and is in a final format within a few days of submission.

Quality assurance of RWIS data is performed at the station through its datalogger, and additional quality assurance is performed by the current host company (Vaisala) after the data are received and processed in their database.

Data management procedures are fully outlined in Marshal, et al (2012).

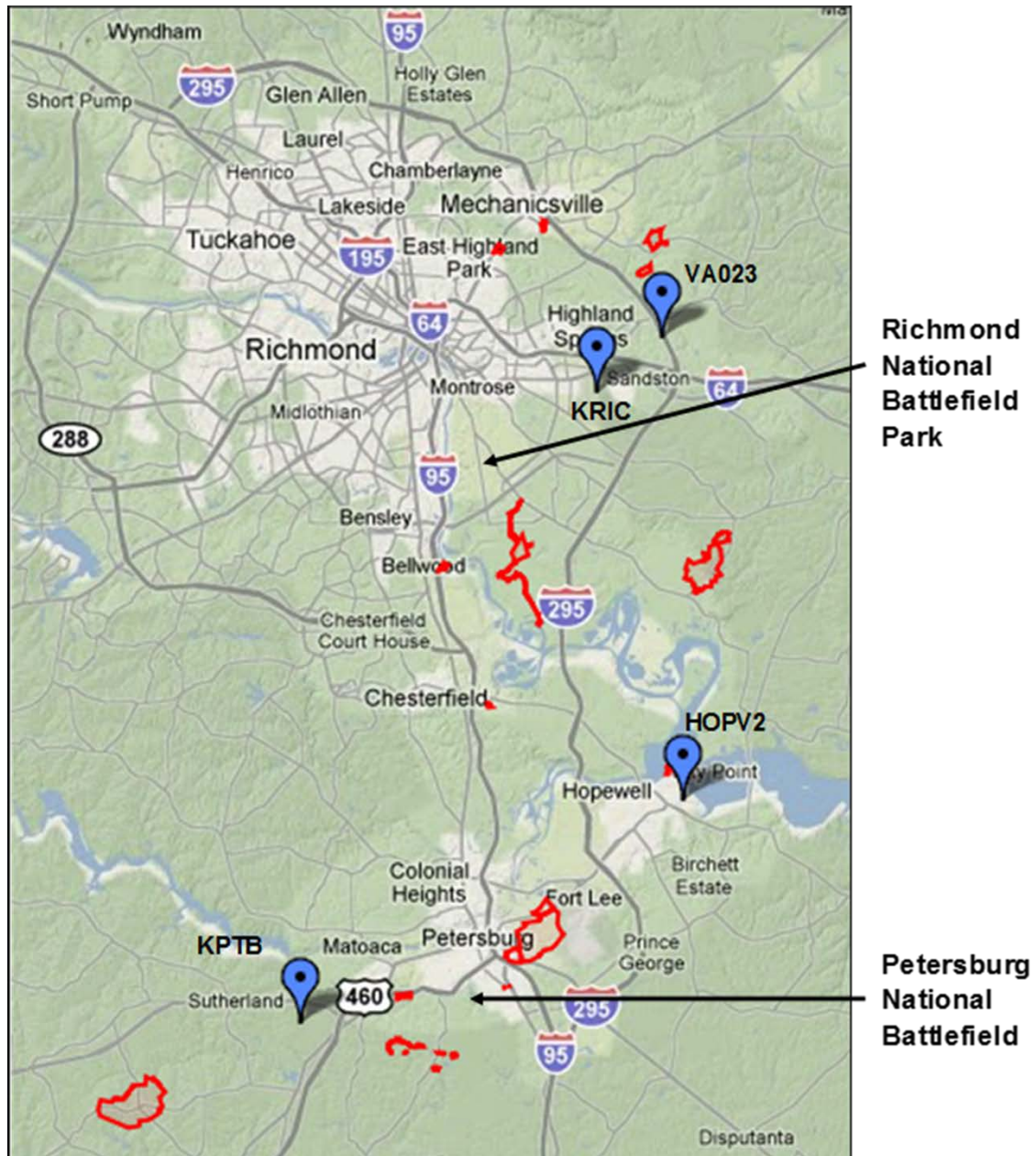


Figure 1. Location of weather observing stations around Petersburg National Battlefield and Richmond National Battlefield Park selected as most representative of the parks. See Table 1 for station names.

Table 1. List of weather observing stations around Petersburg National Battlefield and Richmond National Battlefield Park selected as most representative of the parks in 2016.

Station Name	Station	Observing Network ^A	Period of Record (POR)		Percentage of Time Reporting Temperature for 2016	Percentage of Time Reporting Precipitation for 2016	Percentage of Time Reporting Temperature for entire POR	Percentage of Time Reporting Precipitation for entire POR
Hopewell	HOPV2	COOP	01/01/1960	Present	83.8	91.8	97.3	97.6
I-295 Over Meadow Road	VA023	RWIS	08/24/2005	Present	100	-	65.0	38.5
(Petersburg) Dinwiddie County Airport	KPTB	ASOS	01/01/1996	Present	77.3	NA ^B	82.5	67.1 ^C
Richmond International Airport	KRIC	ASOS	02/01/1949	Present	100	100	96.3	89.3

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

^B KPTB precipitation data for 2016 is not reported due to major inconsistencies with surrounding stations.

^C Percent reporting value from 01/01/1996 – 12/31/2015.

Results

Temperature Summary

Temperature metrics indicate that 2016 was a variable year in terms of temperature, but overall, the year was warmer than normal. Most months had higher than average temperatures (Figures 2 and 3, Table 2 and 3). That said, average annual temperatures were only slightly above normal at Richmond (Table 2). The number of hot days, average annual maximum temperatures, and average annual minimum temperatures were all near long term averages (Table 4). The growing season length was two days shorter than average (Table 4). Three of the four seasons ranked warmer than average, and the summer of 2016 was a near-record season as the 2nd warmest on record in both the Eastern Piedmont and the Tidewater (Table 5). In all, 2016 ranked as the 4th and 6th warmest since the year 1895 in the Tidewater and Eastern Piedmont, respectively (Table 5).

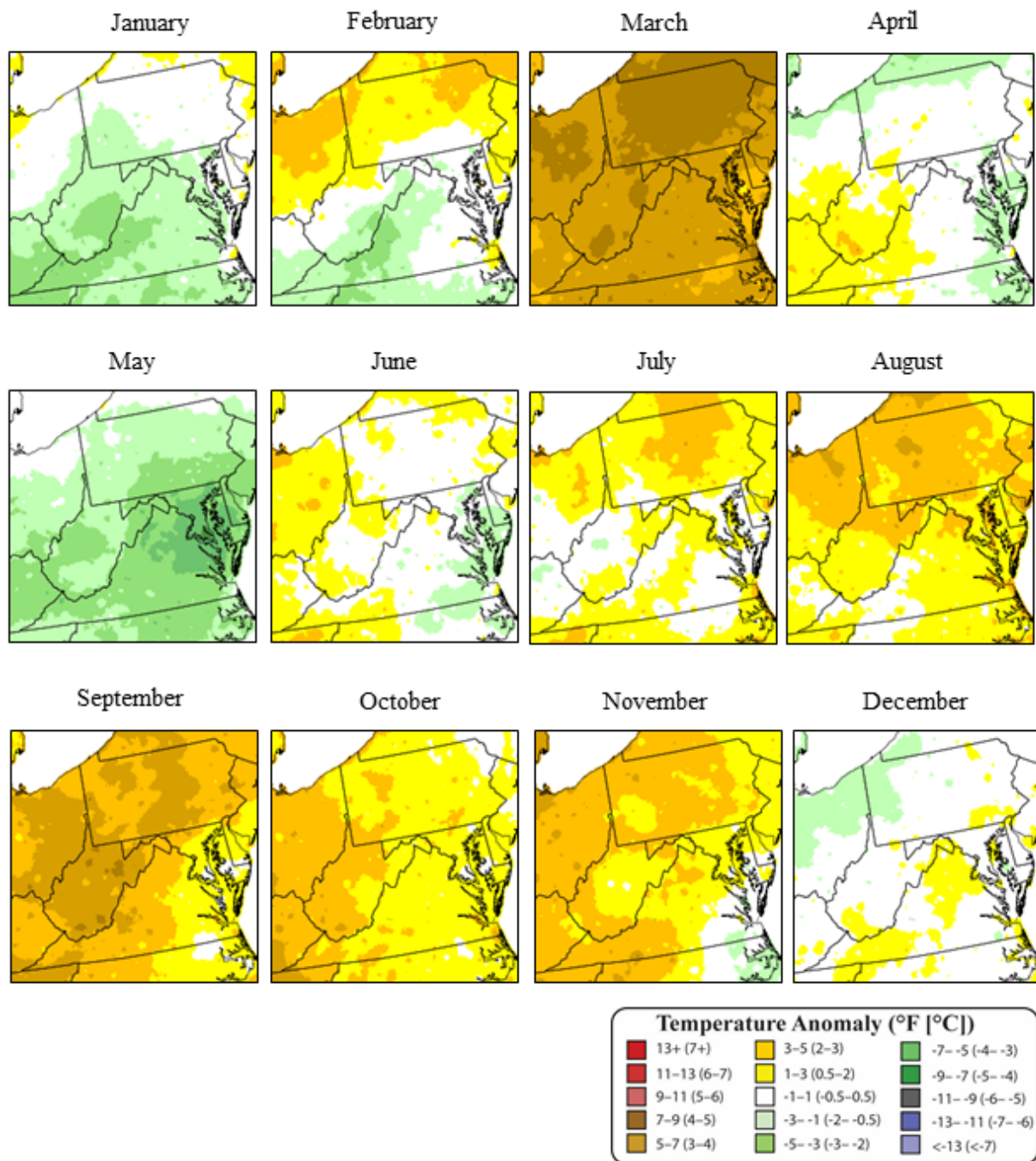


Figure 2. Maps showing departure from average monthly maximum temperature in 2016 compared to the 30-year normal (1981–2010).

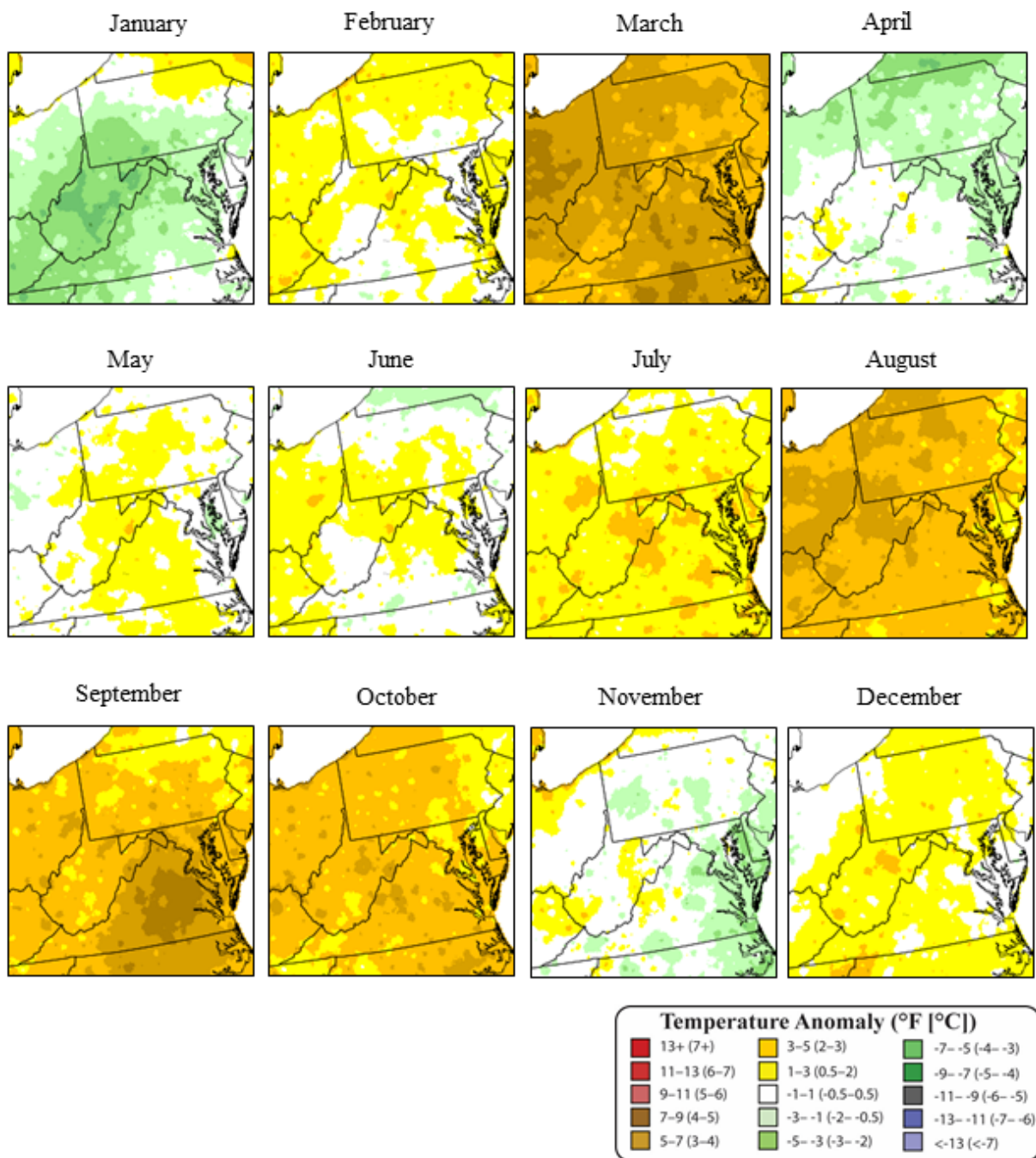


Figure 3. Maps showing departure from average monthly minimum temperature in 2016 compared to the 30-year normal (1981–2010).

Table 2. Summary of 2016 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
Hopewell	HPOV2	-1.6°F	-0.9°F	4.8°F	-1.9°F	-2.9°F	-1.2°F	0.3°F	1.4°F	3.3°F	M	M	-1.4°F	M
		-0.9°C	-0.5°C	2.7°C	-1.1°C	-1.7°C	-0.7°C	0.2°C	0.8°C	1.8°C	M	M	-0.8°C	M
Petersburg*	KPTB	-2.6°F	1.8°F	5.0°F	-1.3°F	-2.7°F	-1.0°F	M	M	M	M	-3.4°F	-0.7°F	M
		-1.5°C	1.0°C	2.8°C	-0.7°C	-1.5°C	-0.5°C	M	M	M	M	-1.9°C	-0.4°C	M
Richmond Airport	KRIC	-2.3°F	0.0°F	5.1°F	-1.3°F	-3.4°F	-1.1°F	0.0°F	1.8°F	2.7°F	2.2°F	-1.1°F	0.5°F	0.2°F
		-1.3°C	0.0°C	2.9°C	-0.8°C	-1.9°C	-0.7°C	0.0°C	1°C	1.5°C	1.2°C	-0.6°C	0.3°C	0.2°C

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

*Indicates a station's Period of Record does not cover the period of 1981-2010 but is five or more years. In this case, the departures from normal values were calculated with normals derived from data spanning 1996-2010.

Table 3. Summary of 2016 monthly average temperatures for selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Hopewell	HPOV2	39.6°F	43.3°F	56.4°F	59.2°F	66.1°F	76.0°F	81.1°F	80.6°F	76.1°F	M	M	42.6°F	M
		4.2°C	6.3°C	13.6°C	15.1°C	18.9°C	24.4°C	27.3°C	27.0°C	24.5°C	M	M	5.9°C	M
I-295	VA023	36.9°F	41.6°F	55.1°F	57.1°F	63.5°F	74.4°F	79.4°F	79.0°F	73.1°F	61.6°F	49.3°F	41.7°F	59.5°F
		2.7°C	5.3°C	12.8°C	13.9°C	17.5°C	23.6°C	26.3°C	26.1°C	22.8°C	16.4°C	9.6°C	5.4°C	15.3°C
Petersburg	KPTB	36.9°F	42.8°F	54.6°F	58.2°F	64.7°F	74.8°F	M	M	M	M	46.6°F	40.1°F	M
		2.7°C	6.0°C	12.6°C	14.6°C	18.2°C	23.8°C	M	M	M	M	8.1°C	4.5°C	M
Richmond Airport	KRIC	35.6°F	40.9°F	53.7°F	56.9°F	63.0°F	74.2°F	79.3°F	79.3°F	73.3°F	61.9°F	49.3°F	41.5°F	59.1°F
		2.0°C	4.9°C	12.1°C	13.8°C	17.2°C	23.4°C	26.3°C	26.3°C	22.9°C	16.6°C	9.6°C	5.3°C	15.1°C

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

Table 4. Status of 2016 temperature indicators compared to the 30-year normal (1981–2010) for a selected station.

Temperature Indicator	Richmond Airport 2016	Richmond Airport 1981–2010
Average Annual Temperature	59.1°F 15.1°C	58.9°F 14.9°C
Average Annual Maximum Temperature	69.5°F 20.8°C	69.6°F 20.9°C
Maximum Temperature	99.0°F 37.2°C	99.8°F 37.7°C
Hot Days (days with Tmax≥90°F/32°C)	43	42
Average Annual Minimum Temperature	49.3°F 9.6°C	48.1°F 8.9°C
Minimum Temperature	9.0°F -12.8°C	9.6°F -12.4°C
Cold Days (days with Tmax≤32°F/0°C)	9	5
Sub-freezing Days (days with Tmin≤32°F/0°C)	74	74
Sub-zero Days (days with Tmin≤0°F/-18°C)	0	0
Growing Season Length (days between last spring Tmin 32°F/0°C and first fall Tmin 32°F/0°C)	216	218

Table 5. Seasonal and annual temperature and precipitation rankings for 2016 over 122 years for the Tidewater (NOAA 2017).

Parameter	VA 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-2016	18-T	74-T	2	17-T	4-T
Precipitation-2016	48	9	29	50	14

1 = warmest/wettest year and 122 = coldest/driest year. T = Tie between multiple years

Table 6. Seasonal and annual temperature and precipitation rankings for 2016 over 122 years for the Eastern Piedmont (NOAA 2017).

Parameter	VA 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-2016	20-T	72-T	2	15-T	6
Precipitation-2016	68	8	51	82	43

1 = warmest/wettest year and 122 = coldest/driest year. T = Tie between multiple years

Precipitation Summary

Although monthly precipitation totals were variable, annual totals were generally above normal (Figure 4 and Table 7). At the Richmond weather station, annual precipitation was 9.0 inches (229 mm) above average (Table 8). Monthly totals ranged from a low of 0.5 inches (13 mm) at Richmond in August to a high of 11.2 inches (284 mm) at Richmond in September (Table 9). Reflecting the variability of the year, August had an average of 13% of normal precipitation though September had an average of 238% of normal rainfall. The wettest day occurred on September 28th when 4.7 inches (119 mm) of rain was recorded (Table 10). In all, 2016 ranked as the 14th and 43rd wettest year on record in the Tidewater and Eastern Piedmont, respectively (Tables 5 and 6). PETE and RICH did not experience any drought conditions during 2016 (Figures 5, 6, and 7).

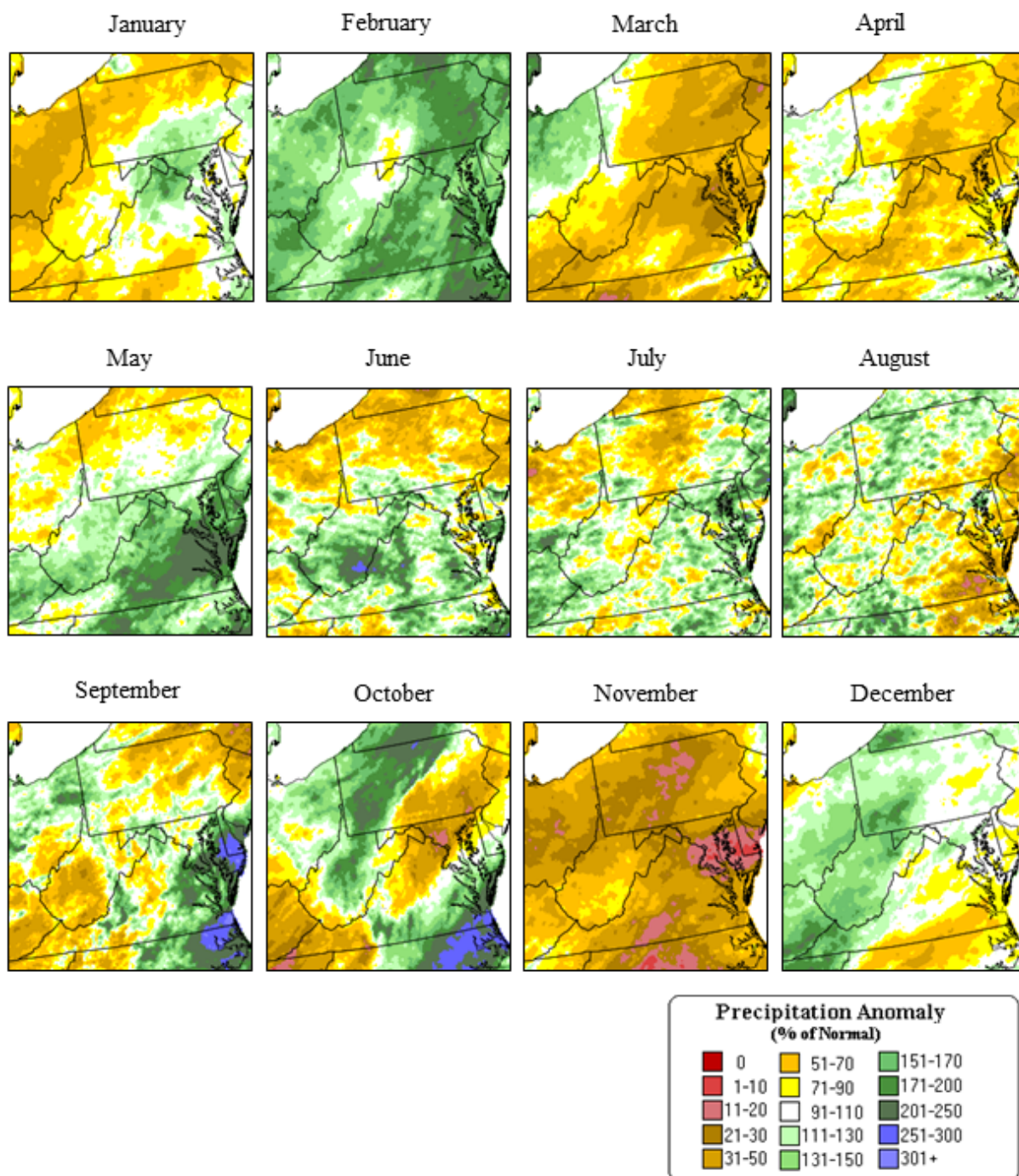


Figure 4. Maps showing percent of average monthly precipitation in 2016 compared to the 30-year normal (1981–2010).

Table 7. Summary of 2016 percent of normal 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
Hopewell	HOPV2	63	191	29	68	258	168	123	14	202	161	M	80	M
Richmond Airport	KRIC	110	154	25	67	258	200	100	11	273	140	34	85	121

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

Table 8. Status of 2016 precipitation indicators compared to the 30-year normal (1981–2010) at Richmond Airport (KRIC).

Precipitation Indicator	Richmond Airport 2016	Richmond Airport 1981–2010
Annual Precipitation	52.8 in 1,341 mm	43.8 in 1,111 mm
Autumn (Oct, Nov, Dec) Precipitation	8.1 in 206 mm	9.5 in 241 mm
Heavy Precipitation Days (days with ≥ 1.0 in (25 mm) rain)	12	11
Extreme Precipitation Days (days with ≥ 2.0 in (51 mm) rain)	3	2
Micro-drought (periods of 7+ days without rain)	9	4
Annual Snowfall	15.1 in 38.4 cm	10.3 in 26.2 cm
Measurable Snow Days (days with ≥ 0.1 in (0.3 cm) snow)	7	6
Moderate Snow Days (days with ≥ 3.0 in (7.6 cm) snow)	2	1
Heavy Snow Days (days with ≥ 5.0 in (12.7 cm) snow)	2	1

Table 9. Summary of 2016 monthly total precipitation for selected stations.

Station name	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Hopewell	HOPV2	2.2 in	6.1 in	1.2 in	2.6 in	9.8 in	5.7 in	5.8 in	0.7 in	9.3 in	5.3 in	M	2.8 in	M
		56 mm	155 mm	30 mm	66 mm	249 mm	145 mm	147 mm	18 mm	236 mm	135 mm	M	71 mm	M
Richmond Airport	KRIC	3.3 in	4.3 in	1.0 in	2.2 in	9.8 in	7.8 in	4.5 in	0.5 in	11.2 in	4.2 in	1.1 in	2.8 in	52.8 in
		84 mm	109 mm	25 mm	56 mm	249 mm	198 mm	114 mm	13 mm	284 mm	107 mm	28 mm	71 mm	1,341 mm

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

Table 10. Top five wettest days and top five dry spells (consecutive days with a trace or less of liquid precipitation) during 2016 from weather observing stations at Richmond Airport (KRIC) and Hopewell (HOPV2).

Wettest Days in 2016	Dry Spells in 2016
Sept 28: 4.7 in (119 mm)	Aug. 17 – Sept. 2
June 3: 3.6 in (91 mm)	Nov. 16 – Nov. 28
Oct. 8: 3.3 in (84 mm)	Oct. 10 – Oct. 21
June 17: 2.2 in (56 mm)	March 4 – March 14
Oct 1: 2.1 in (53 mm)	June 6 – June 15

Drought Status

The monthly Palmer Drought Severity Index (PDSI) differed slightly between climate divisions. In the Tidewater, the PDSI for 2016 indicates moist conditions throughout the year with the year ending “moderately moist” (Figure 5). In the Eastern Piedmont, the PDSI was more variable but never exceeded “normal” conditions (Figure 6). Similarly, the far majority of locations in Virginia never entered drought conditions during 2016 as determined by the Drought Intensity Index (Figure 7). In contrast, a number of states across the Southeast did experience drought conditions, including exceptional droughts in parts of Georgia and Alabama (Figure 8).

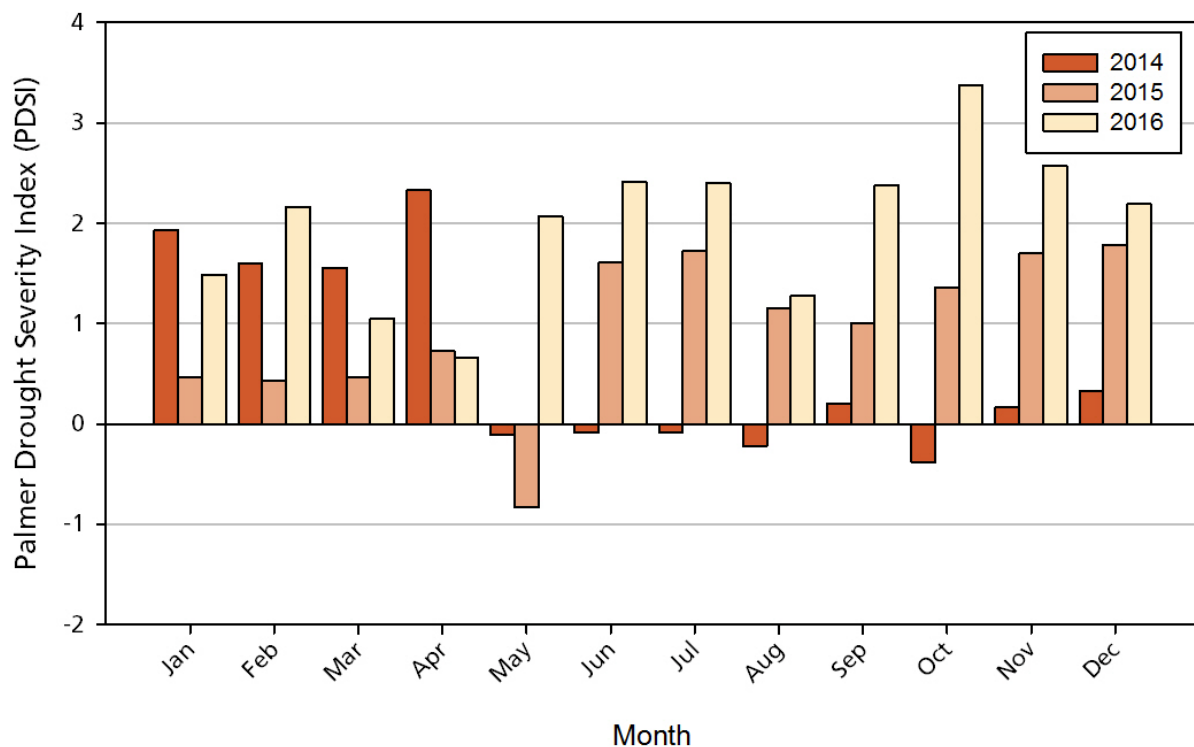


Figure 5. Palmer Drought Severity Index (PDSI) for the Tidewater, 2014–2016. Positive values indicate periods of above normal precipitation (0 to 2: near normal; 2 to 3: moderate moisture; >3: very moist) and negative values indicate periods of drought (0 to -2: near normal; -2 to -3: moderate drought; <-3: severe to extreme drought).

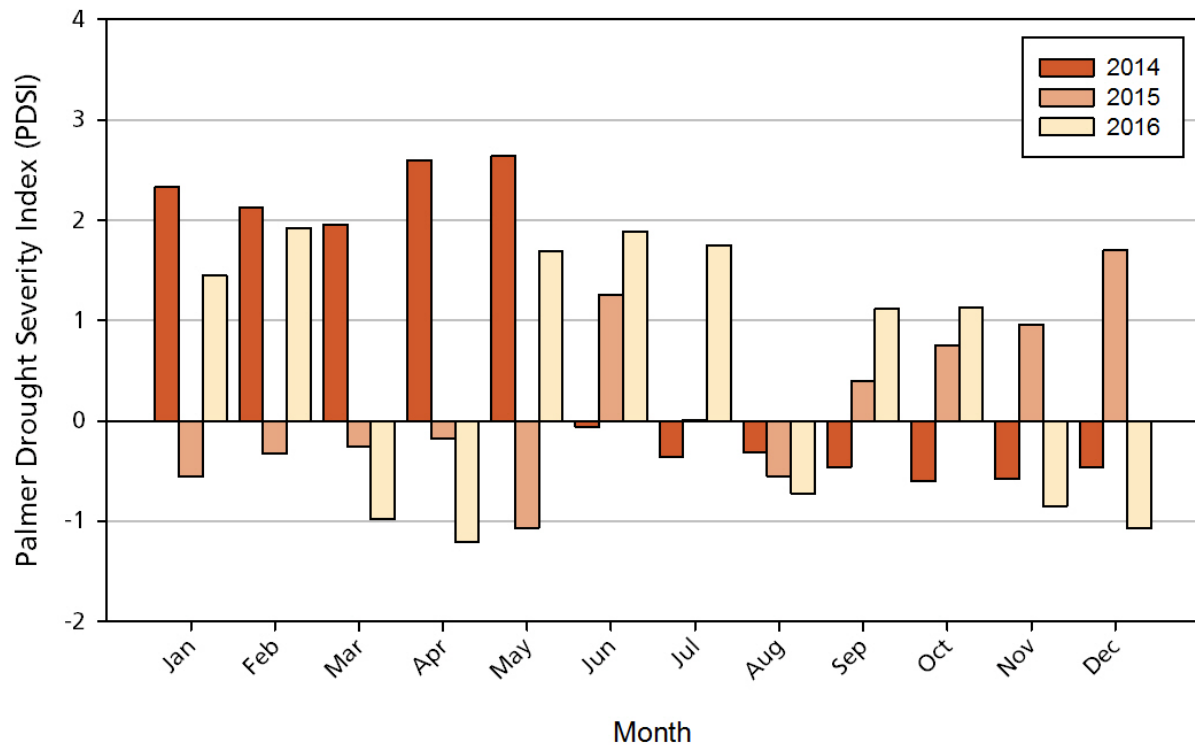


Figure 6. Palmer Drought Severity Index (PDSI) for the Eastern Piedmont, 2014–2016. Positive values indicate periods of above normal precipitation (0 to 2: near normal; 2 to 3: moderate moisture; >3: very moist) and negative values indicate periods of drought (0 to -2: near normal; -2 to -3: moderate drought; <-3: severe to extreme drought).

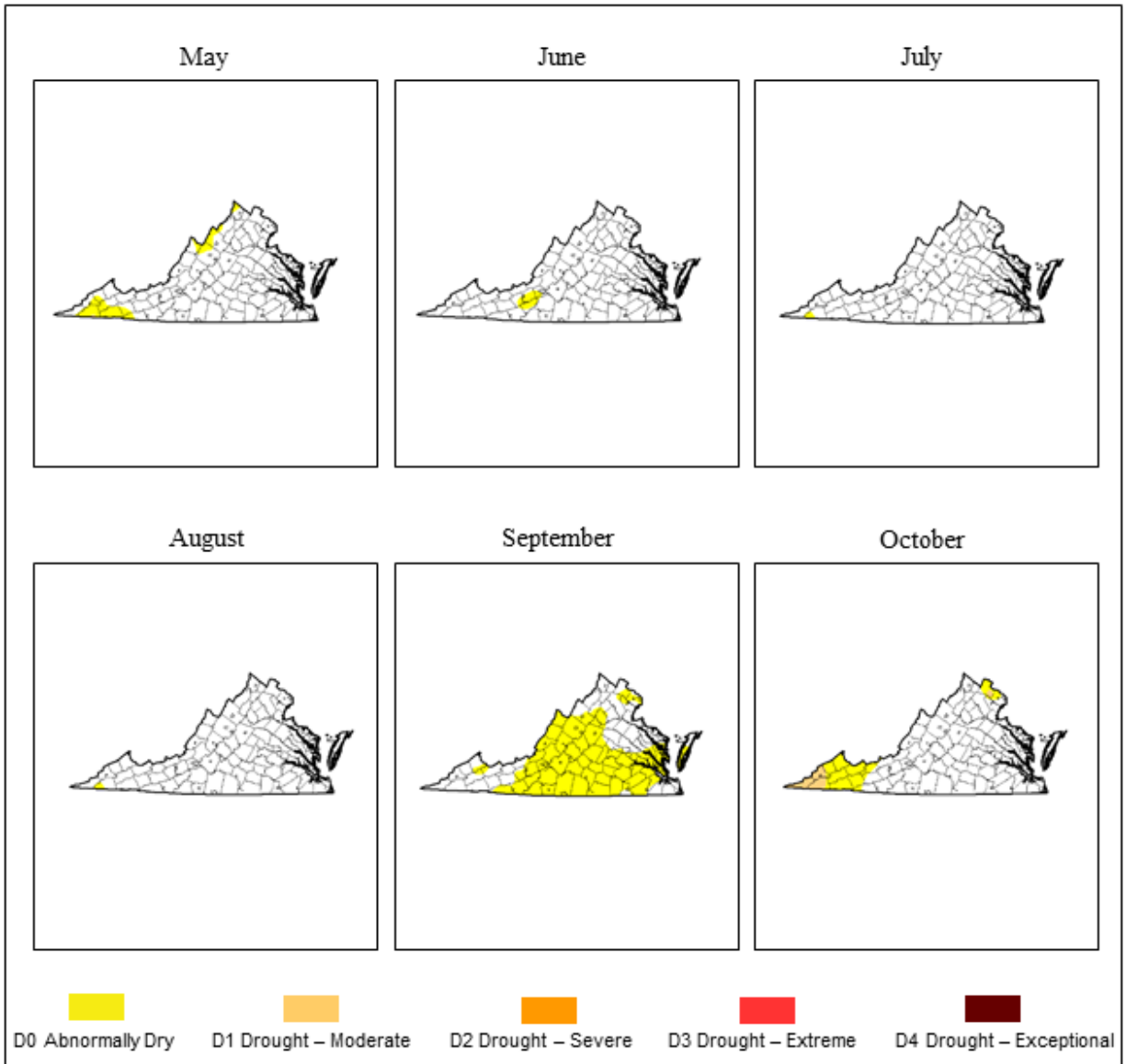


Figure 7. Mid-month values of the United States Drought Monitor (DM) - Drought Intensity Index for Virginia in 2016.

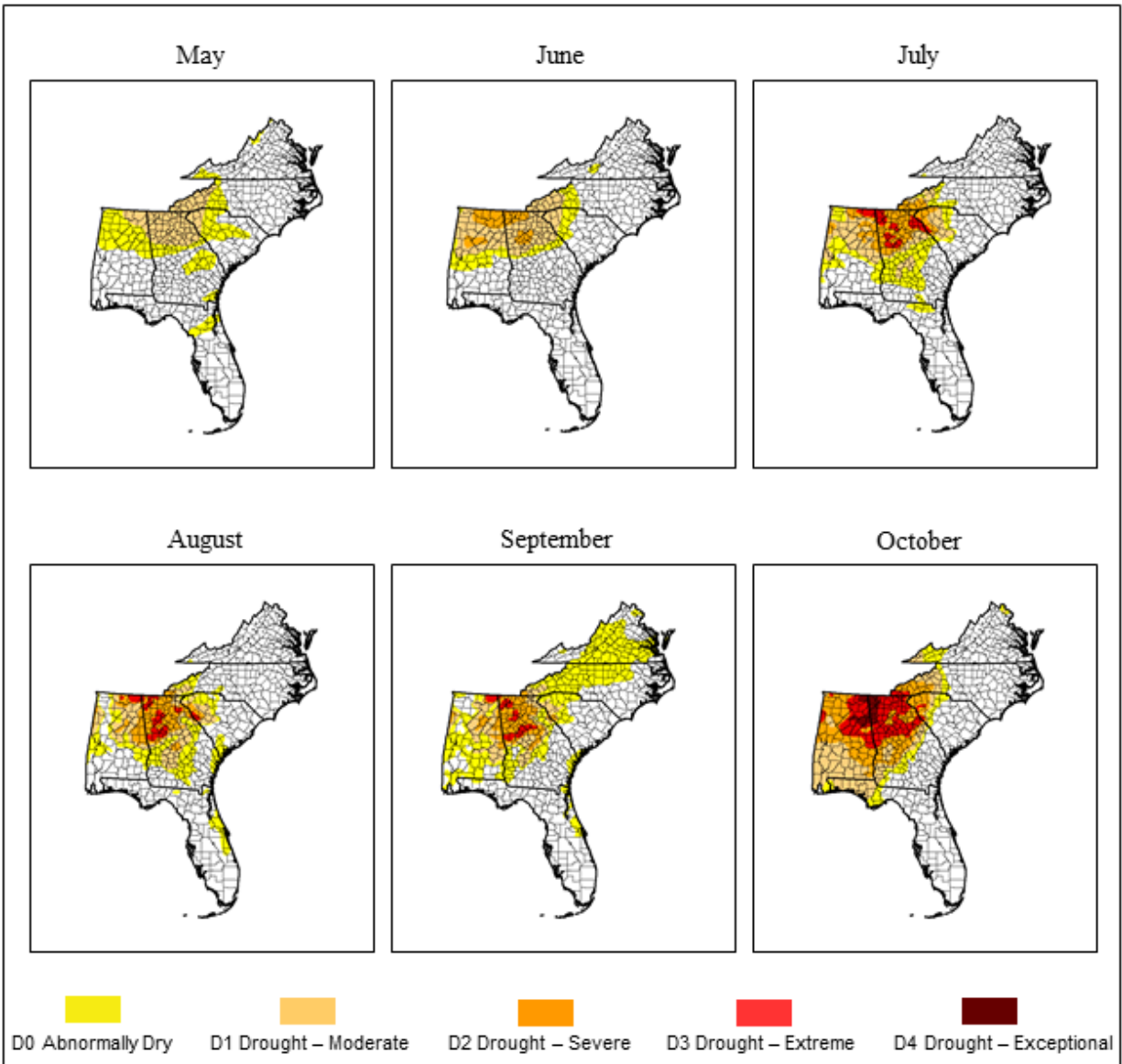


Figure 8. Mid-month values of the United States Drought Monitor (DM) - Drought Intensity Index for the Southeast in 2016.

Literature Cited

- 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.
- Knight, P., K. Imhoff, and A. Person. 2016. Weather of Petersburg National Battlefield and Richmond National Battlefield Park: Mid-Atlantic Network summary report for 2014. Natural Resource Data Series. NPS/MIDN/NRR—2016/1114. National Park Service. Fort Collins, Colorado
- 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). 2017. National Climate Data Center and United States Department of Agriculture.
<http://droughtmonitor.unl.edu/MapsAndData/MapArchive.aspx> (accessed 12 April 2017).
- National Oceanic and Atmospheric Administration (NOAA). 2017. National Centers for Environmental Information Climatological Rankings. Available at:
<http://www.ncdc.noaa.gov/temp-and-precip/climatological-rankings/> (accessed 10 May 2017).

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