



Petersburg National Battlefield and Richmond National Battlefield Park

Weather of 2009

Natural Resource Data Series NPS/MIDN/NRDS—2010/093



ON THE COVER

View of James River from Drewry's Bluff, Richmond National Battlefield Park.
Photograph by: James A. Comiskey, National Park Service.

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Weather of 2009

Natural Resource Data Series NPS/MIDN/NRDS—2010/093

Paul Knight, Tiffany Wisniewski, Chad Bahrmann, and Sonya Miller

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

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

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

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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List of Key Acronyms

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
NB	National Battlefield
NBP	National Battlefield Park
NCDC	National Climatic Data Center
NWS	National Weather Service
PDSI	Palmer Drought Severity Index
PETE	Petersburg National Battlefield
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RAWS	Remote Automated Weather Stations
RICH	Richmond National Battlefield 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).

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.

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/usclimate/map.html>). Virginia is divided into six climate divisions. These 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. 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 area. The southwest winds gain additional warmth when descending the crest of the Appalachians. The last freeze typically occurs in mid-April and first frosts appear in late October or early November.

Precipitation is fairly evenly distributed throughout the year. Annual amounts generally range between 38–48 in (965–1,219 mm), while the majority of places receive 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, while 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 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 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).

Observation Stations

A total of 33 weather observing stations, comprising four weather networks, were selected around Petersburg NB and Richmond NBP. 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 (Knight et al., in preparation). A subset of these weather observing networks (CWOP; 13 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 four stations were ultimately used for this 2009 report: Richmond, Petersburg, Hopewell, and I-295 over Meadow Rd. (Figure 1, Table 1).

Of the four stations, Richmond and Hopewell have a Period of Record (POR) sufficiently long for a 30-year normal (1971–2000). A normal was also calculated for Petersburg based on a POR from 1996–2008. Monthly averages and deviations from normal are presented for all stations for precipitation and temperature except the VA DOT site at Meadow Road which only has five 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/gmaps/NPS_DEVELOPMENT/interface.php.

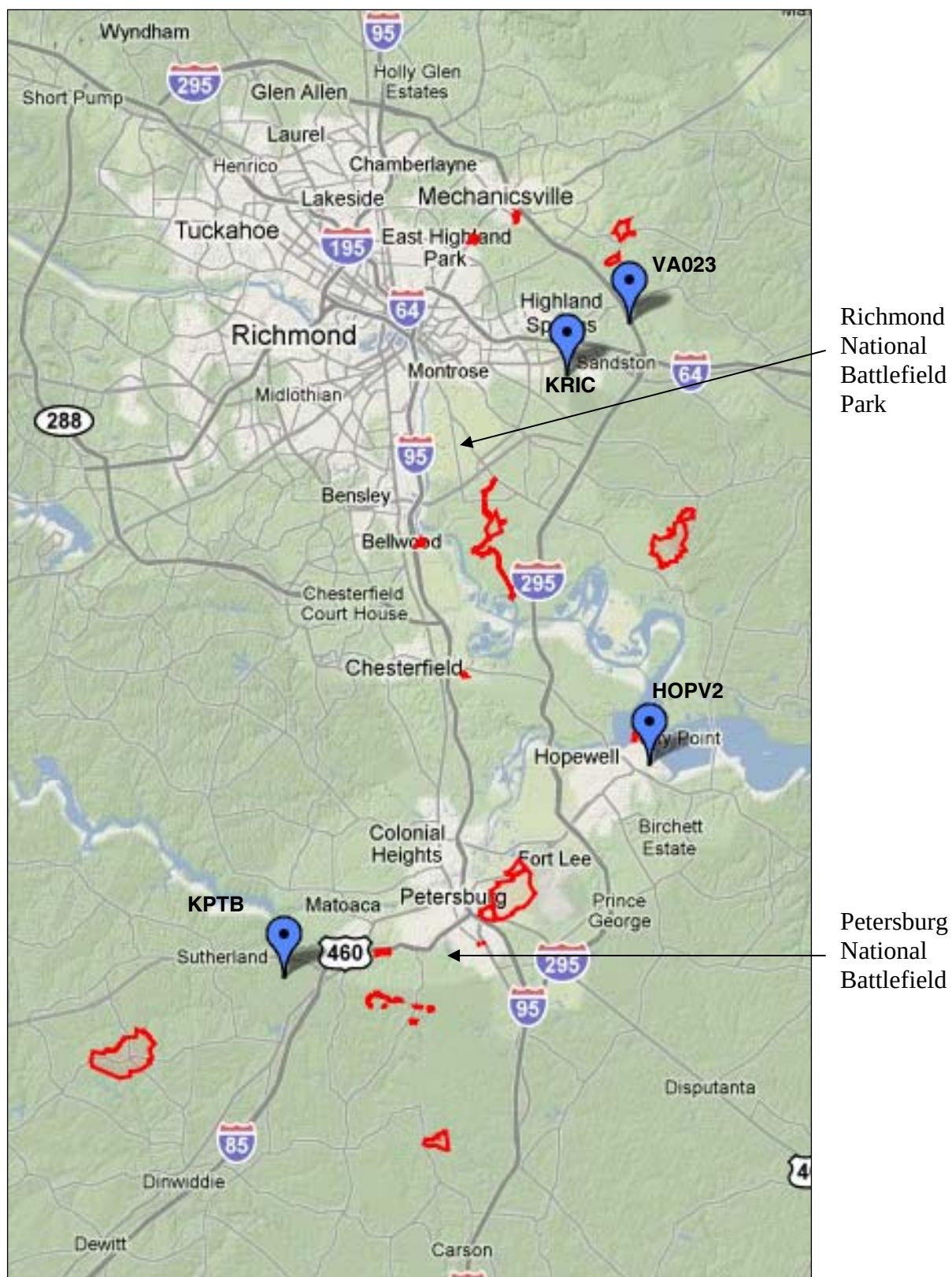


Figure 1. Location of weather observing stations around Petersburg National Battlefield and Richmond National Battlefield Park selected as most representative of the parks in 2009.

Table 1. List of weather observing stations around Petersburg National Battlefield and Richmond National Battlefield Park selected as most representative of the parks in 2009.

Station	Observing Network	Station Name	Period of Record (POR)		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
KRIC	FAA	Richmond	02/01/1949	Present	100.0	100.0	95.7	95.7
KPTB	FAA	Petersburg	01/01/1996	Present	100.0	100.0	77.5	77.5
HOPV2	COOP	Hopewell	01/01/1960	Present	100.0	100.0	97.5	97.7
VA023	VADOT	I-295 over Meadow Rd.	08/24/2005	Present	95.9	95.9	94.8	94.8

Temperature Summary

It was another warmer-than-average year in Petersburg NB and Richmond NBP (Table 2, Figures 2 and 3). Warm anomalies were amplified by consistently above-average nighttime minimums (Figure 3)¹.

January was the coldest month of the year, with monthly departures ranging from 0.2–4.2°F (0.1–to 2.4°C) below normal (Tables 3 and 4). The lowest readings of 2009 occurred at mid-month when minimum temperatures fell to 4°F (-15.6°C) at Richmond and 13°F (-10.6°C) at Hopewell, both within a few degrees of the average annual minimum (Table 2). February turned much milder and March was cooler than the long-term average (Table 4). Overall, the winter was the 56th coolest in the Tidewater and Eastern Piedmont since records began in 1895 (Tables 5 and 6).

Spring began with a rather warm April. Monthly temperatures ranged from 58.9°F (14.9°C) at Richmond to 62.6°F (17.0°C) at Hopewell (Table 3). May continued to be warm, as mean temperatures were between 1.1–2.8°F (0.6–1.5°C) above normal (Table 4). June brought daytime readings that were below average (Figure 2), but nighttime temperatures stayed above normal (Figure 3), and the result was another warmer-than-average month (Table 4). The spring season ranked as the 7th warmest in the Tidewater and the 20th warmest in the Eastern Piedmont since records began in 1895 (Tables 5 and 6).

Summer of 2009 started and ended cool, but August was the warmest month of the year. Cool days and nights during July resulted in mean temperatures ranging from 0.9–2.1°F (0.5–1.2°C) below the normal (Table 4). Readings during August varied from 78.4 °F (25.8°C) at the Virginia DOT site on Meadow Road to 81.5 °F (27.5°C) in Hopewell (Table 3). Cooler-than-average days during September contributed to slightly below-normal temperatures across the region (Table 4). The lack of persistent heat lowered the tally of hot days to between 33–42 days compared with a long-term average of 41–58 days, respectively (Table 2). The highest reading of 2009 was virtually normal with a value of 98°F (36.7°C) (Table 2) and the season ranked very close to the 115-year average of 58 (Tables 5 and 6).

The autumn began with cool daytime readings and mild nights in October (Figures 2 and 3). November was the warmest month, with monthly mean temperatures ranging from 1.7–4.0 °F (0.9–2.2°C) above the 1971–2000 means (Table 4). December was notably colder. The number of sub-freezing nights was fewer than the 30-year average (Table 2) and the length of the growing season was about six to eight weeks longer than the 30-year average (Table 2). The annual maximum temperatures averaged near normal, but minimum readings averaged 2.2 °F (1.3°C) above normal (Table 2).

¹ The maps in Figures 2 and 3 were created using estimates from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). PRISM uses an interpolation scheme for temperature between actual observations and corrects these estimates for changes in topography across the region (Daly et al. 2002). More information can be found at <http://www.prism.oregonstate.edu/>.

Table 2. Status of 2009 temperature indicators compared to the 30-year normal (1971–2000) at the Richmond (KRIC) and Hopewell (HOPV2) weather observing stations.

Temperature Indicator	Richmond, VA 2009	Richmond, VA 1971–2000	Hopewell, VA 2009	Hopewell, VA 1971–2000
Average Annual Temperature	58.8°F 14.9°C	57.7°F 14.3°C	61.4°F 16.3°C	60.3°F 15.7°C
Average Annual Maximum Temperature	68.8°F 20.4°C	67.9°F 19.9°C	70.9°F 21.6°C	72°F 22.2°C
Summer Maximum (highest temperature)	98°F 36.7°C	98.8°F 37.1°C	98°F 36.7°C	99.5°F 37.5°C
Hot Days (days with Tmax ≥90°F/32°C)	33	41	42	58
Average Annual Minimum Temperature	48.8°F 9.3°C	47.5°F 8.6°C	51.9°F 11.1°C	48.6°F 9.2°C
Winter Minimum (lowest temperature)	4°F -15.6°C	6.6°F -14.1°C	13°F -10.6°C	7.4°F -13.7°C
Cold Days (days with Tmax ≤32°F/0°F)	4	7	4	3
Sub-freezing Nights (days with Tmin ≤32°F/0°C)	76	81	56	70
Cold Winter Nights (days with Tmin ≤0°F/-17.8°C)	0	0	0	0
Growing Season Length (days between last spring 32°F/0°C and first fall 32°F/0°C)	251	209	256	204

Petersburg National Battlefield
and Richmond National Battlefield Park
Departure from Average Monthly Maximum Temperature
2009 vs. 1971–2000

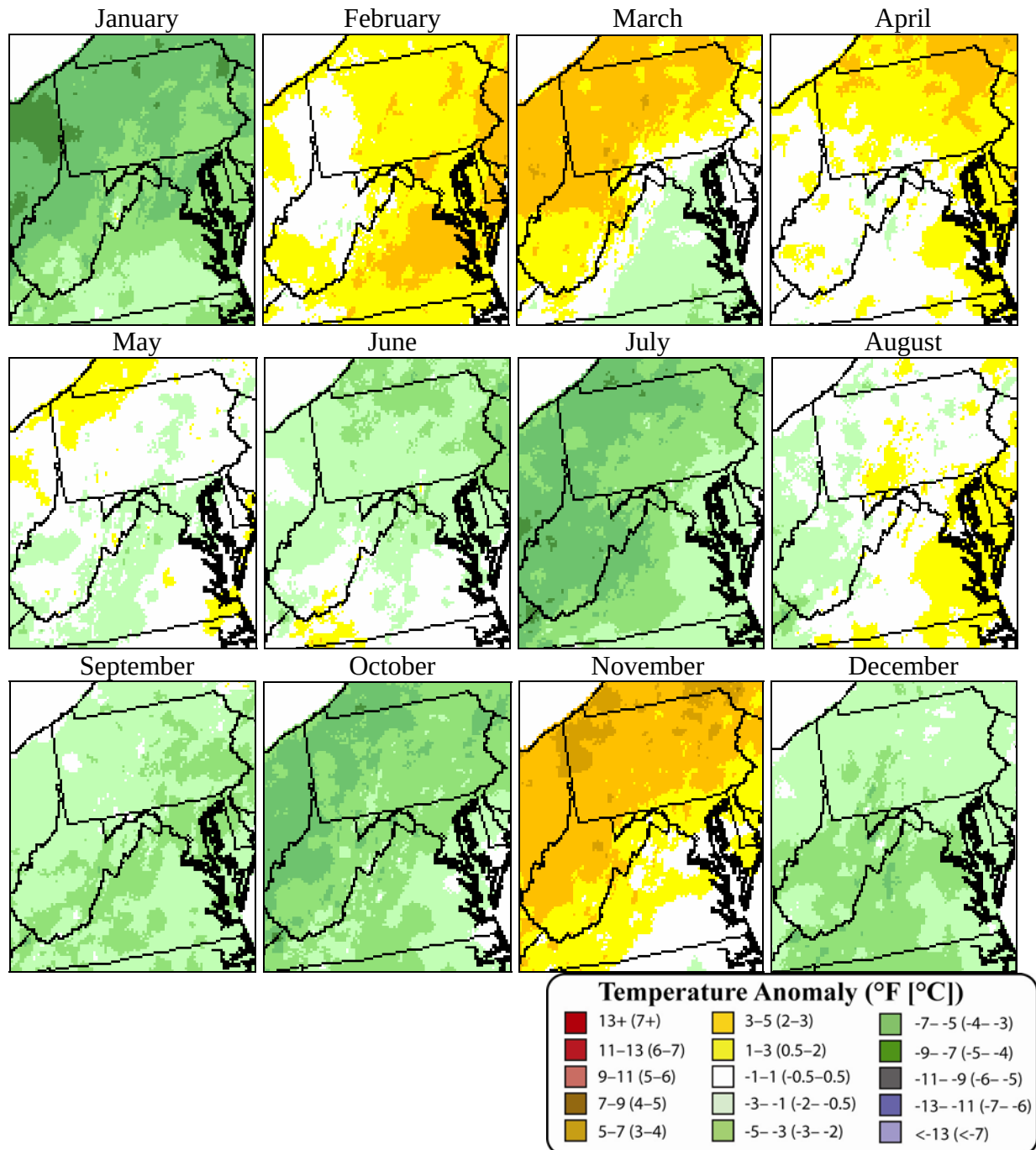


Figure 2. Maps showing departure from average monthly maximum temperature compared to the 30-year normal (1971–2000).

Petersburg National Battlefield
and Richmond National Battlefield Park
Departure from Average Monthly Minimum Temperature
2009 vs. 1971–2000

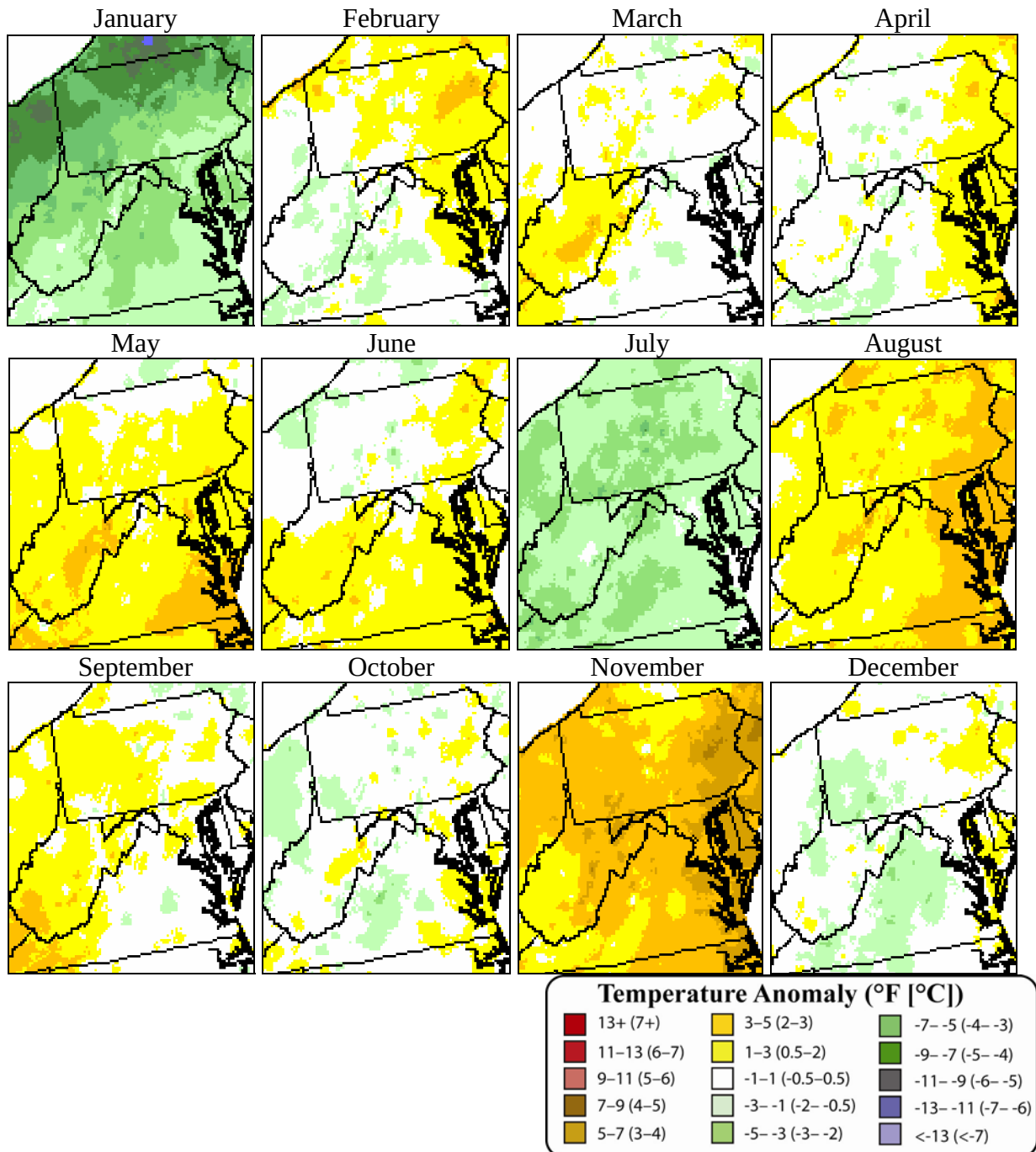


Figure 3. Maps showing departure from average monthly minimum temperature compared to the 30-year normal (1971–2000).

Table 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
Richmond	KRIC	35.2°F	42.2°F	46.7°F	58.9°F	68.1°F	75.5°F	77.0°F	79.9°F	69.9°F	59.0°F	53.0°F	39.4°F	58.8°F
		1.8°C	5.7°C	8.2°C	14.9°C	20.1°C	24.2°C	25.0°C	26.6°C	20.9°C	15.0°C	11.7°C	4.1°C	14.9°C
Petersburg	KPTB	35.7°F	42.2°F	47.2°F	58.9°F	68.4°F	75.4°F	76.5°F	79.3°F	69.6°F	58.9°F	52.0°F	39.3°F	58.6°F
		2.1°C	5.6°C	8.5°C	14.9°C	20.2°C	24.1°C	24.7°C	26.3°C	20.9°C	15.0°C	11.1°C	4.1°C	14.8°C
Hopewell	HOPV2	39.5°F	46.3°F	50.4°F	62.6°F	69.9°F	76.7°F	78.5°F	81.5°F	71.6°F	62.4°F	55.2°F	42.0°F	61.4°F
		4.1°C	7.9°C	10.2°C	17.0°C	21.1°C	24.8°C	25.9°C	27.5°C	22.0°C	16.9°C	12.9°C	5.5°C	16.3°C
I-295 over Meadow Road	VA023	35.3°F	42.4°F	46.9°F	59.3°F	66.9°F	74.5°F	75.8°F	78.4°F	68.5°F	59.6°F	51.8°F	38.4°F	58.2°F
		1.8°C	5.8°C	8.3°C	15.1°C	19.4°C	23.6°C	24.3°C	25.8°C	20.3°C	15.3°C	11.0°C	3.5°C	14.5°C

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
Richmond	KRIC	-1.2°F	2.7°F	-1.0°F	1.8°F	2.8°F	2.0°F	-0.9°F	3.6°F	0.1°F	0.7°F	4.0°F	-1.0°F	1.1°F
		-0.6°C	1.5°C	-0.5°C	1.0°C	1.5°C	1.1°C	-0.5°C	2.0°C	0.1°C	0.4°C	2.2°C	-0.6°C	0.6°C
Petersburg*	KPTB	-4.2°F	1.1°F	-2.1°F	-0.3°F	1.1°F	0.2°F	-2.1°F	1.6°F	-0.9°F	-0.6°F	1.7°F	-2.1°F	-0.6°F
		-2.4°C	0.6°C	-1.1°C	-0.2°C	0.6°C	0.1°C	-1.2°C	0.9°C	-0.5°C	-0.3°C	0.9°C	-1.2°C	-0.3°C
Hopewell	HOPV2	-0.2°F	3.5°F	-0.3°F	2.8°F	2.1°F	1.1°F	-1.1°F	3.5°F	-0.5°F	1.3°F	3.3°F	-1.6°F	1.1°F
		-0.1°C	2.0°C	-0.2°C	1.5°C	1.2°C	0.6°C	-0.6°C	2.0°C	-0.3°C	0.7°C	1.8°C	-0.9°C	0.6°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. Stations with a period of record of less than 5 years were not included in this table.

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

Climate Division 1 Rankings Tidewater	Jan–Feb–Mar WINTER	Apr–May–Jun SPRING	Jul–Aug–Sep SUMMER	Oct–Nov–Dec AUTUMN
Temperature-2009	59	7	58	40
Precipitation-2009	91	25	31	1
1 = warmest/wettest year and 115 = coldest/driest year				

Table 6. Seasonal temperature and precipitation rankings over 115 years for the Eastern Piedmont (NOAA 2010).

Climate Division 2 Rankings Eastern Piedmont	Jan–Feb–Mar WINTER	Apr–May–Jun SPRING	Jul–Aug–Sep SUMMER	Oct–Nov–Dec AUTUMN
Temperature-2009	59	20	62	50
Precipitation-2009	95	30	90	1
1 = warmest/wettest year and 115 = coldest/driest year				

Precipitation Summary

The year was characterized by its precipitation extremes at Petersburg NB and Richmond NBP, with two separate months ranked as the top five wettest (November and December) and one for the driest (February) on record (Tables 5 and 6). Overall, the year was wetter than normal (Table 7), as an unusually dry winter was offset by a wet spring and a very wet autumn (Figure 4).

Similar to other locations across the region, the winter months for Petersburg NB and Richmond NBP were among the driest in twenty-five years. The Tidewater, which encompasses most of Petersburg NB and Richmond NBP, reported the 24th driest winter in 115 years of records (Table 5). There were three long dry spells during the winter, from January 9–26, February 4–17, and March 3–12 (Table 8). February was the driest month of the year with only 19–25 percent of normal precipitation falling (Tables 9 and 10). Annual snowfall totals for 2009 were about 6 in (15 cm) above the long-term average in Richmond, though the number of snowy days was normal (Table 7).

However, as quickly as the precipitation ceased in the winter, it began again during spring. The month of June was the wettest for this period, with 4.3 in (110 mm) of rain reported in Richmond and 4.4 in (112 mm) in Hopewell, and all locations tallying more than 115 percent of the normal values (Tables 9 and 10). The wettest day in the spring also occurred in June, as Richmond received 1.7 in (43 mm) of rain in a 24-hour period on June 3 (Table 7). When combined with a moist May, it was the 25th wettest spring recorded in the Tidewater (Table 5).

Summer rainfall was highly variable across the Petersburg NB and Richmond NBP region. As an example, the Tidewater, which encompasses most of Richmond NBP, reported the 31st wettest summer in 115 years of records, while the adjacent Eastern Piedmont tallied its 25th driest summer of record (Tables 5 and 6). None of the selected representative weather stations measured more than 100 percent of average rainfall (Table 10) during this three-month period. There were no direct effects from tropical storms or hurricanes. Two dry spells occurred in September; the first from September 11–22 and the second spanning into October (Sept 30–Oct 9) (Table 7).

The final three months of the year were the wettest on record in Petersburg NB and Richmond NBP (Tables 5 and 6). October had precipitation totals ranging from 62–100 percent of normal (Table 10). November and December were excessively wet with the three wettest days of the year occurring during this period. On November 12, Richmond measured 3.5 in (89 mm) for the most in a 24 hour period during 2009 (Table 8). Both months had more than 260 percent of normal precipitation (Table 10). Overall, 2009 brought the region an excess ranging from 4.5–5.9 in (114–160 mm), or more than one month's normal precipitation (Table 7).

Table 7. Status of 2009 precipitation indicators compared to the 30-year normal (1971–2000) at the Richmond (KRIC) and Hopewell (HOPV2) weather observing stations.

Precipitation Indicator	Richmond, VA 2009	Richmond, VA 1971–2000	Hopewell, VA 2009	Hopewell, VA 1971–2000
Annual Precipitation	48.4 in 1,229 mm	43.9 in 1,115 mm	51.2 in 1,301 mm	45.3 in 1,151 mm
Autumn (Oct, Nov, Dec) Precipitation	21.4 in 544 mm	9.8 in 249 mm	21.3 in 541 mm	10.0 in 254 mm
Heavy Rain (days with ≥ 1.0 in (25 mm) rain)	12	10	16	12
Extreme Rain (days with ≥ 2.0 in (51 mm) rain)	1	2	2	2
Micro-drought (strings of 7+ days without rain)	9	9	11	9
Annual Snowfall	14.0 in 35.6 cm	8.4 in 21.3 cm	7.8 in 19.8 cm	8.1 in 20.6 cm
Snow (days with ≥ 0.1 in (0.3 cm) snow)	5	5	4	4
Moderate Snow (days with ≥ 2.0 in (5.0 cm) snow)	3	1	2	2
Heavy Snow (days with ≥ 5.0 in (12.7 cm) snow)	1	1	0	1

Petersburg National Battlefield
and Richmond National Battlefield Park
Percent of Average Monthly Precipitation
2009 vs. 1971–2000

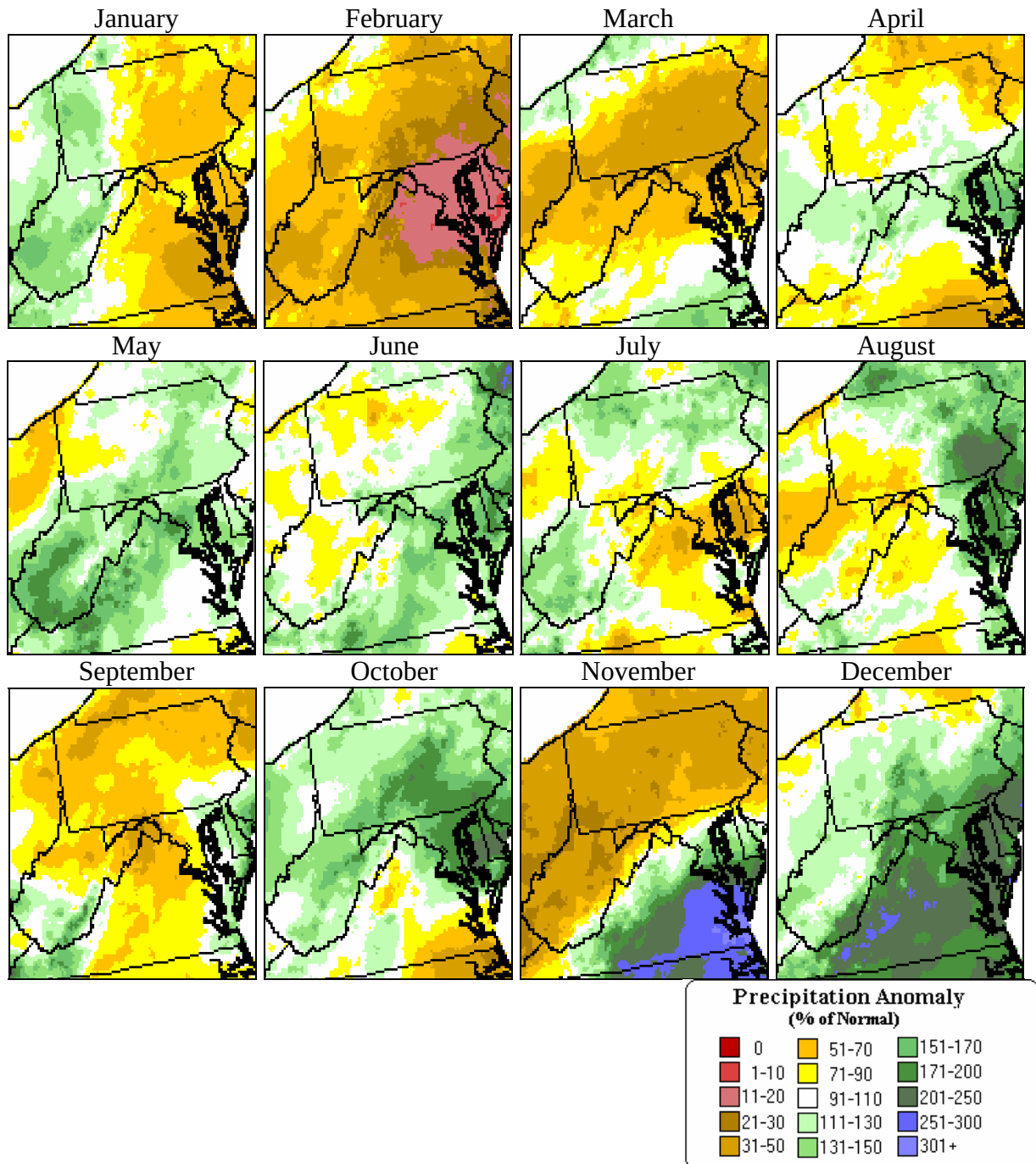


Figure 4. Maps showing percent of average monthly precipitation compared to the 30-year normal (1971–2000).

Table 8. Top five wettest days and top five dry spells (consecutive days with a trace or less of rainfall) during 2009 from the weather observing stations at Richmond (KRIC) and Hopewell (HOPV2).

Wettest Days in 2009	Dry Spells in 2009
Nov. 12: 3.5 in (89 mm)	Jan. 9–26
Dec. 3: 2.4 in (61 mm)	Feb. 4–17
Dec. 9: 1.8 in (45 mm)	Sept. 11–22
Jun. 3: 1.7 in (43 mm)	Mar. 3–12
Aug. 14: 1.6 in (41 mm)	Sept. 30–Oct. 9

Table 9. 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
Richmond	KRIC	1.5 in	0.7 in	4.3 in	2.6 in	3.7 in	4.3 in	3.4 in	4.0 in	2.5 in	3.6 in	9.6 in	8.2 in	48.4 in
		38 mm	19 mm	108 mm	65 mm	94 mm	110 mm	86 mm	103 mm	63 mm	91 mm	244 mm	207 mm	1,229 mm
Petersburg	KPTB	2.0 in	0.6 in	5.4 in	3.2 in	3.7 in	4.1 in	2.3 in	2.9 in	3.3 in	2.2 in	8.7 in	8.3 in	46.5 in
		50 mm	15 mm	137 mm	81 mm	94 mm	104 mm	56 mm	72 mm	83 mm	57 mm	222 mm	211 mm	1,181 mm
Hopewell	HOPV2	1.9 in	0.6 in	5.5 in	3.5 in	4.9 in	4.4 in	2.9 in	3.9 in	2.4 in	2.4 in	9.4 in	9.5 in	51.2 in
		47 mm	16 mm	140 mm	89 mm	124 mm	112 mm	72 mm	99 mm	61 mm	62 mm	239 mm	240 mm	1,301 mm
I-295 over Meadow Road	VA023	1.4 in	0.3 in	5.5 in	2.4 in	4.3 in	4.8 in	4.8 in	2.5 in	2.3 in	2.0 in	10.5 in	9.9 in	50.7 in
		35 mm	8 mm	140 mm	62 mm	110 mm	121 mm	121 mm	63 mm	59 mm	50 mm	268 mm	251 mm	1,289 mm

Table 10. Summary of 2009 percent of normal total 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
Richmond	KRIC	42	25	104	81	94	122	73	97	62	100	314	262	110
Petersburg*	KPTB	56	19	132	100	93	116	47	68	82	62	285	267	106
Hopewell	HOPV2	46	20	129	103	121	157	63	93	51	68	285	300	113

*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. Stations with a Period of Record of less than 5 years were not included in this table.

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 Eastern Piedmont 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 with dry conditions. The dry pattern broke during the spring, ending 27 consecutive months with below-average values of the PDSI. Drier-than-average weather returned during the summer and early autumn, which caused the drought index to reach abnormally dry levels again. An exceptionally wet November and December raised the PDSI to very moist conditions by the end of the year. Compared to previous years, 2009 had near normal conditions, particularly during the growing season from March through October.

The DM – Drought Severity Index for Virginia (Figure 6) and the Southeast (Figure 7) shows a pattern similar to the PDSI for the growing season (May through October); with August being abnormally dry (D0).

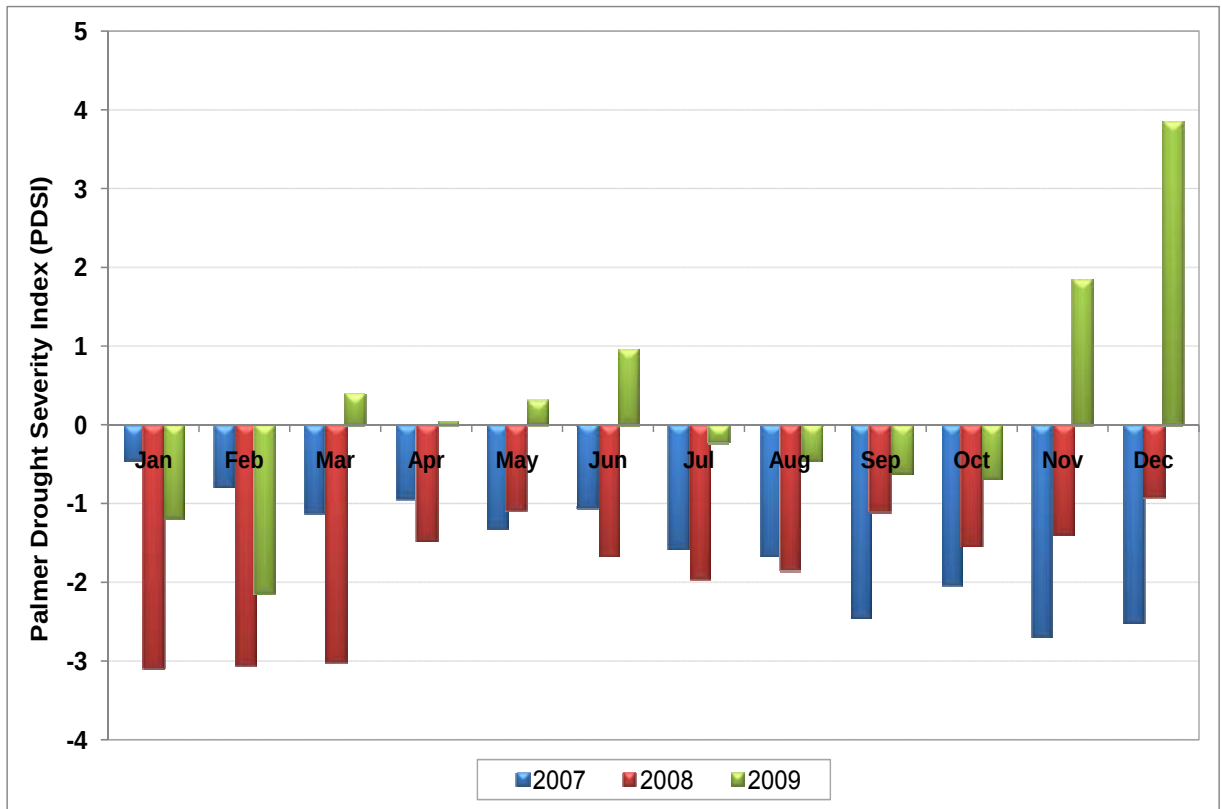


Figure 5. Palmer Drought Severity Index (PDSI) for the Eastern Piedmont, 2007–2009.

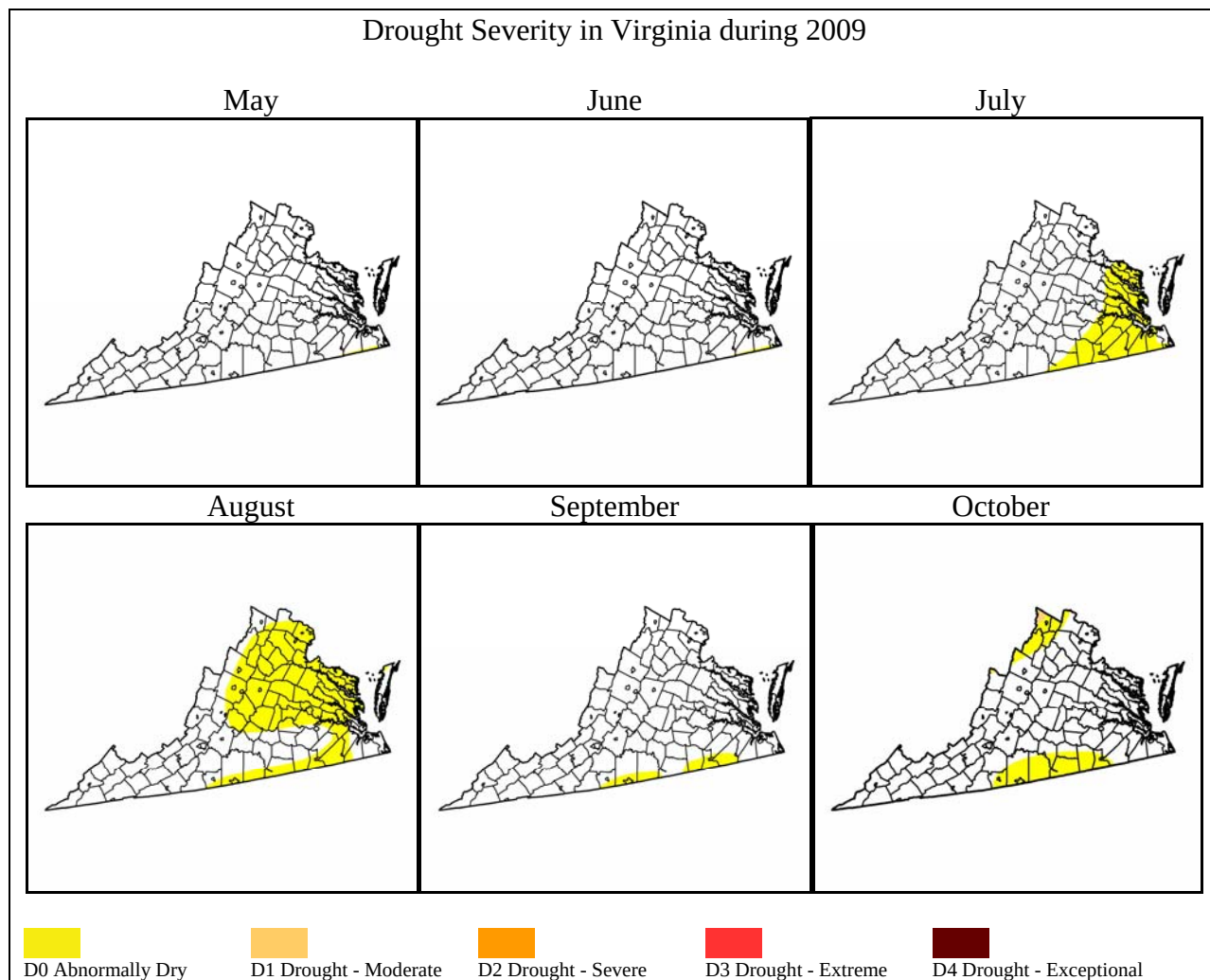


Figure 6. Mid-month values of the Palmer Drought Severity Index for Virginia in 2009.

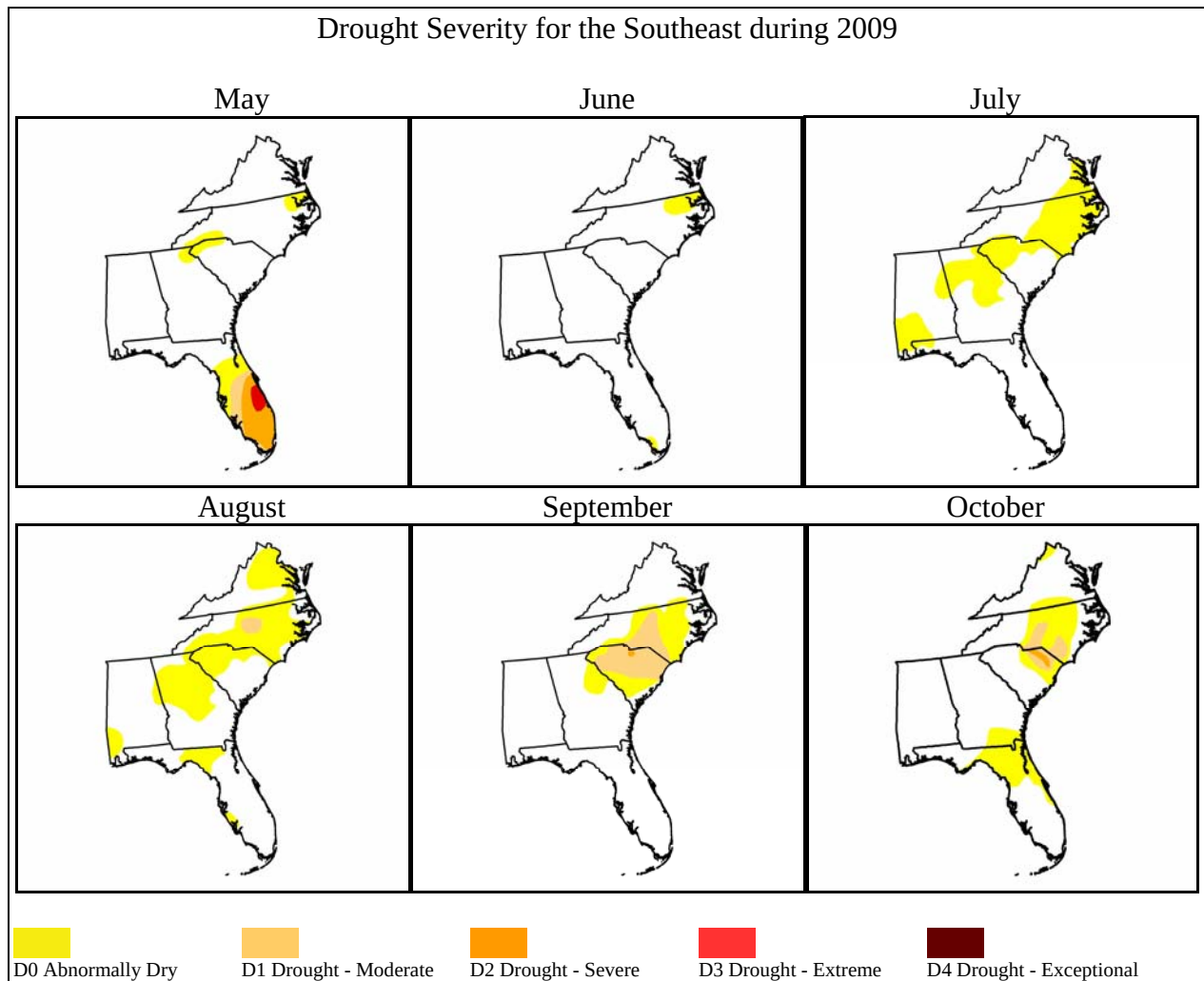


Figure 7. Mid-month values of the Palmer Drought Severity Index for the Southeast in 2009.

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Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

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