



Weather of Petersburg National Battlefield and Richmond National Battlefield Park

Mid-Atlantic Network Summary Report for 2014

Natural Resource Report NPS/MIDN/NRR—2016/1114



ON THE COVER

Petersburg National Battlefield.

Photograph by: James M. Thomas.

Weather of Petersburg National Battlefield and Richmond National Battlefield Park

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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, 2014, and to place current patterns and trends in an appropriate historical, regional, and global 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 objectives:

- 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 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 (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 2014's climate summary and trends.

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. 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. 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. 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), 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, 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).

Observation Stations

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 2014.

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. A total of four stations were ultimately used for this 2014 report: Richmond, Petersburg, Hopewell, and I-295 over Meadow Rd. (Figure 1, Table 1).

Two stations, Richmond Airport (1930-current) and Hopewell (1917-current), were used for a long-term trend analysis using the period of record for both stations ending December 31, 2013. Graphs of these long-term trends are shown in the Appendix section of this document. For temperatures, long-term means and the standard deviation above and below the long-term mean are computed for each indicator. Because precipitation distributions do not fall on a normal curve like temperature distributions do, standard deviations are not computed for the precipitation indicators.

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 2014) normals cover the period 1981–2010. In this report, the 30-year normals established by NCDC are used as the baseline for comparisons (e.g., departures from normal). In cases where data for the 30-year normal period are not available, we use alternative comparisons such as the new pseudo-normals from NCDC or a recent 10-year period. In some cases, sufficient data may simply not be available to calculate normals. For metrics that NCDC may not routinely calculate a normal, such as the number of days with more than 2 in (55 mm) of rain or liquid equivalent, normals are calculated using the same time period (e.g., 1981–2010) as the current NCDC standard. Throughout the report, descriptions of a station’s values as compared to the normals are described as a difference from the “average”,

“mean”, “typical”, “long-term value”, as well as “normal”, to improve the readability of the document. However, all of these terms are comparing a value from one year at that station to that station’s normal, whether it is the 30-year normal or the pseudo-normal calculated on a shorter time frame

Of the four stations, Richmond and Hopewell have a Period of Record (POR) sufficiently long for a 30-year normal (normals 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 ten 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>.

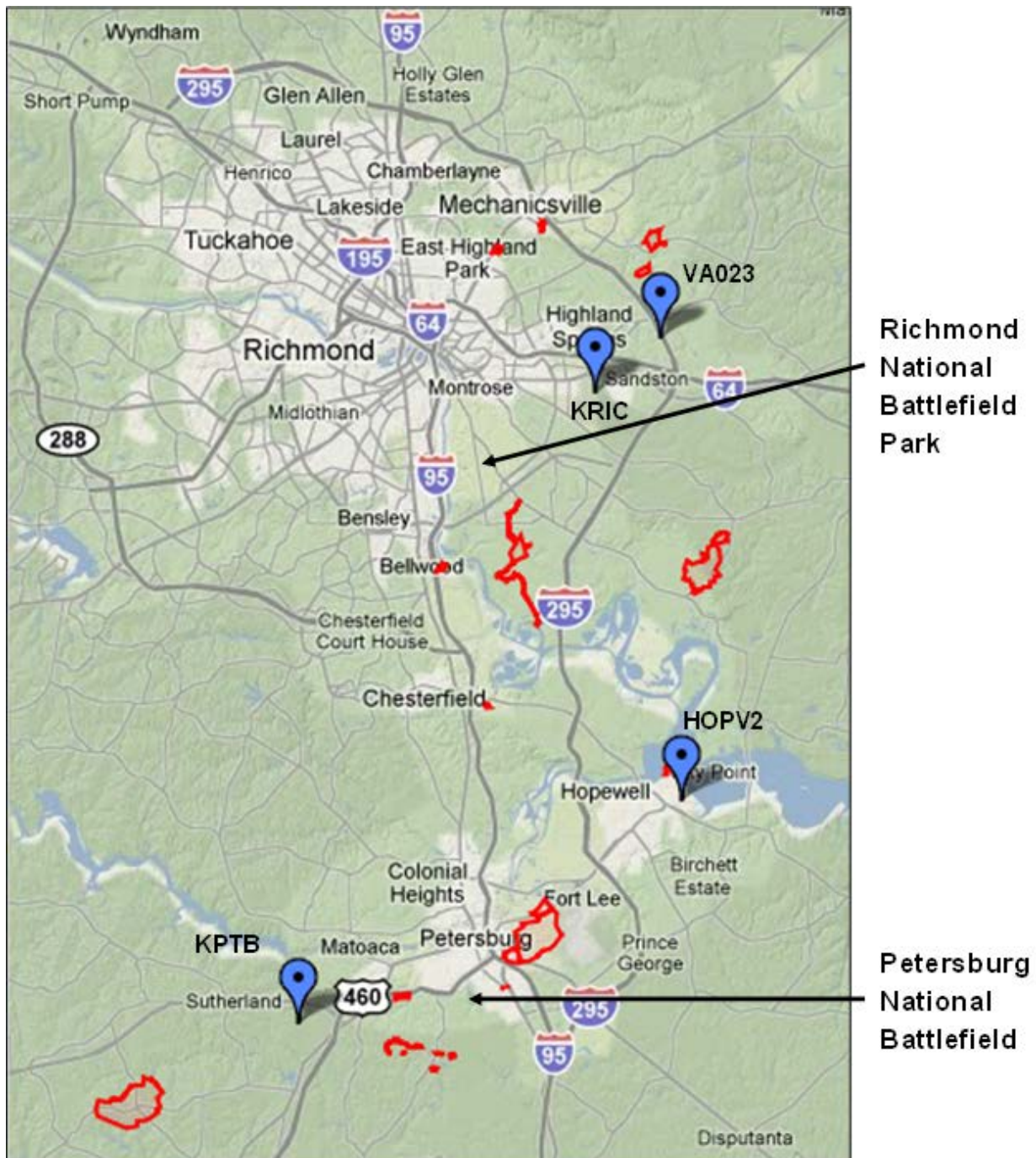


Figure 1. Location of weather observing stations around Petersburg National Battlefield and Richmond National Battlefield Park selected as most representative of the parks in 2014. See Table 1 for station names.

Table 1. List of weather observing stations around Petersburg National Battlefield and Richmond National Battlefield Park selected as most representative of the parks in 2014.

Station	Observing Network ¹	Name	Period of Record (POR)		Percentage of Time Reporting Temperature for 2014	Percentage of Time Reporting Precipitation for 2014	Percentage of Time Reporting Temperature for entire POR	Percentage of Time Reporting Precipitation for entire POR
KRIC	ASOS	Richmond International Airport	01/01/1930	Present	100.0	100.0	96.2	89.1
KPTB	ASOS	(Petersburg) Dinwiddie County Airport	01/01/1996	Present	95.3	86.0	82.7	66.6
HOPV2	COOP	Hopewell	10/03/1916	Present	98.4	99.2	97.5	97.7
VA023	RWIS	I-295 Over Meadow Road	08/24/2005	Present	-	-	66.9	46.3

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

Temperature Summary

It was a nearly average year for the area around Petersburg NB and Richmond NBP (Table 2, Figures 2 and 3). Only the spring months along with October and December in 2014 had widespread above normal readings, leaving seven months near normal or cooler than average (Figure 3)¹.

January was very cold with monthly departures ranging from 2.6 to 4.2°F (1.5 to 2.3°C) below normal (Tables 3 and 4). The lowest readings of 2014 occurred on January 30th when minimum temperatures fell to 4°F (-15.6°C) at Richmond and 7°F (-13.9°C) at Hopewell, both about 4-8°F (2.2-4.4°C) below the average annual minimum (Table 2). February stayed cold with daytime readings below average (Figures 2 and 3). The cold spell culminated in March as readings averaged about 3.5°F (1.9°C) below the long-term mean (Table 4). Overall, the winter tied as the 19th coolest in the Tidewater since records began in 1895 (Table 5).

Spring began mild. April's monthly temperatures ranged from 59.1°F (15.1°C) at Richmond to 62.4°F (16.9°C) at Petersburg (Table 3). May turned a bit warmer, as mean temperatures were between +2.5°F to +6.2°F (+1.4°C to +3.4°C) from normal (Table 4). June brought mostly positive anomalies (Figure 2) ranging from +0.5°F to +2.8°F (+0.3°C to 1.5°C) from normal (Table 4). The spring season ranked as the 18th warmest in the Tidewater and in the Eastern Piedmont since records began in 1895 (Tables 5 and 6).

Summer of 2014 started a bit warm, but August and September departures were below or near normal (Figures 2 and 3). Moderate days and warm nights during July resulted in mean temperatures ranging from -0.6°F to +2.2°F (-0.3°C to +1.2°C) from the normal at the stations (Table 4). Readings during August varied from 73.4°F (23.0°C) at Petersburg to 77.1°F (25.1°C) in Hopewell (Table 3). Slightly cooler-than-average days were off-set by very mild nights during September which contributed to above-normal temperatures in parts of the region (Table 4). The warmth in June and early July raised the tally of hot days in Richmond to 45 days compared with a long-term average of 42 days (Table 2). The opposite occurred in Hopewell where there were fewer than normal hot days (41 compared 46, respectively). The highest reading of 2014 was 101°F (38.3°C), slightly above the normal (Table 2), and the year had only two days above 100°F (37.8°C). The summer season ranked the 40th to 43rd coolest in 120 years in the Tidewater and the Eastern Piedmont, respectively (Tables 5 and 6).

The autumn began with mild daytime and warm nighttime readings in October (Figures 2 and 3). October was generally above seasonal levels with monthly mean temperatures ranging from -

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/>.

0.1°F to +3.0°F (-0.1 to +1.7°C) from the 1981–2010 means (Table 4). November turned much cooler and brought negative departures to all the stations. December was also mild such that its departures ranged from 1.6°F to 2.9°F (0.9°C to 1.5°C) above normal. The number of sub-freezing days was well above the 30-year average (Table 2). The annual maximum temperatures averaged 0.3°F (0.2°C) below normal to 0.1°F (0.1°C) above normal and minimum readings averaged 0.3°F (0.2°C) to as much as 0.8°F (0.5°C) below normal (Table 2).

Table 2. Status of 2014 temperature indicators compared to the 30-year normal (1981–2010) and the station period of record at the Richmond Airport (KRIC) and Hopewell (HOPV2) weather observing stations.

Temperature Indicator	Richmond Airport 2014	Richmond Airport 1981–2010	Richmond Airport 1930-2013 Mean (± 1 SD)	Hopewell 2014	Hopewell 1981–2010	Hopewell 1917-2013 Mean (± 1 SD)
Average Annual Temperature	58.8°F 14.9°C	58.9°F 14.9°C	58.2 (56.9 – 59.4) °F 14.6 (13.8 – 15.2) °C	61.2°F 16.2°C	61.5°F 16.4°C	60.4 (59.1 – 61.7) °F 15.8 (15.1 – 16.5) °C
Average Annual Maximum Temperature	69.3°F 20.7°C	69.6°F 20.9°C	NA	71.7°F 22.1°C	71.6°F 22.0°C	NA
Maximum Temperature	101.0°F 38.3°C	99.8°F 37.7°C	99.2 (96.3 – 102.1) °F 37.3 (35.7 – 38.9) °C	97.0°F 36.1°C	100.3°F 37.9°C	99.4 (96.6 – 102.2) °F 37.4 (35.9 – 39.0) °C
Hot Days (days with Tmax $\geq$ 90°F/32°C)	45	42	43 (29 – 57)	41	46	56 (39 – 72)
Average Annual Minimum Temperature	48.3°F 9.1°C	48.1°F 8.9°C	NA	50.6°F 10.3°C	51.4°F 10.8°C	NA
Minimum Temperature	4.0°F -15.6°C	9.6°F -12.4°C	6.8 (0.1 - 13.4) °F -14.0 (-10.3 to -17.7) °C	7.0°F -13.9°C	11.3°F -11.5°C	8.9 (2.5 - 15.3) °F -12.8 (-9.3 to -16.4) °C
Cold Days (days with Tmax $\leq$ 32°F/0°C)	7	5	NA	1	2	NA
Sub-freezing Days (days with Tmin $\leq$ 32°F/0°C)	85	74	83 (70 – 96)	70	52	70 (56– 84)
Sub-zero Days (days with Tmin $\leq$ 0°F/-17.8°C)	0	0	NA	0	0	NA
Growing Season Length (days between last spring Tmin 32°F/0°C and first fall Tmin 32°F/0°C)	220	218	203 (185 – 221)	220	214 ¹	206 (185 – 226)

¹Normal growing season length for Hopewell (1981-2010) was approximated using temperature data from Petersburg, VA (KPTW).

**Petersburg National Battlefield
and Richmond National Battlefield Park
Departure from Average Monthly Maximum Temperature
2014 vs. 1981–2010**

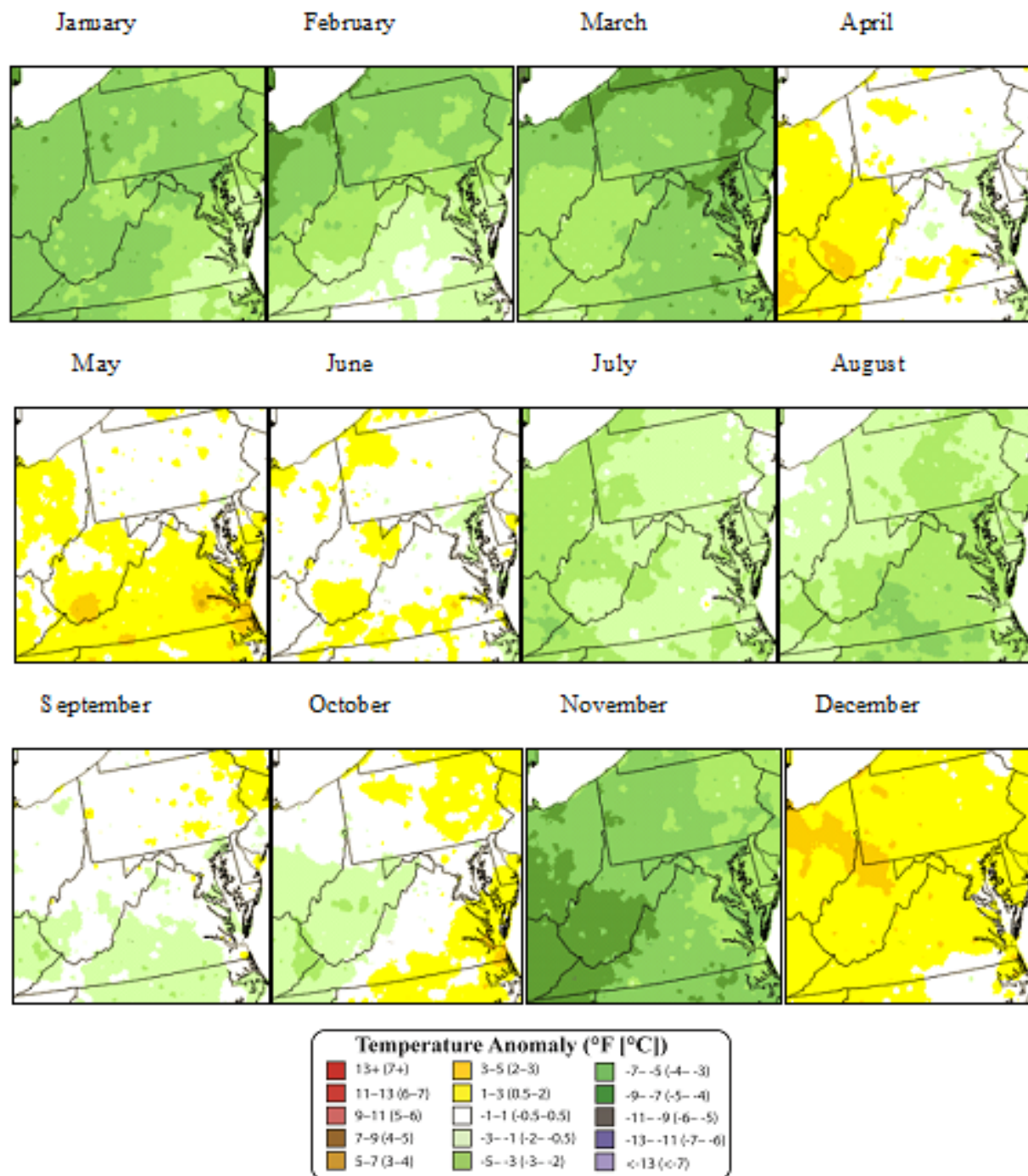


Figure 2. Maps showing departure from average monthly maximum temperature in 2014 compared to the 30-year normal (1981–2010).

**Petersburg National Battlefield
and Richmond National Battlefield Park
Departure from Average Monthly Minimum Temperature
2014 vs. 1981–2010**

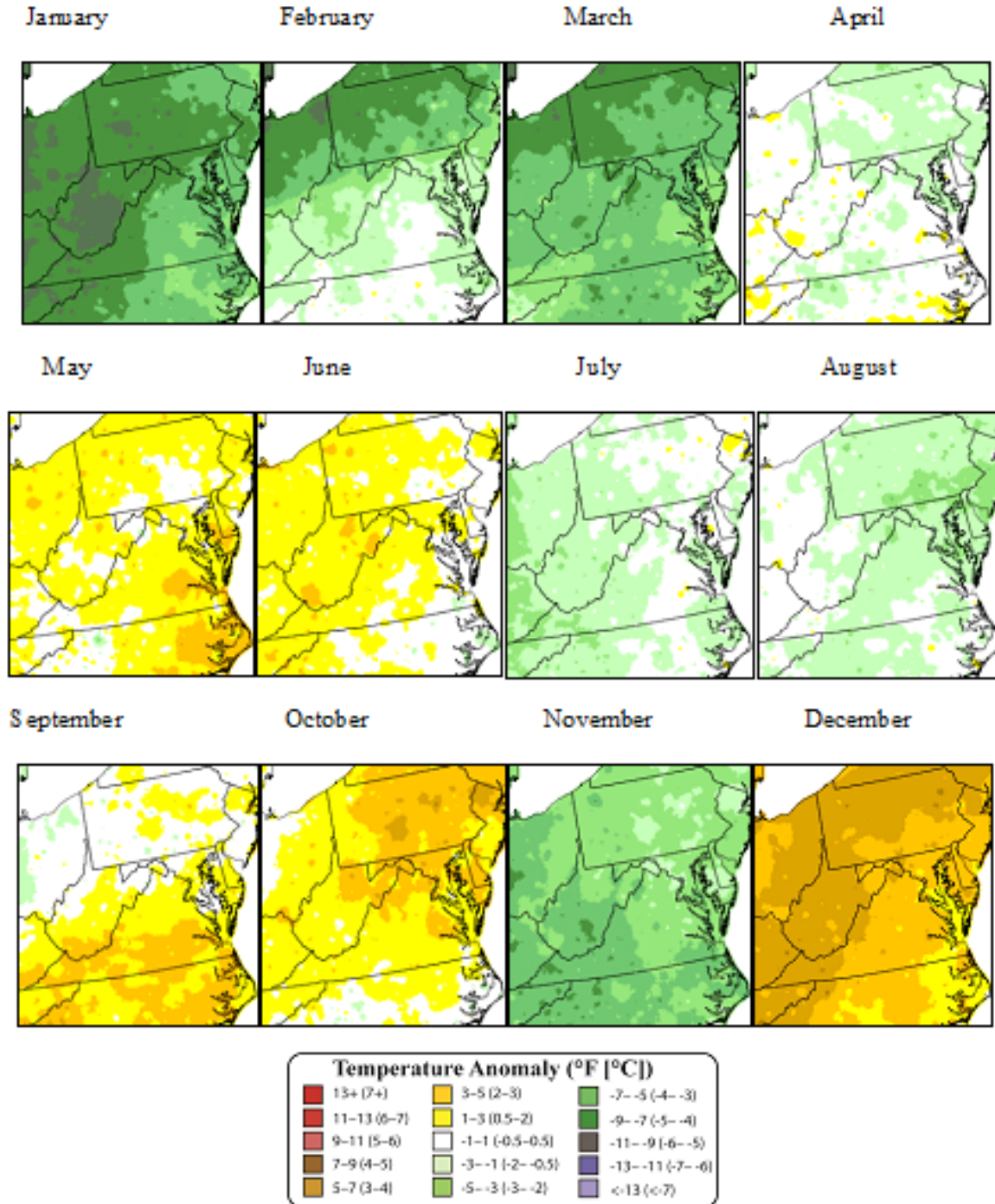


Figure 3. Maps showing departure from average monthly minimum temperature in 2014 compared to the 30-year normal (1981–2010).

Table 3. Summary of 2014 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	33.7°F	39.8°F	45.0°F	59.1°F	70.0°F	76.6°F	79.5°F	76.4°F	72.7°F	62.3°F	47.1°F	43.9°F	58.8°F
		0.9°C	4.3°C	7.2°C	15.1°C	21.1°C	24.8°C	26.4°C	24.6°C	22.6°C	16.8°C	8.4°C	6.6°C	14.9°C
Petersburg Airport	KPTB	36.6°F	42.3°F	M	62.4°F	72.7°F	79.8°F	81.4°F	73.4°F	69.2°F	59.2°F	44.8°F	42.6°F	60.4°F
		2.5°C	5.7°C	M	16.9°C	22.6°C	26.6°C	27.5°C	23.0°C	20.7°C	15.1°C	7.1°C	5.9°C	15.8°C
Hopewell	HOPV2	38.5°F	43.9°F	48.1°F	61.6°F	71.5°F	77.7°F	80.2°F	77.1°F	74.0°F	65.4°F	49.9°F	46.5°F	61.2°F
		3.6°C	6.6°C	8.9°C	16.4°C	21.9°C	25.4°C	26.8°C	25.1°C	23.3°C	18.6°C	9.9°C	8.1°C	16.2°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 2014 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	-4.2°F	-1.1°F	-3.6°F	0.9°F	3.6°F	1.3°F	0.2°F	-1.1°F	2.1°F	2.6°F	-3.3°F	2.9°F	0.0°F
		-2.3°C	-0.6°C	-2.0°C	0.5°C	2.0°C	0.7°C	0.1°C	-0.6°C	1.2°C	1.4°C	-1.8°C	1.5°C	0.0°C
Petersburg Airport ¹	KPTB	-2.6°F	1.4°F	M	4.5°F	6.2°F	2.8°F	2.2°F	-4.1°F	-1.4°F	-0.1°F	-5.5°F	1.6°F	1.0°F
		-1.5°C	0.8°C	M	2.5°C	3.4°C	1.5°C	1.2°C	-2.3°C	-0.8°C	-0.1°C	-3.1°C	0.9°C	0.6°C
Hopewell	HOPV2	-2.7°F	-0.3°F	-3.5°F	0.5°F	2.5°F	0.5°F	-0.6°F	-2.1°F	1.2°F	3.0°F	-3.4°F	2.5°F	-0.2°F
		-1.5°C	-0.2°C	-1.9°C	0.3°C	1.4°C	0.3°C	-0.3°C	-1.2°C	0.7°C	1.7°C	-1.9°C	1.4°C	-0.1°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.

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

Table 5. Seasonal and annual temperature and precipitation rankings for 2014 over 120 years for the Tidewater (NOAA 2015).

	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-2014	102-T	24-T	81-T	43	73-T
Precipitation-2014	71-T	26	56	64	49

1 = warmest/wettest year and 120 = coldest/driest year. T = tie between multiple years.

Table 6. Seasonal and annual temperature and precipitation rankings for 2014 over 120 years for the Eastern Piedmont (NOAA 2015).

	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-2014	105	18-T	78-T	43	75-T
Precipitation-2014	59	18	79	48-T	50

1 = warmest/wettest year and 120 = coldest/driest year. T = tie between multiple years.

Precipitation Summary

The year was characterized by mixed conditions at Petersburg NB and Richmond NBP, as one station (Hopewell) recorded 1.1 in (28 mm) above normal rainfall, while the other indicator station (Richmond) tallied 8.1 in (204 mm) less than the annual average in 2014 (Table 7). Overall, a wet spring was partially offset by a somewhat dry summer (Tables 5 and 6).

Similar to other locations across the region, the winter months for Petersburg NB and Richmond NBP were very close to normal. The Eastern Piedmont, which encompasses part of Richmond NBP, reported the 59nd wettest winter (essentially normal) in 120 years of records (Table 6). There was one long dry spell during the winter, from February 22-March 2 (Table 8). Despite this, February was close to normal, though in some locations as much as 110 percent of normal precipitation fell (Tables 9 and 10). Annual snowfall totals for 2014 were above the long-term average as 14.5 in (36.8 cm) was tallied at Richmond and 9.3 in (23.6 cm) at Hopewell (Table 7).

A precipitation surplus began to grow in the spring. The month of April was wetter than average with 3.6 in (91 mm) of rain reported in Petersburg and 3.9 in (98 mm) in Hopewell, and all locations recorded higher than normal values (Tables 9 and 10). There were two long dry spells during the spring (April 16-24 and June 23-July 9) and when combined with a drier than average May and a mixed June, it was the 18th wettest spring recorded in the Eastern Piedmont (Table 5).

Summer rainfall was diverse across the Petersburg NB and Richmond NBP region. As an example, the Tidewater, which encompasses most of Richmond NBP, reported the 56th wettest summer in 120 years of records, while the adjacent Eastern Piedmont tallied its 42nd driest summer of record (Tables 5 and 6). Across the season, each station had at least one month well below average and two stations had at least one month with greater than 100% of average (Table 10). No direct effects of tropical cyclones were noted during this quarter of 2014, but three of the wettest days of the year occurred, all during late July and August. Two dry spells occurred in this period from August 24 - September 2 and from September 11-23 (Table 8). As a result, September's rainfall was only 33-75 percent of normal (Table 10).

The final three months of the year were increasingly moist in the Tidewater and the Eastern Piedmont region (Tables 5 and 6). October had precipitation ranging from 56-88 percent of normal (Table 10). November was slightly wetter with totals ranging from 35 to 101 percent of normal and Hopewell tallying 3.5 in (90 mm) during this month (Tables 9 and 10). December brought above-average precipitation. No notable dry spells or wet days occurred in the autumn (Tables 8) in 2014. Overall, 2014 featured near average number of micro-droughts and near to a bit below normal number of extreme precipitation days (Table 7).

Table 7. Status of 2014 precipitation indicators compared to the 30-year normal (1981–2010) and the station period of record at the Richmond Airport (KRIC) and Hopewell (HOPV2) weather observing stations.

Precipitation Indicator	Richmond Airport 2014	Richmond Airport 1981–2010	Richmond Airport 1930-2013 Mean (min – max)	Hopewell 2014	Hopewell 1981–2010	Hopewell 1917-2013 Mean (min – max)
Annual Precipitation	35.7 in 907 mm	43.8 in 1,111 mm	43.7 (22.9 – 63.3) in 1,110 (582 – 1,608) mm	47.4 in 1,204 mm	46.3 in 1,176 mm	43.9 (23.4 – 71.2) in 1,115 (594 – 1,808) mm
Autumn (Oct, Nov, Dec) Precipitation	8.7 in 221 mm	9.5 in 241 mm	9.4 (2.5 – 21.4) in 239 (64 – 544) mm	9.3 in 236 mm	10.3 in 262 mm	9.2 (2.2 – 21.3) in 234 (56 – 541) mm
Heavy Precipitation Days (days with ≥ 1.0 in [25 mm] rain)	8	11	NA	14	13	NA
Extreme Precipitation Days (days with ≥ 2.0 in [51 mm] rain)	0	2	2 (0 – 7)	4	3	2(0 – 8)
Micro-drought (periods of 7+ days without rain)	6	4	NA	9	8	NA
Annual Snowfall	14.5 in 36.8 cm	10.3 in 26.2 cm	12.7 (T – 47.0) in 32.3 (T – 119.4) cm	9.3 in 23.6 cm	3.9 in 9.9 cm	7.3 (0 – 48.0) in 18.5 (0 – 121.9) cm
Measurable Snow Days (days with ≥ 0.1 in [0.3 cm] snow)	7	6	NA	4	1	NA
Moderate Snow Days (days with ≥ 3.0 in [7.6 cm] snow)	2	1	NA	0	1	NA
Heavy Snow Days (days with ≥ 5.0 in [12.7 cm] snow)	0	1	NA	0	0	NA

T = “trace”

**Petersburg National Battlefield
and Richmond National Battlefield Park
Percent of Average Monthly Precipitation
2014 vs. 1981–2010**

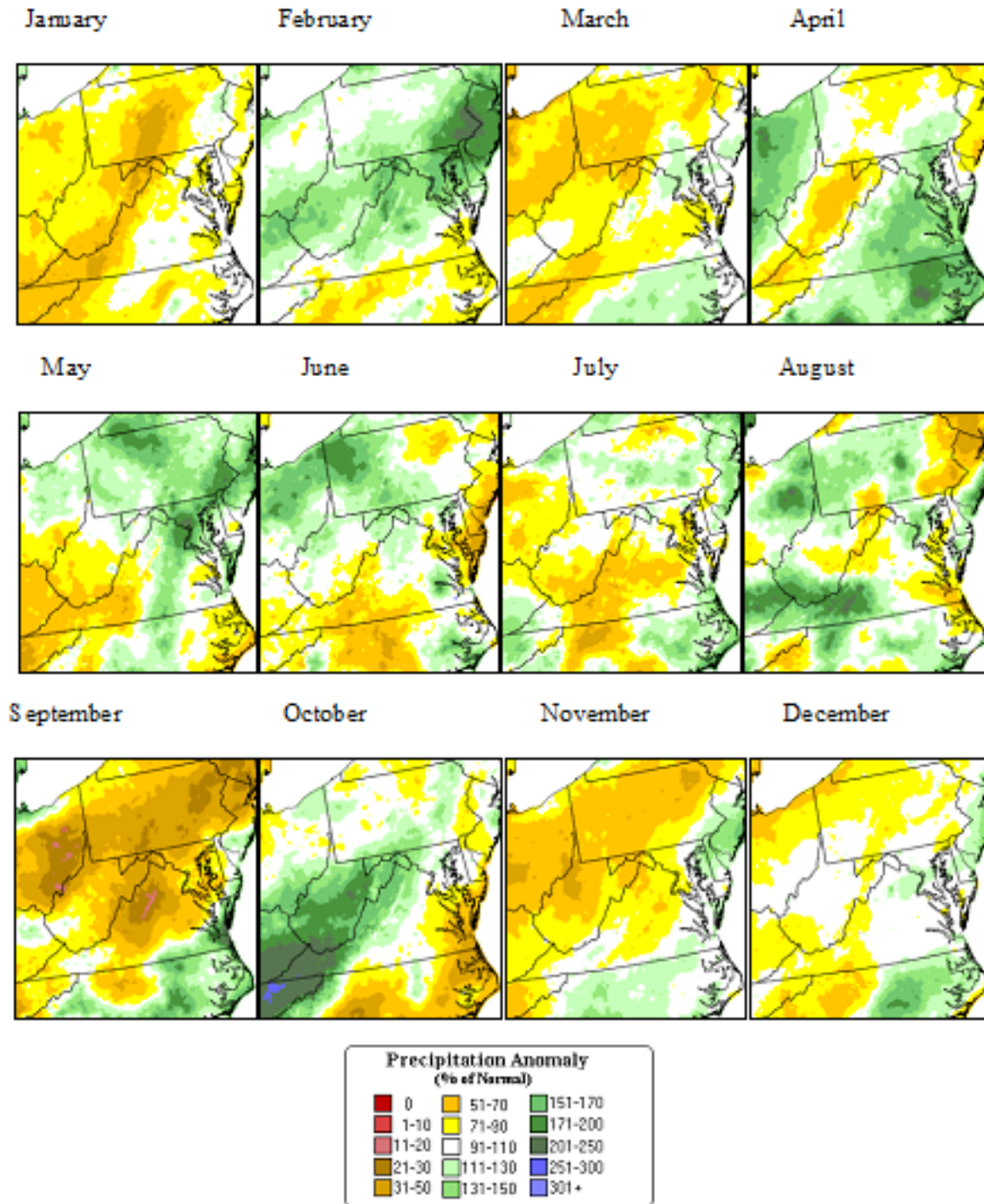


Figure 4. Maps showing percent of average monthly precipitation in 2014 compared to the 30-year normal (1981–2010).

Table 8. Top five wettest days and top five dry spells (consecutive days with a trace or less of liquid precipitation) during 2014 from the weather observing stations at Richmond Airport (KRIC) and Hopewell (HOPV2).

Wettest Days in 2014	Dry Spells in 2014
June 12: 2.90 in (73.6 mm)	June 23-July 9
June 11: 2.50 in (63.5 mm)	Sept. 11-Sept. 23
Aug. 02: 2.25 in (57.2 mm)	Aug. 24-Sept. 02
July 25: 2.00 in (50.8 mm)	Feb. 22-Mar. 02
Aug. 18: 1.98 in (50.3 mm)	Apr. 16-24

Table 9. Summary of 2014 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	3.3 in	3.0 in	3.2 in	4.1 in	2.4 in	3.4 in	2.6 in	3.6 in	1.4 in	2.6 in	3.0 in	3.1 in	35.7 in
		83 mm	77 mm	82 mm	103 mm	62 mm	86 mm	67 mm	92 mm	34 mm	67 mm	75 mm	80 mm	908 mm
Petersburg Airport	KPTB	0.9 in	2.6 in	3.2 in	3.6 in	1.7 in	3.7 in	6.0 in	3.3 in	3.1 in	M	1.2 in	3.6 in	32.8 in
		22 mm	67 mm	82 mm	91 mm	42 mm	94 mm	151 mm	85 mm	79 mm	M	29 mm	90 mm	832 mm
Hopewell	HOPV2	2.5 in	3.0 in	3.3 in	3.9 in	3.8 in	9.3 in	5.0 in	5.2 in	2.3 in	1.9 in	3.5 in	3.9 in	47.4 in
		64 mm	75 mm	83 mm	98 mm	96 mm	236 mm	126 mm	133 mm	57 mm	47 mm	90 mm	98 mm	1205 mm

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

Table 10. Summary of 2014 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	108	110	80	124	65	86	58	77	33	88	91	96	82
Petersburg Airport ¹	KPTB	28	95	80	109	44	94	132	71	75	M	35	109	75
Hopewell	HOPV2	73	93	80	103	98	278	107	104	49	56	101	111	102

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.

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

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 2014 are shown in Figure 5.

According to the PDSI, 2014 started off moderately wetter than normal with PDSI values at or above a 2.0. A dry June allowed the PDSI to come back down to near zero. For the remainder of the year, normal to slightly below normal precipitation was seen as the PDSI was slightly below zero. Comparing 2014 with the previous year, showed similar trends but seasonally reversed meaning the previous year started off near to slightly above normal and the latter half of the year was moderately wetter than normal which ultimately continued into 2014.

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 2014). 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 2014.

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). No droughts were recorded in all of Virginia, and only a limited number of “abnormally dry” locations were noted in the central areas of the state during the end of the growing season.

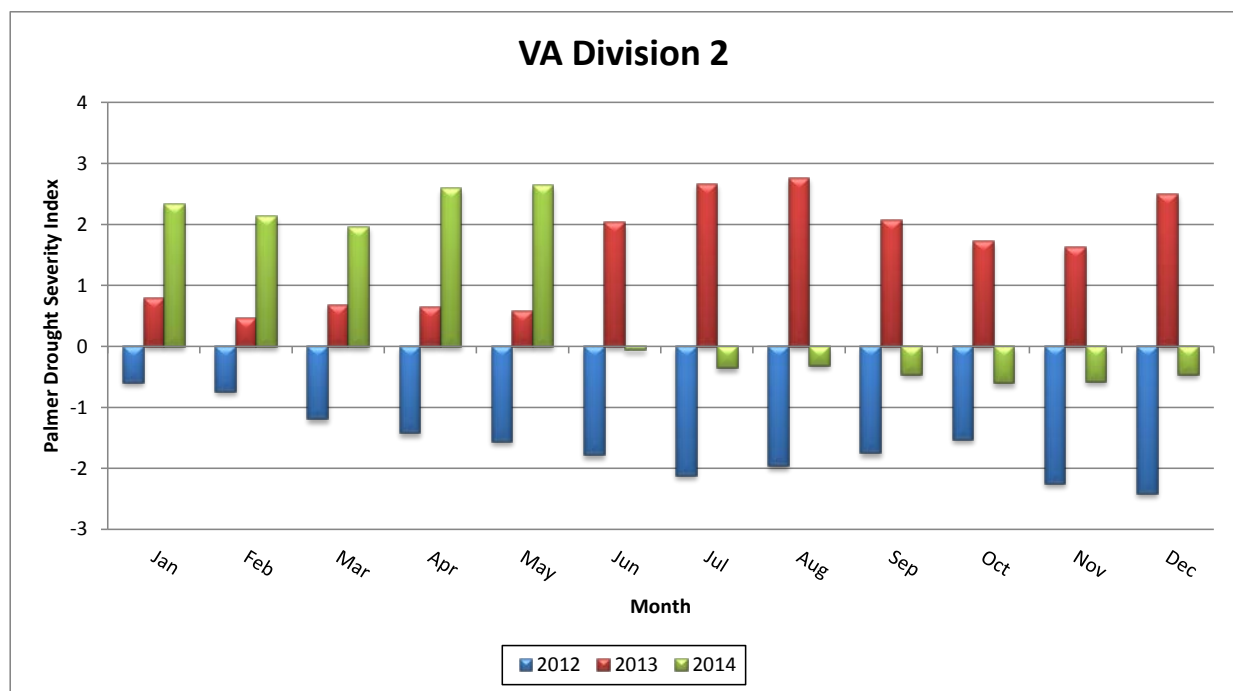


Figure 5. Palmer Drought Severity Index (PDSI) for the Eastern Piedmont, 2012–2014.

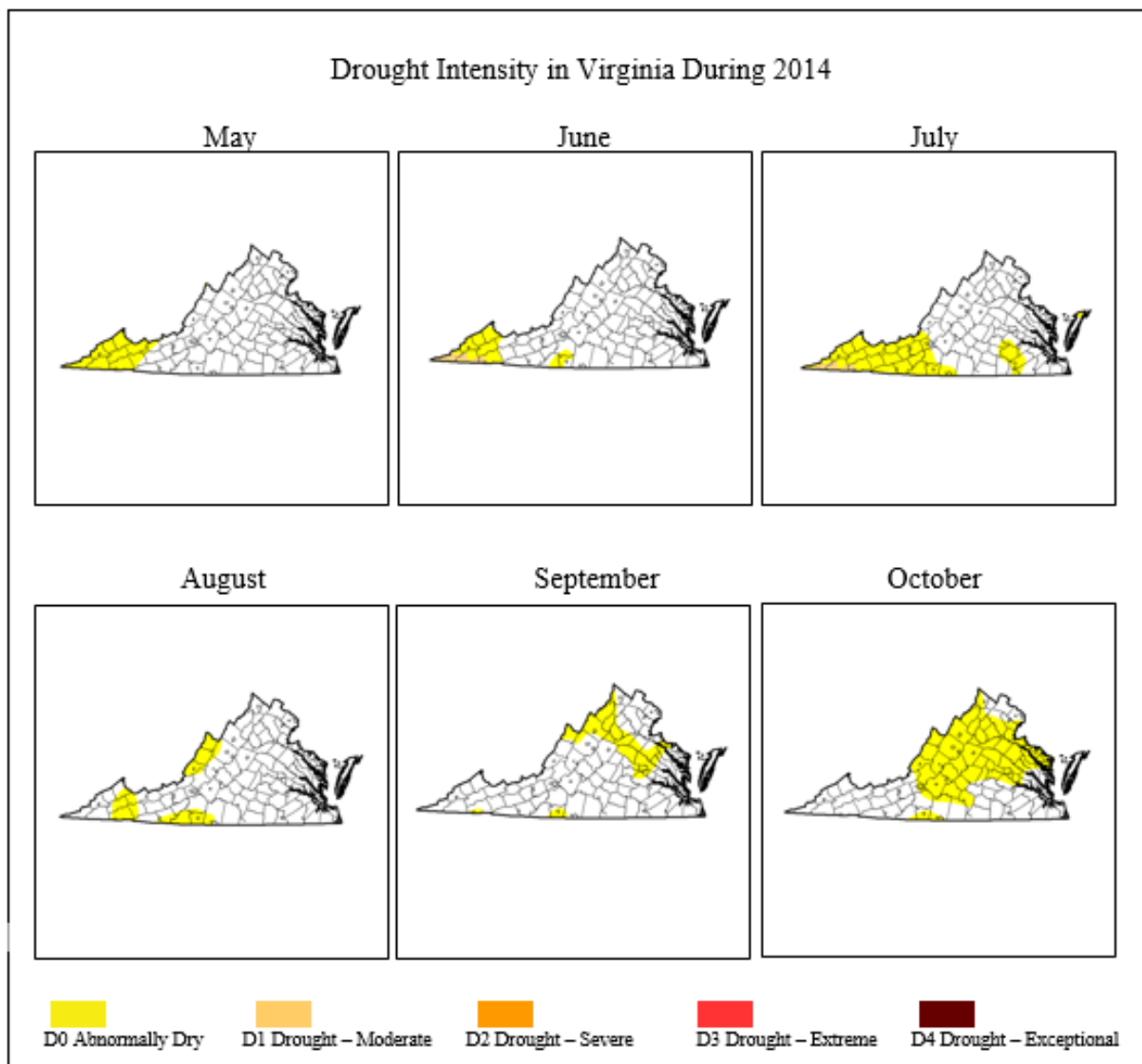


Figure 6. Mid-month values of the United States Drought Monitor (DM) - Drought Intensity Index for Virginia in 2014.

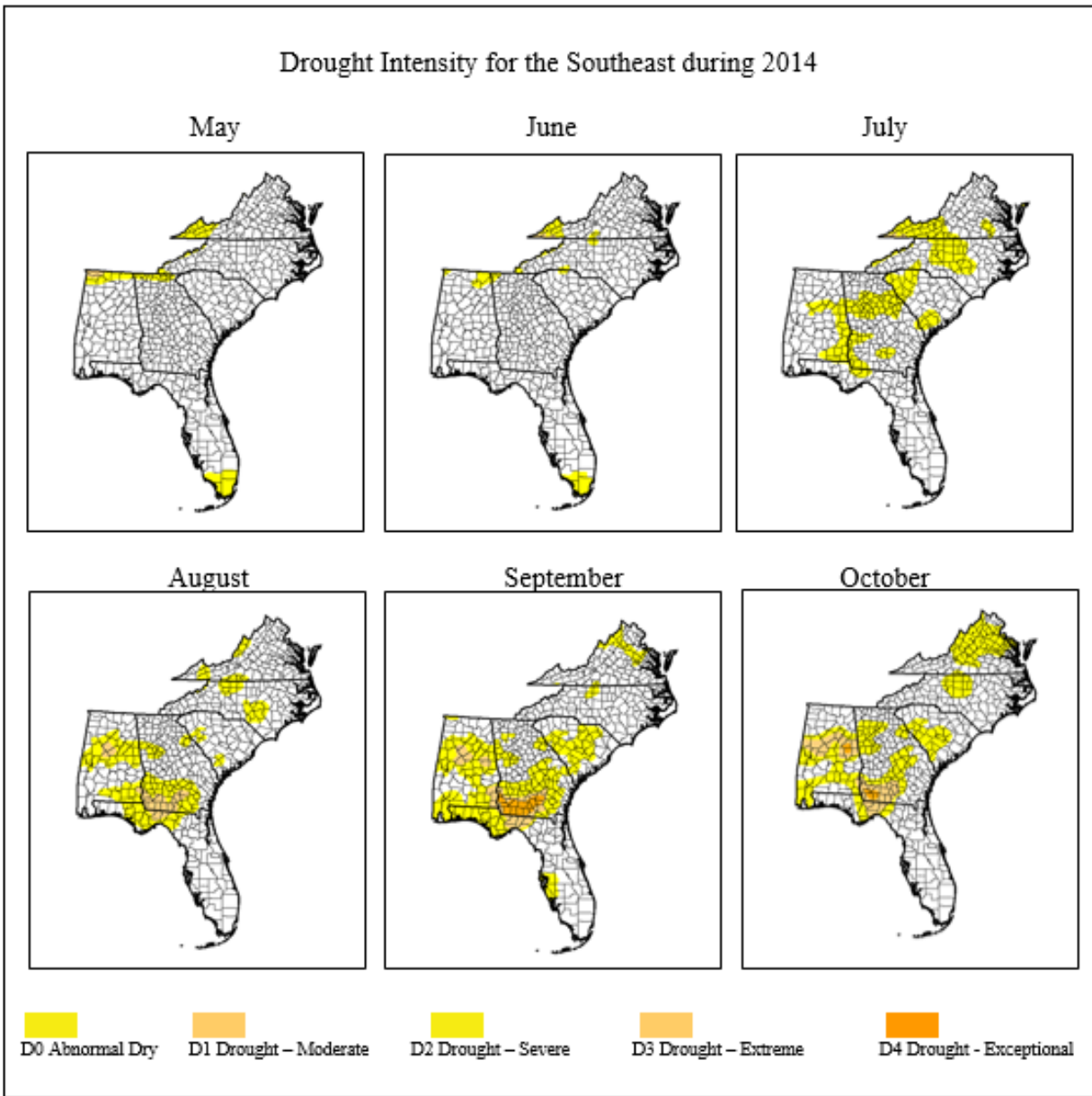


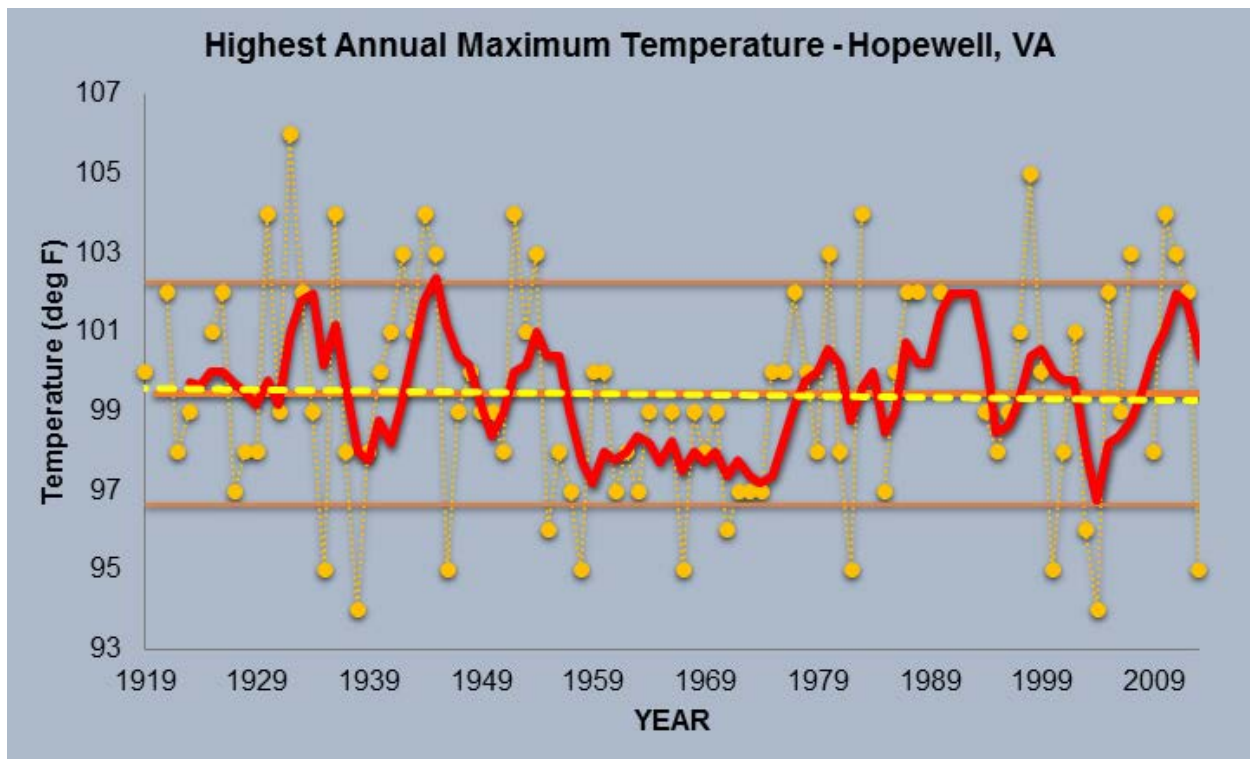
Figure 7. Mid-month values of the United States Drought Monitor (DM) - Drought Intensity Index for the Southeast in 2014.

References

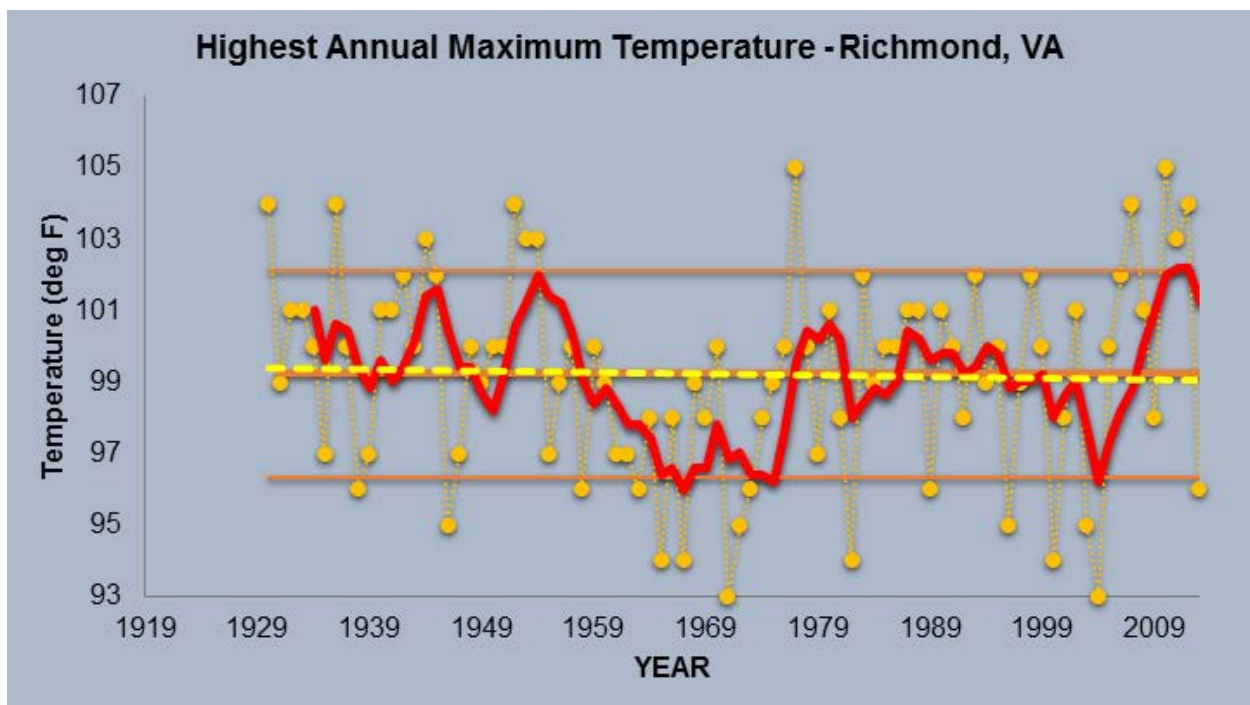
- Comiskey, J. A., and K. K. Callahan. 2008. Mid-Atlantic Network vital signs monitoring plan. Natural Resource Report NPS/MIDN/NRR—2008/071. National Park Service, Fort Collins, CO.
- Daly, C., W. P. Gibson, G. H. Taylor, G. L. Johnson, and P. Pasteris. 2002. A knowledge-based approach to the statistical 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, CO.
- Gawtry, S., and J. Stenger. 2007. Climate Summary, Shenandoah National Park. Natural Resources Report NPS/NER/NRR—2007/017. National Park Service, Philadelphia, PA.
- 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). 2014. National Climate Data Center and United States Department of Agriculture. <http://droughtmonitor.unl.edu/MapsAndData/MapArchive.aspx> (accessed 8 August 2015).
- National Oceanic and Atmospheric Administration (NOAA). 2015. National Climatic Data Center Climatological Rankings. Available at: <http://www.ncdc.noaa.gov/temp-and-precip/climatological-rankings> (accessed 3 September 2015)

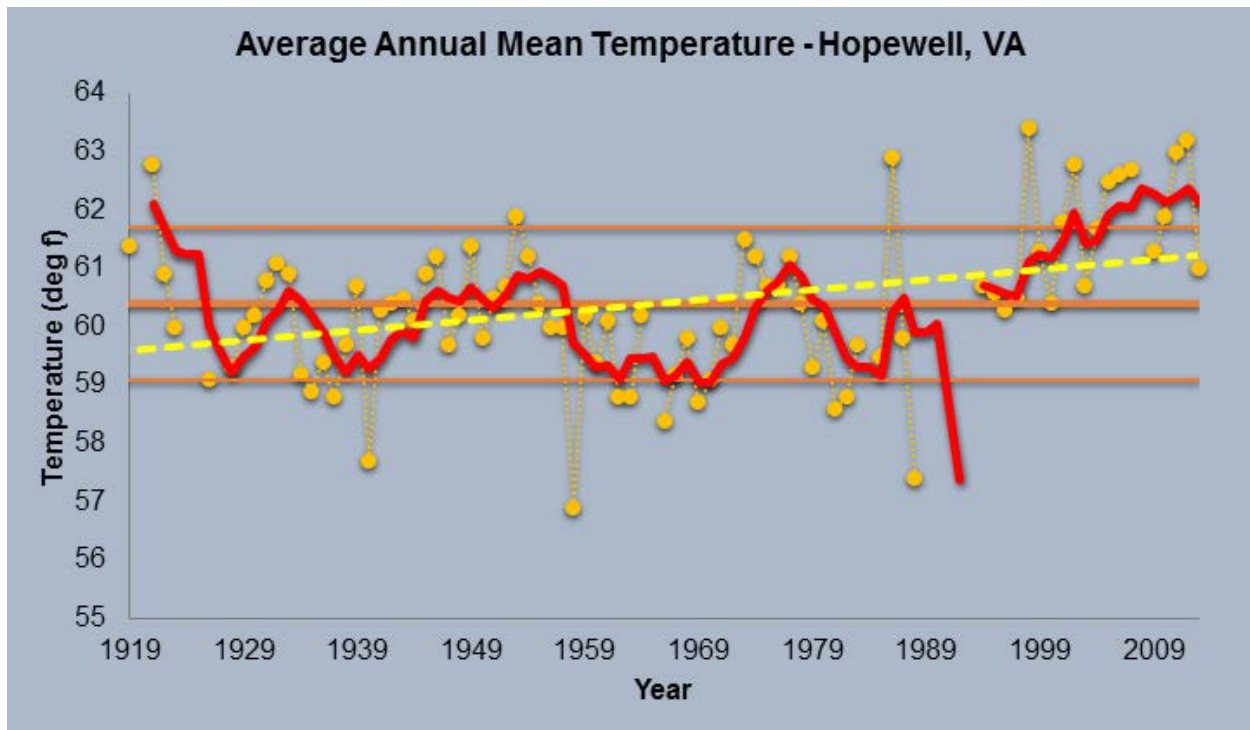
Appendix

Below are graphs illustrating long-term trend analysis for multiple climate indicators at the Hopewell and Richmond weather stations. For temperature indicators, yearly values are marked by the dotted orange line, the 5-year moving average is indicated by the thick red line, the long-term linear trend is shown by the dotted yellow line, the long-term mean is marked by the thick orange line, and the first standard deviation above and below the long-term mean are delineated by the solid orange lines. Similarly for precipitation indicators, yearly values are marked by the dotted teal line, the 5-year moving average is indicated by the thick green line, the long-term linear trend is shown by the dotted yellow line, and the long-term mean is delineated by the thick light blue line.

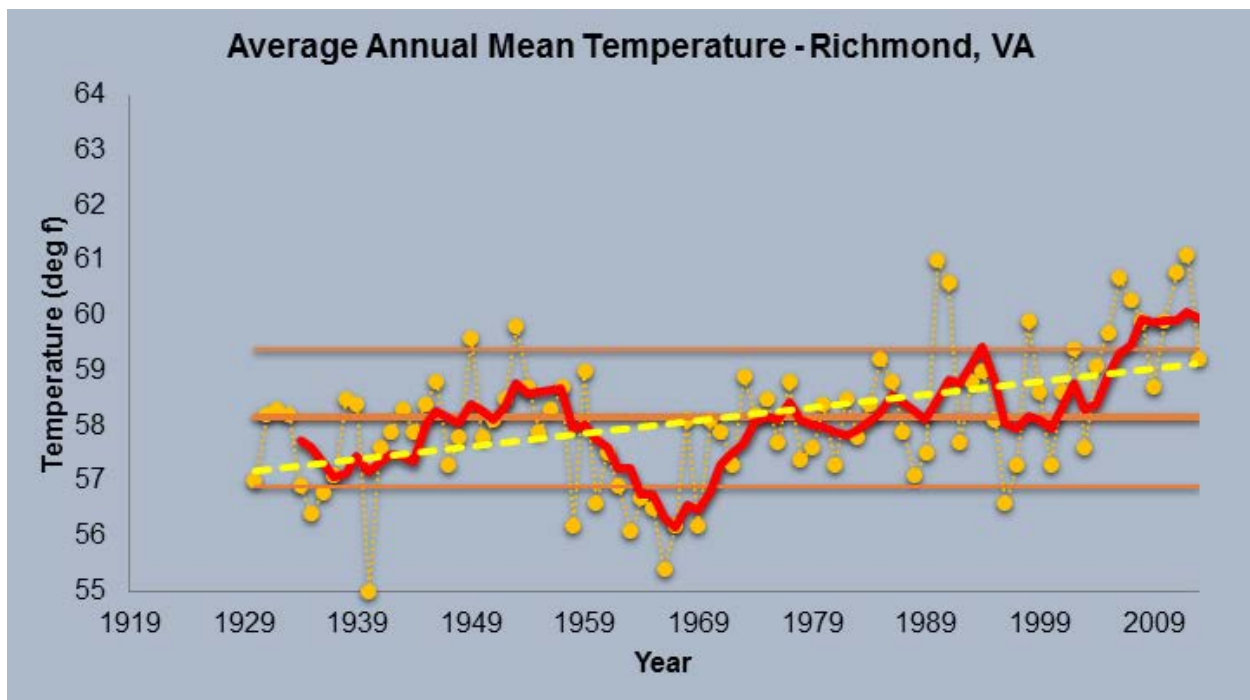


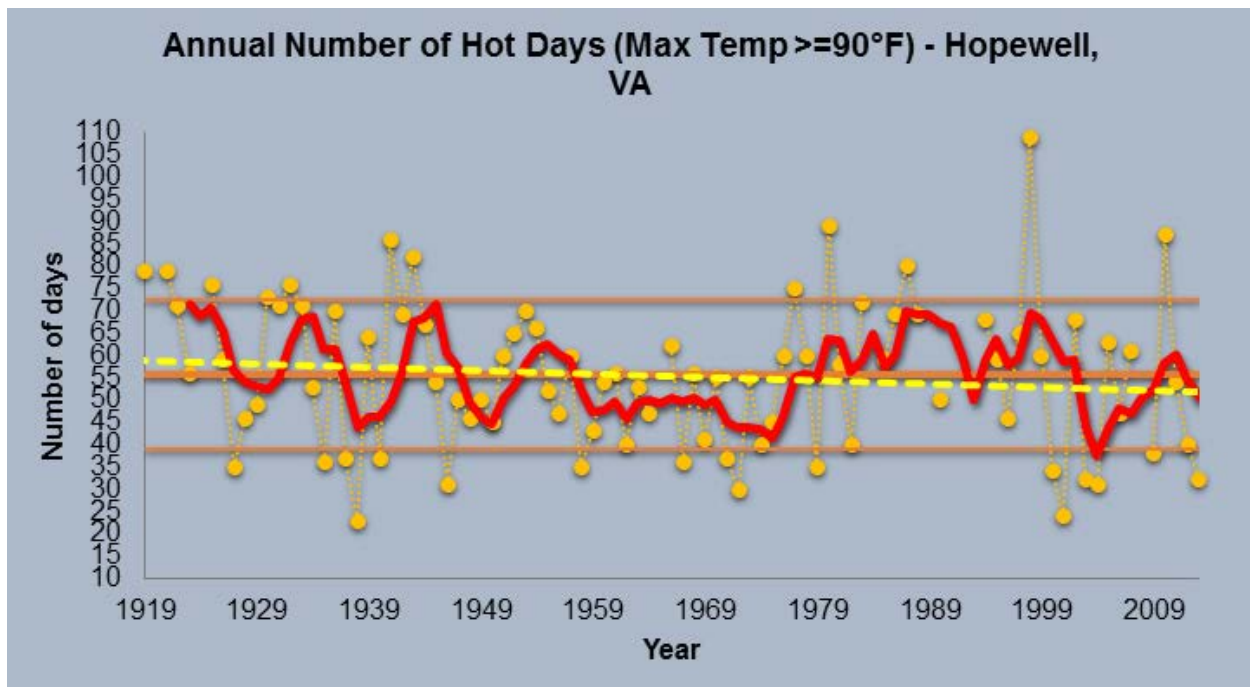
Annual Maximum Trends: The stations are relatively close to each other (only 29.4km apart), and the trends are small (less than 1°F per 50 years) and similar to each other. The average annual maximum temperature is 99.4°F (± 1 SD ranges from 96.6-102.2°F) at Hopewell and 99.2°F (± 1 SD ranges from 96.3-102.1°F) at Richmond (Table 2).



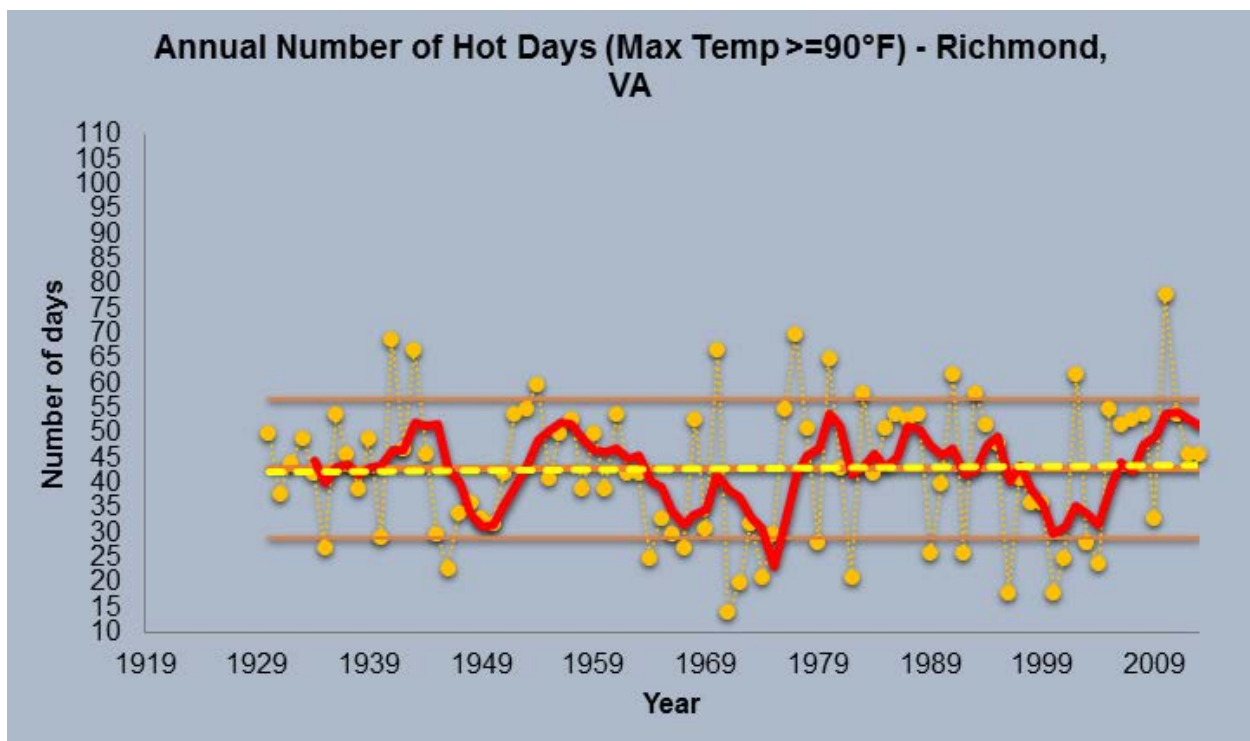


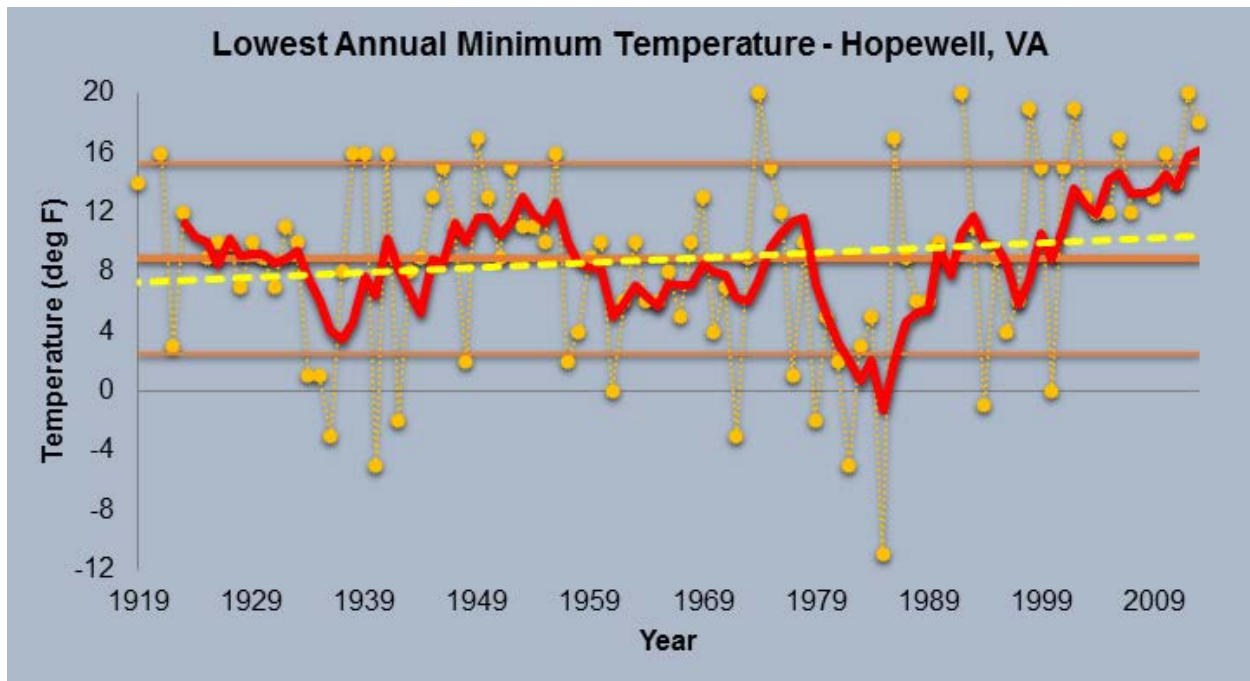
Annual Mean Trends: The annual temperature (average of maximum and minimum) shows an increasing trend at each location (more than 2°F over each station's POR), consistent with long-term warming. The average annual mean temperature at Hopewell is 60.4°F (± 1 SD ranges from 59.1-61.7°F) and at Richmond is 58.2°F (± 1 SD ranges from 56.9-59.4°F) (Table 2).



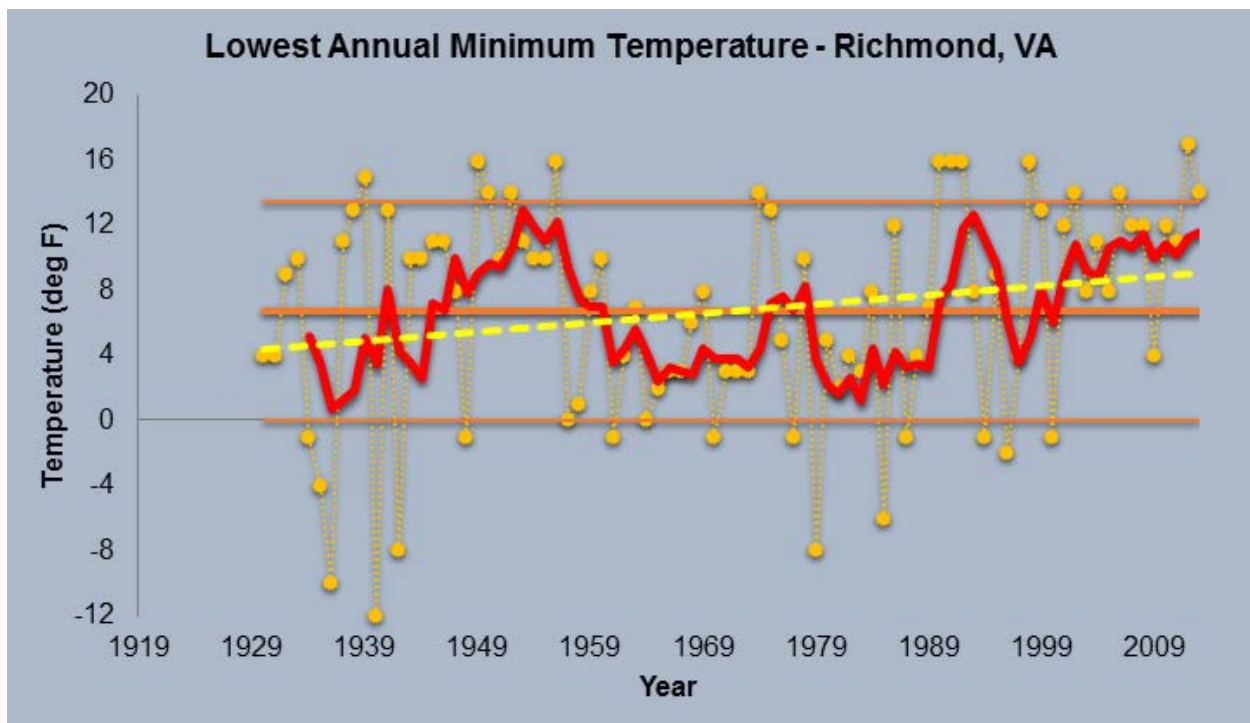


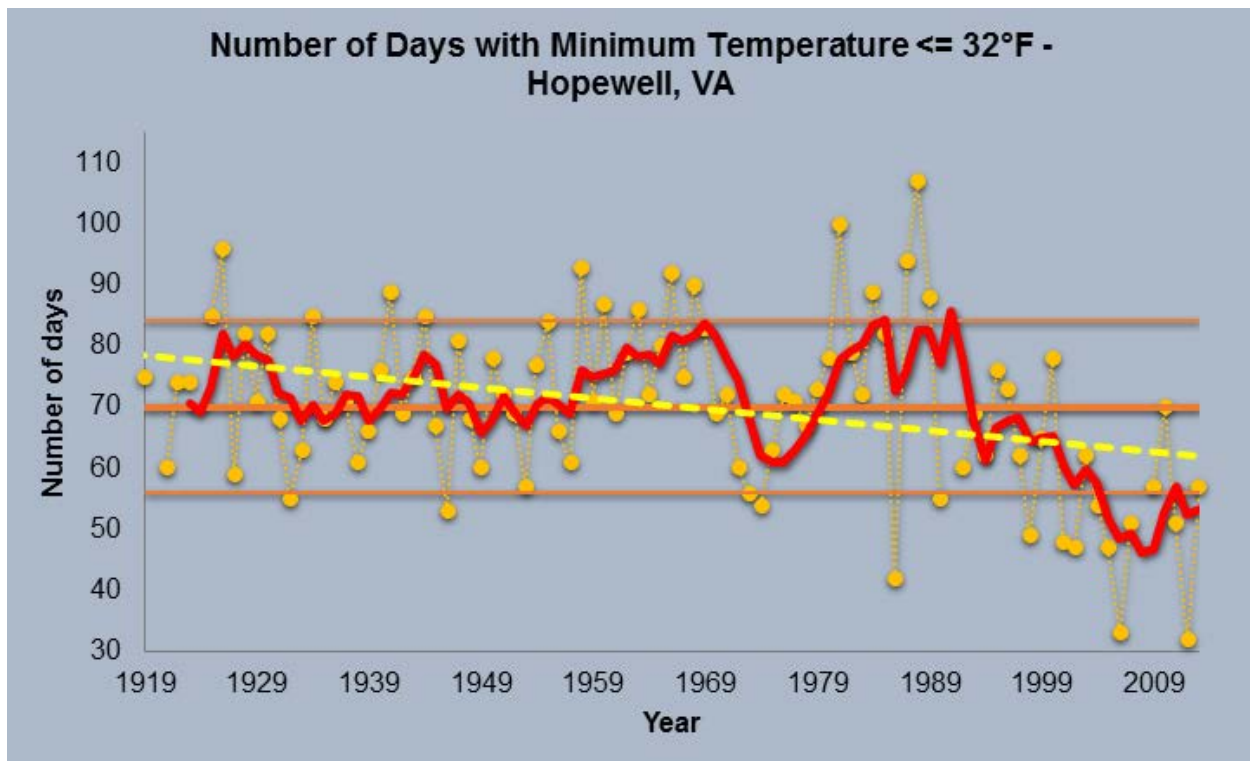
Annual Number of Hot Days: Although Hopewell shows a decreasing trend in hot summer days, Richmond shows essentially no trend. The average number of annual hot days is 56 ($\pm 1\text{SD}$ ranges from 39-72) at Hopewell and 43 ($\pm 1\text{SD}$ ranges from 29-57) at Richmond (Table 2).



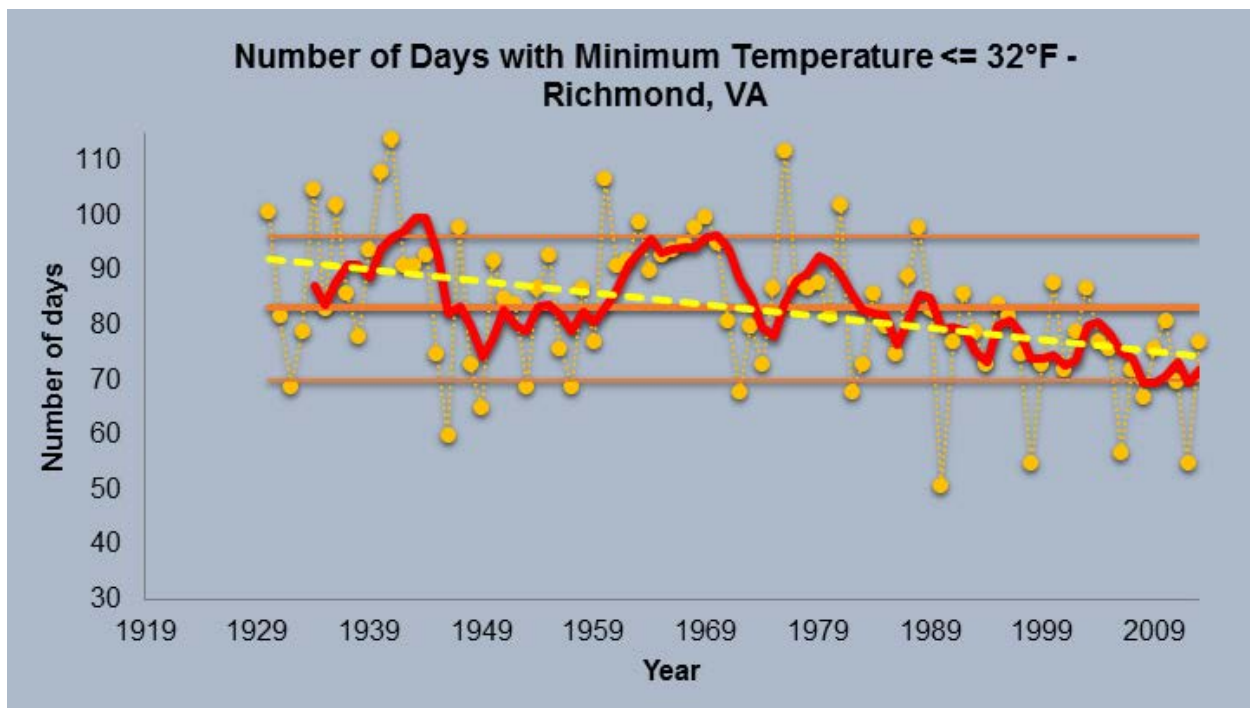


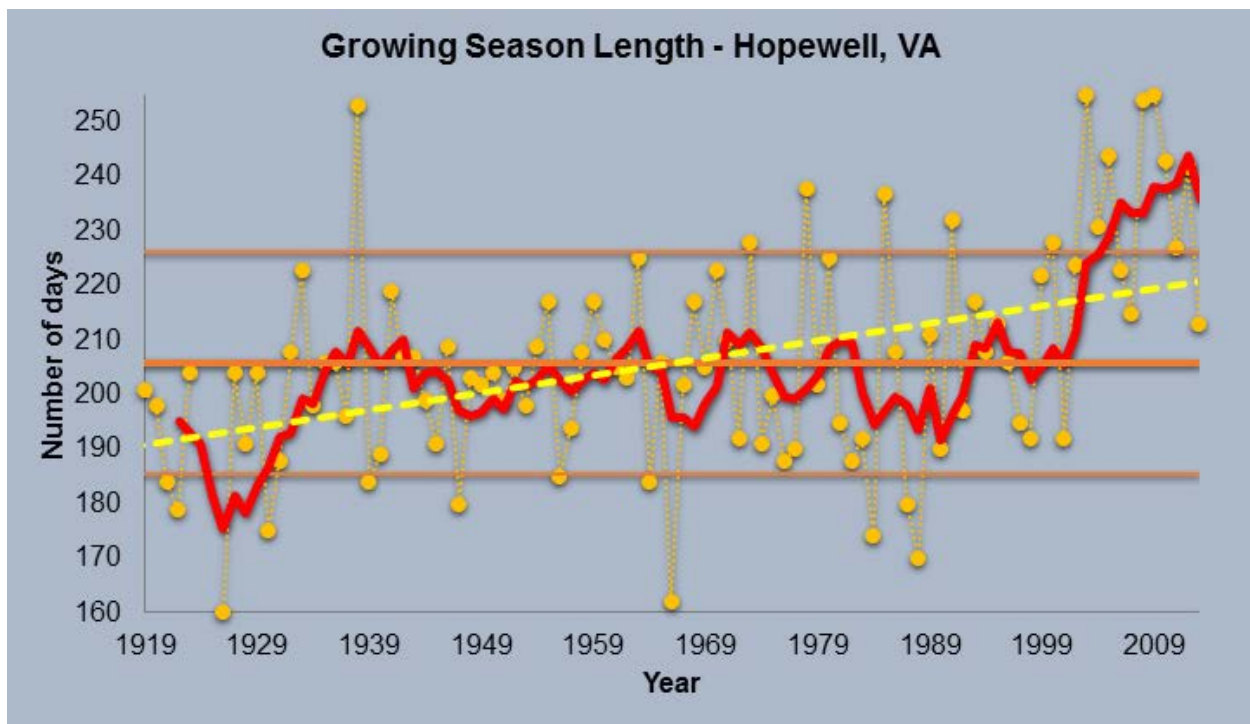
Annual Lowest Minimum Temperature: The upward trend (around 5°F over the course of the POR) at both stations explains part of the annual mean temperature rise. The average annual minimum temperature is 8.9°F (± 1 SD ranges from 2.5-15.3°F) at Hopewell and 6.8°F (± 1 SD ranges from 0.1 – 13.4°F) at Richmond (Table 2).



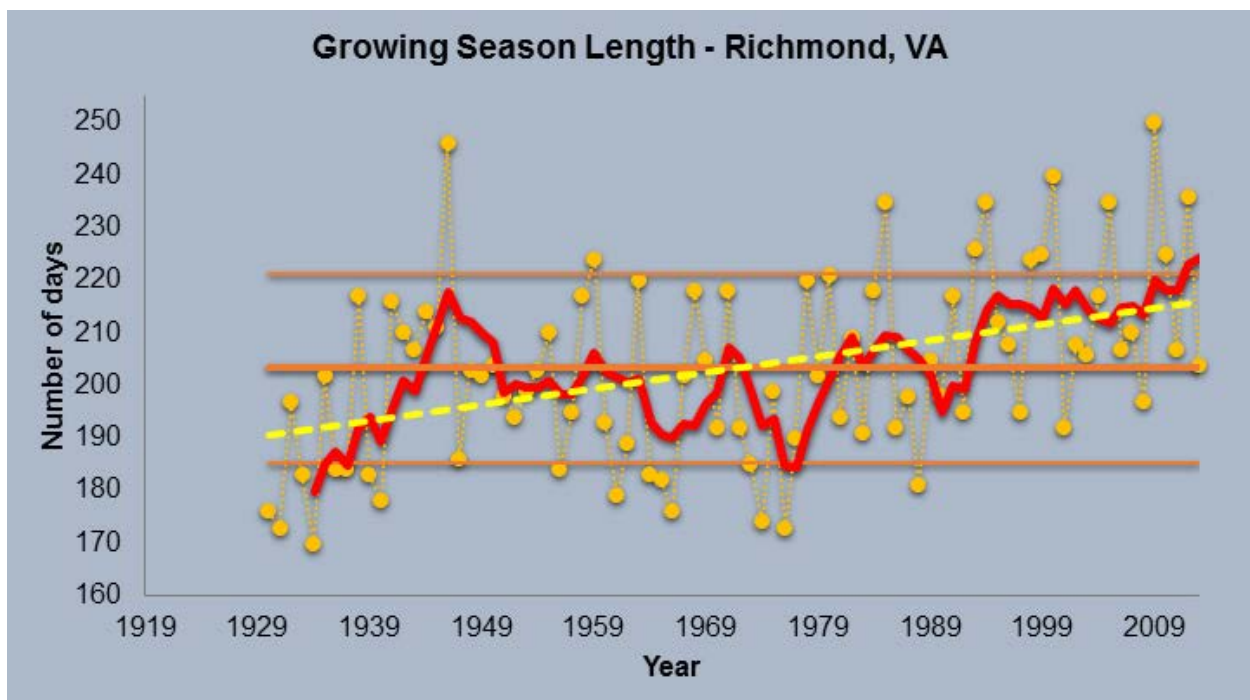


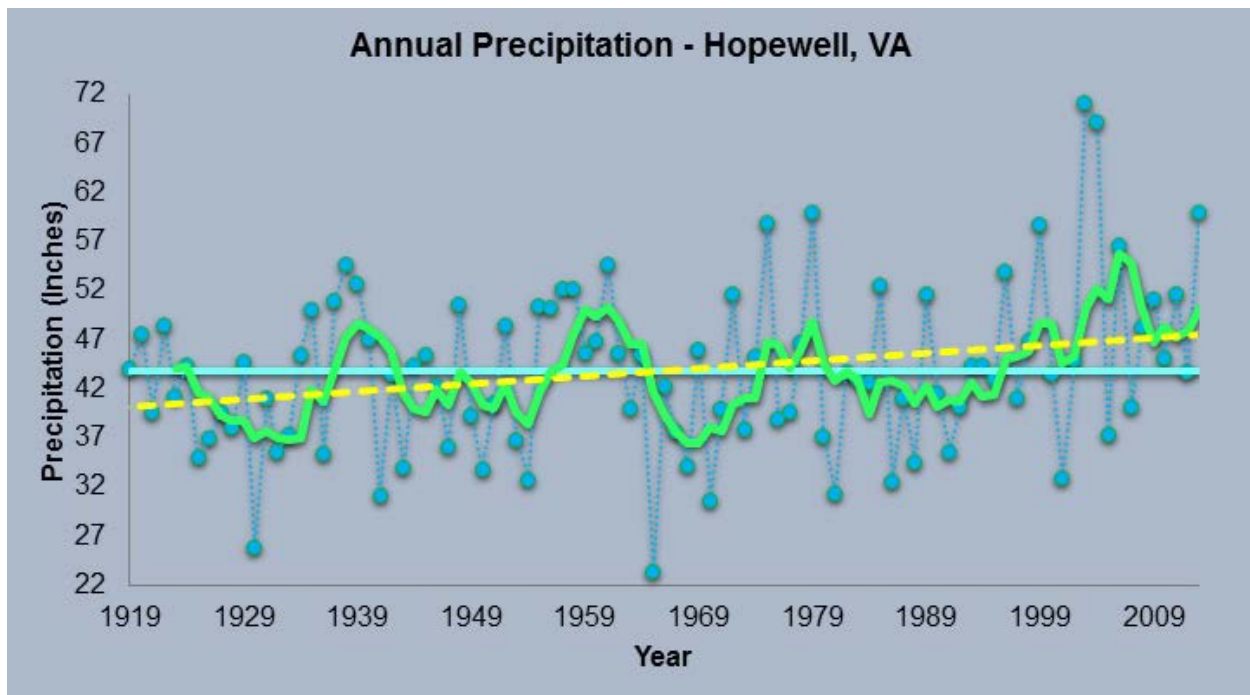
Annual Number of Days with Minimums at or below Freezing: The trend does show a decrease with about 15 fewer nights below freezing now compared to 80 years ago at both stations. The average number of nights is 70 ($\pm 1\text{SD}$ ranges from 56-84) at Hopewell and 83 ($\pm 1\text{SD}$ ranges from 70-96) at Richmond (Table 2).



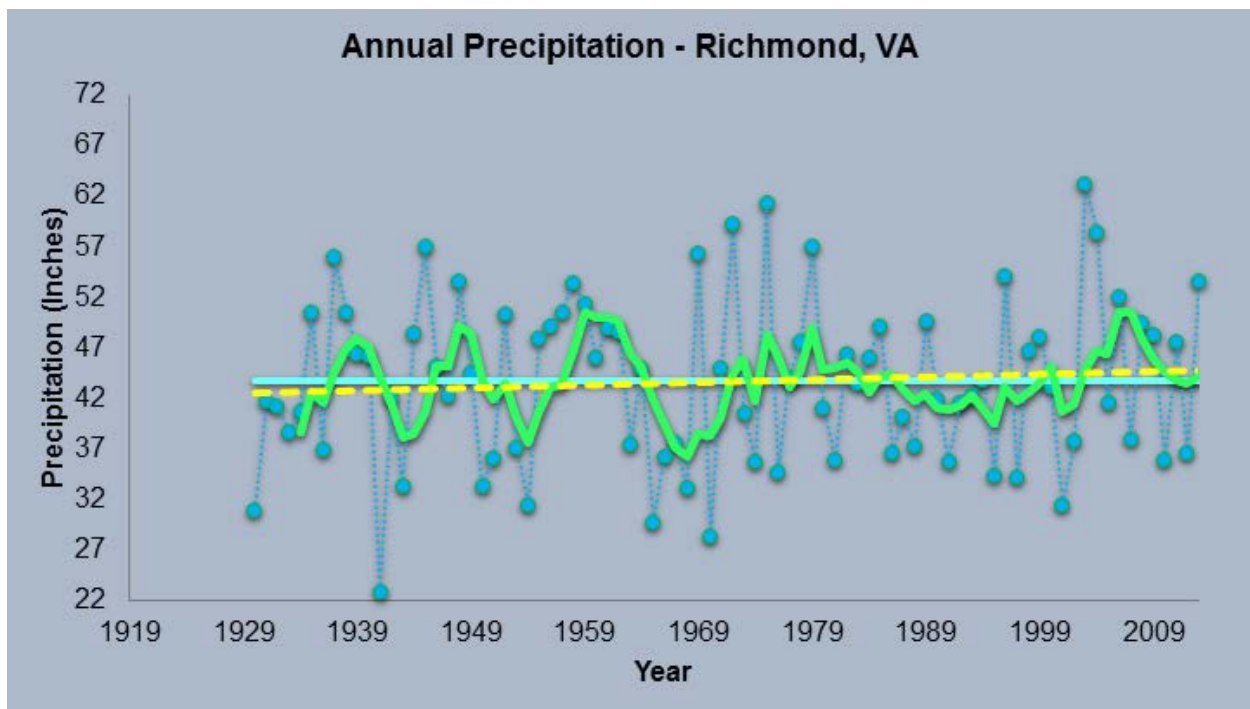


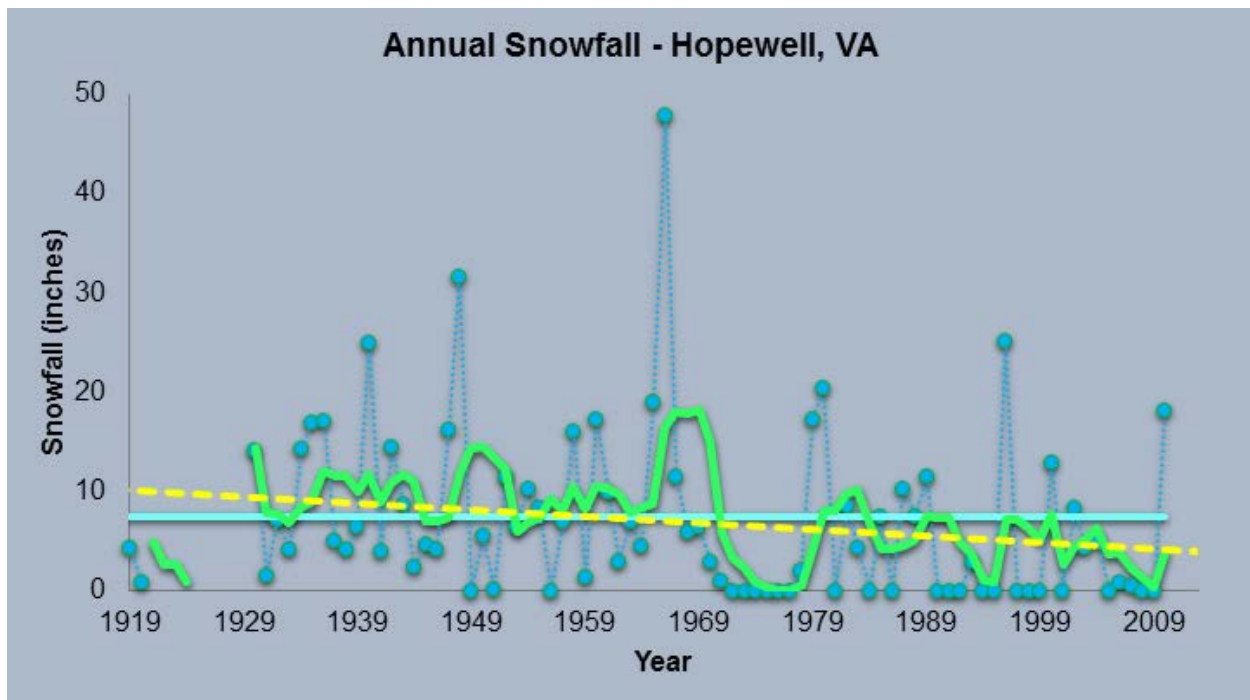
Growing Season Length Trends: Both stations show an increase in the length of the growing season with about a month increase in the past 80 years. The average annual number of days in the growing season is 206 ($\pm 1SD$ ranges from 185-226) at Hopewell and 203 ($\pm 1SD$ ranges from 185-221) at Richmond (Table 2).



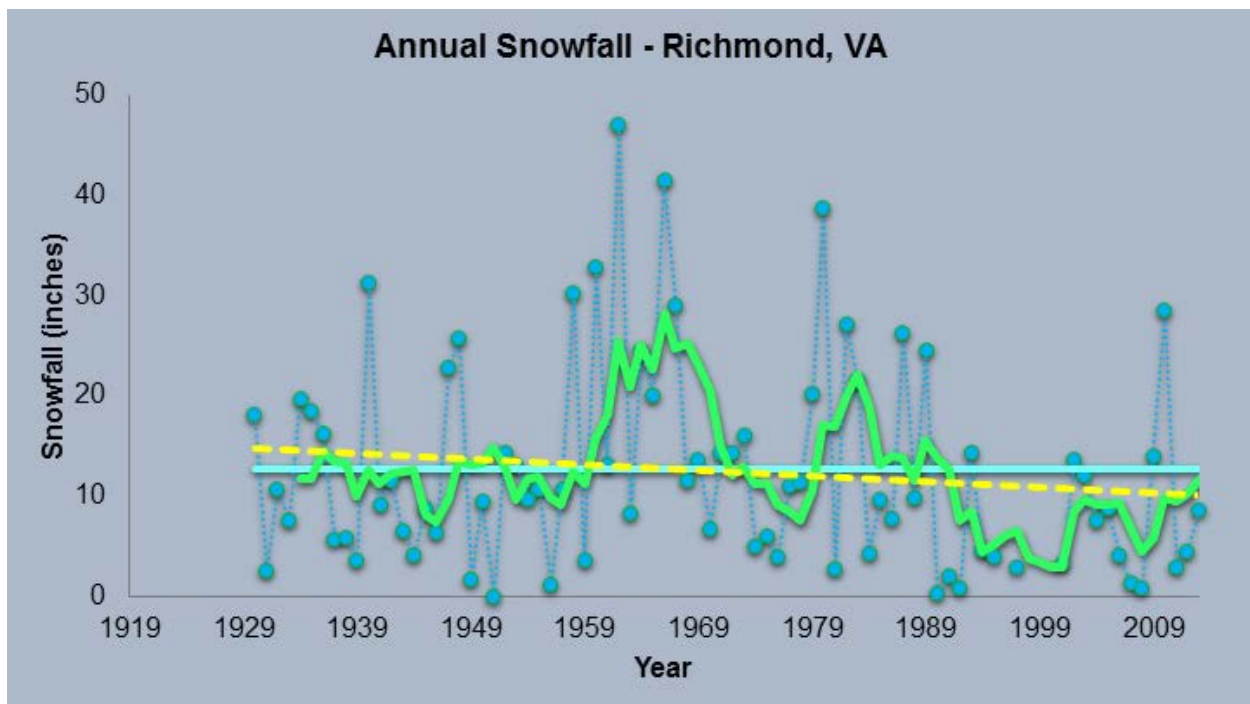


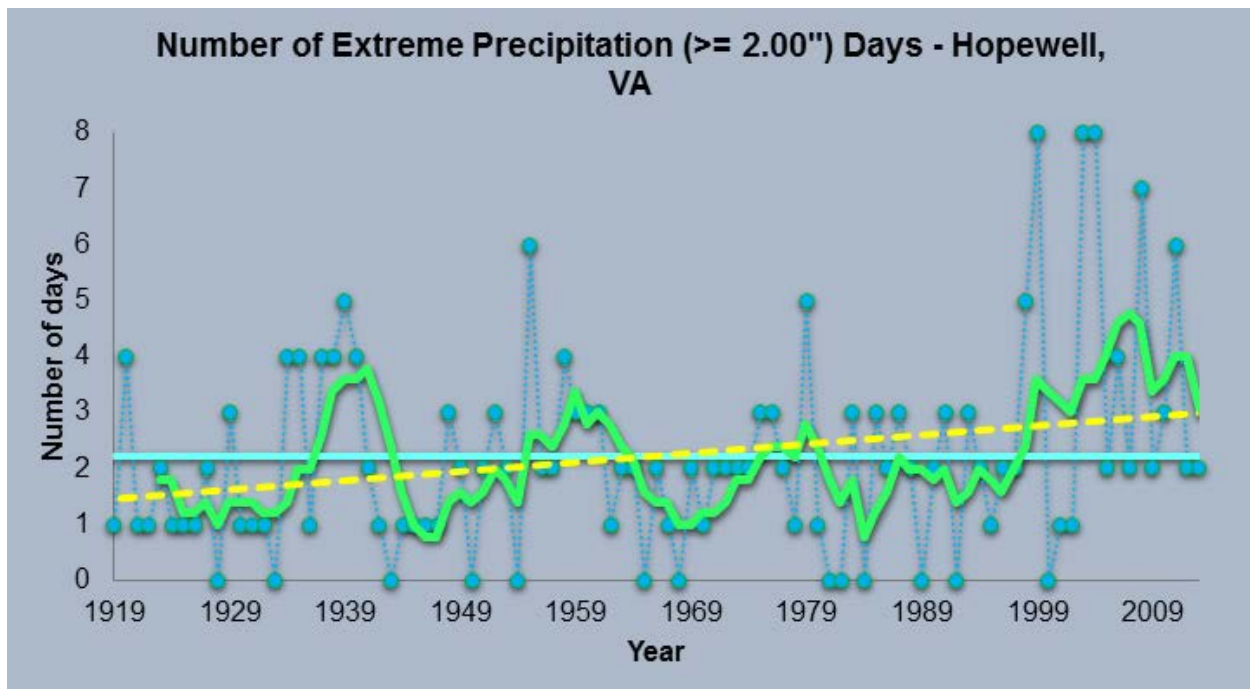
Annual Precipitation Trends: Hopewell shows a modest rise (approx. 6 in. over the past ~100 years) in annual precipitation, whereas Richmond displays only a slight rise. The average annual precipitation at Hopewell is 43.9 in. (min of 23.4 in and max of 71.2 in) and 43.7 in (min of 22.9 in and max of 63.3 in) at Richmond (Table 6).



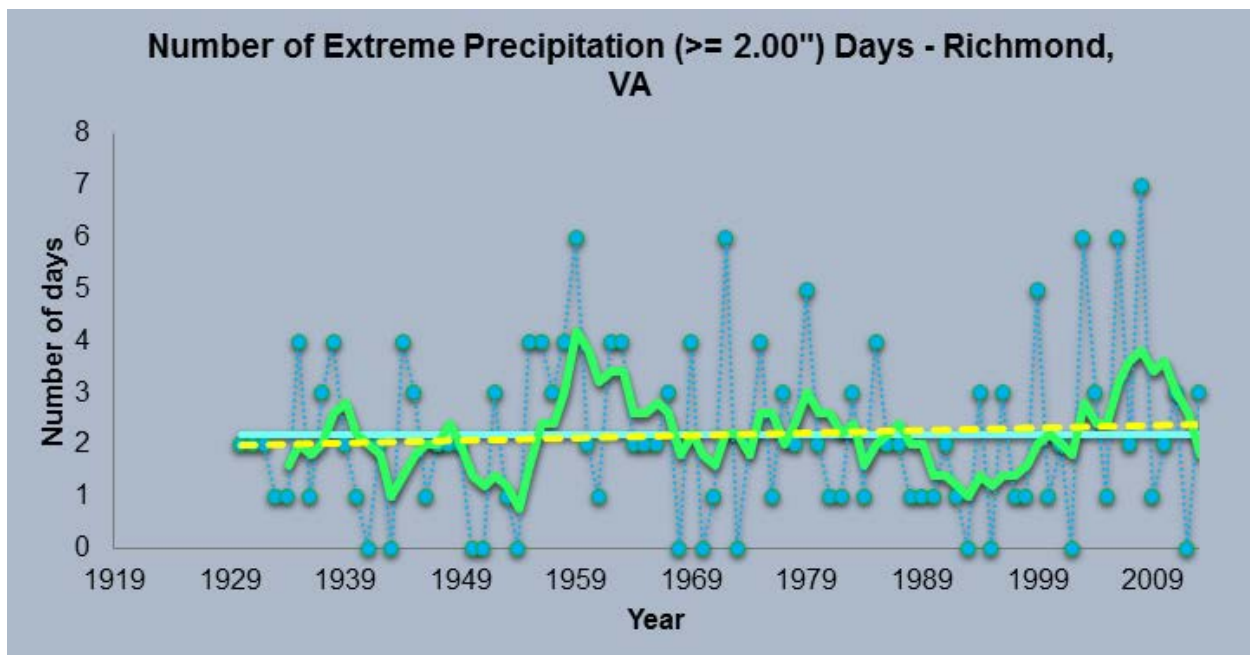


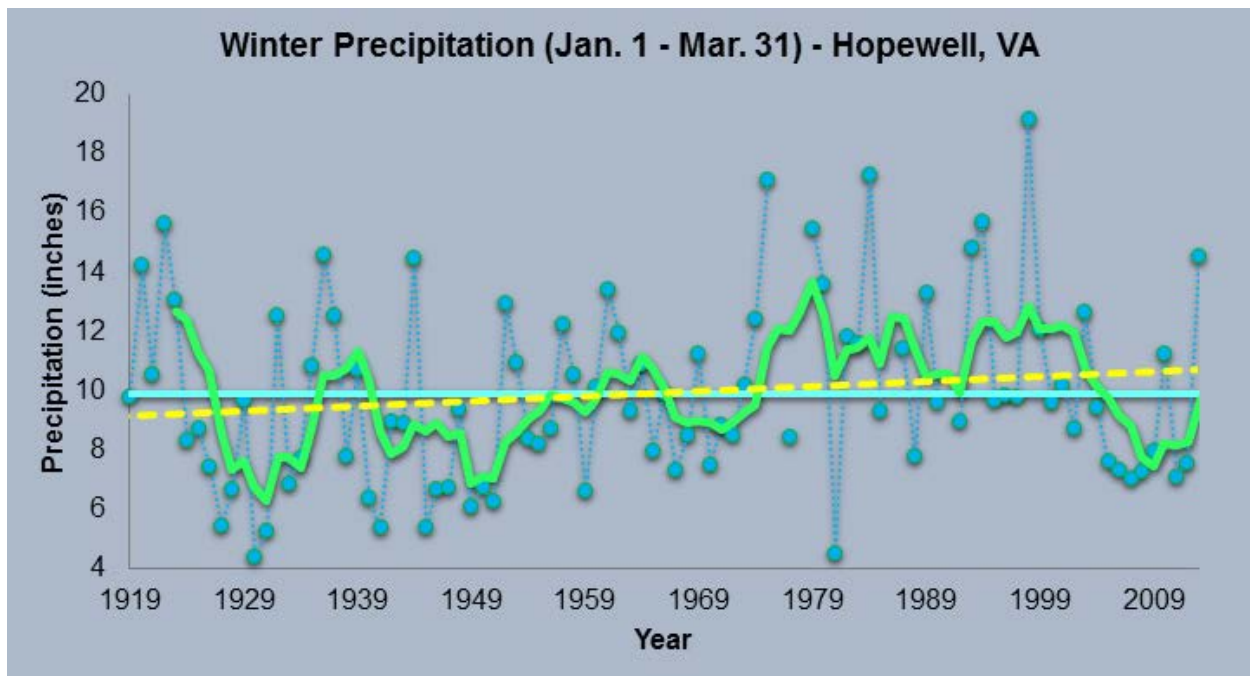
Annual Snowfall Trends: Both stations display a decrease in annual snowfall, approximately a 30% decline. The average annual snowfall amount at Hopewell is 7.3 in. (min of 0 in and max of 48.0 in) and 12.7 in (min of trace and max of 47.0 in) at Richmond (Table 6).



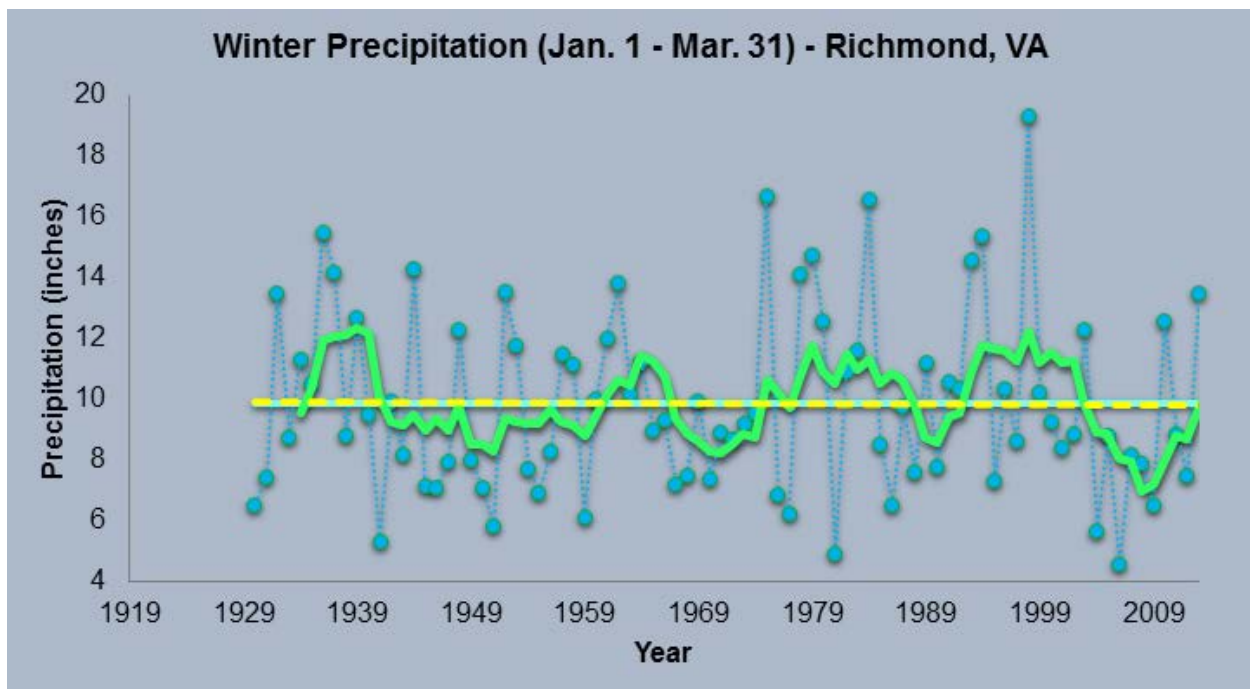


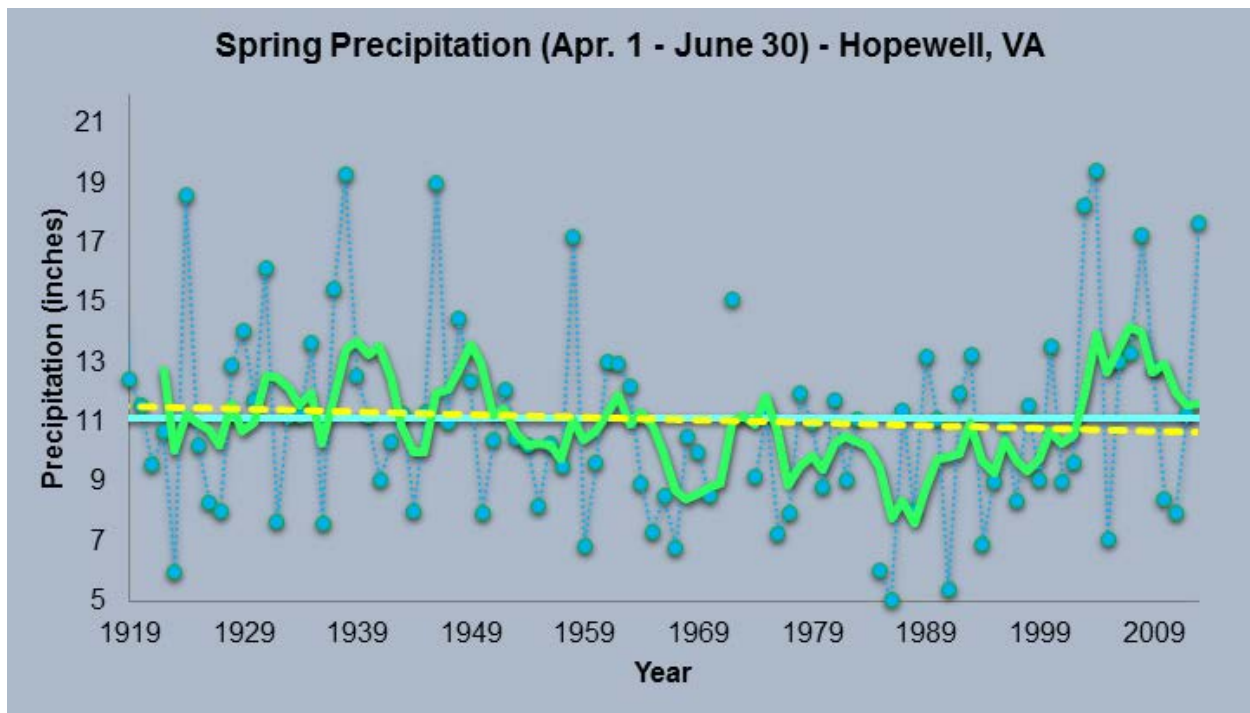
Annual Number of Extreme Precipitation Events: Hopewell displays an upward trend (about a day and half over the past ~100 years) in extreme precipitation days, whereas Richmond shows virtually no trend.. The average number of days at Hopewell is 2 (min of 0 and max of 8) and is also 2 (min of 0 and max of 7) at Richmond (Table 6).



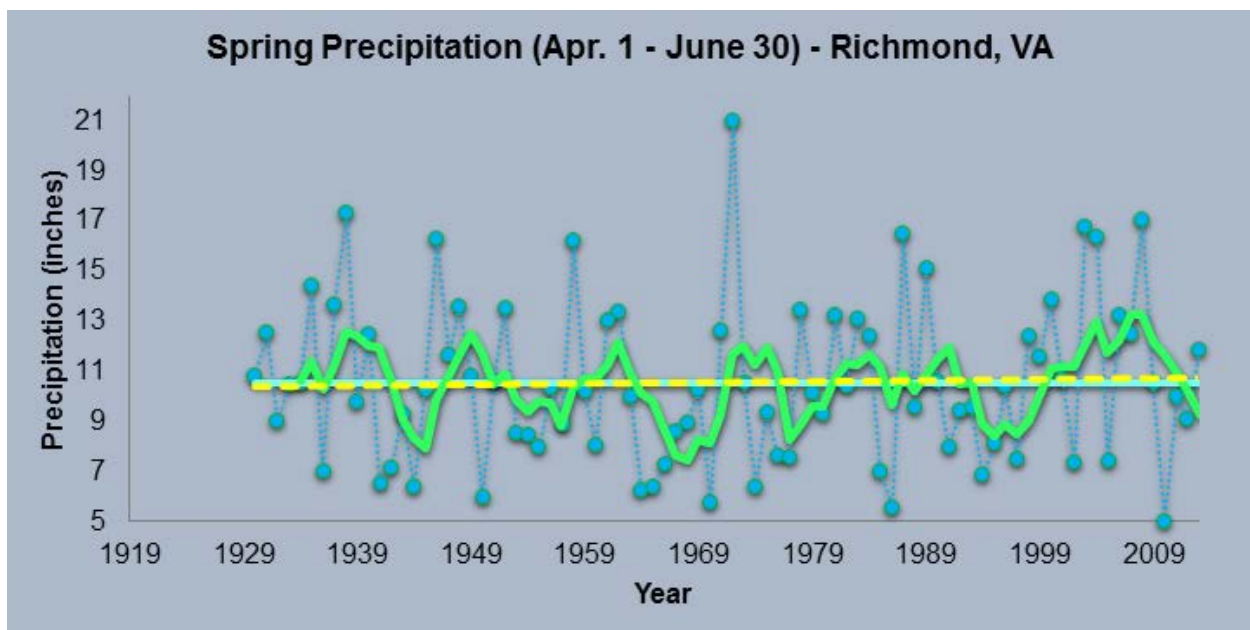


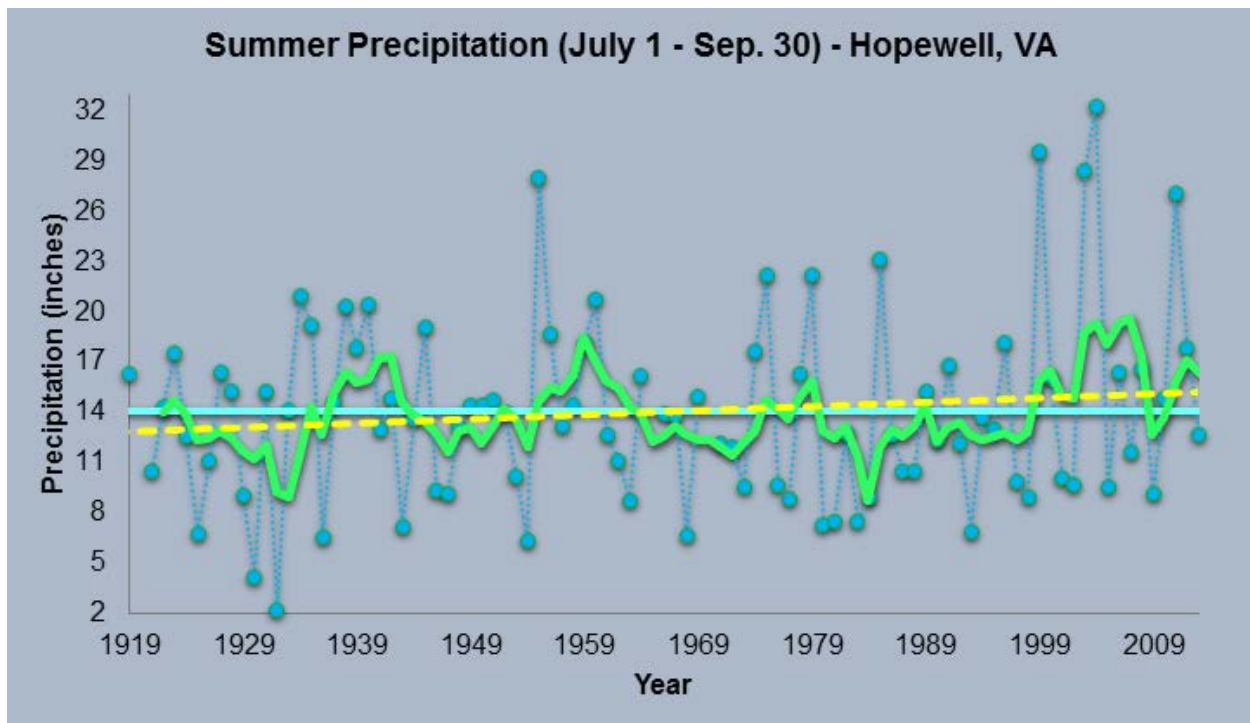
Winter Precipitation Trends: Hopewell shows a slight increase (about 1 in over the past 100 years), whereas Richmond displays no trend in winter precipitation. Hopewell's winter precipitation has ranged between 4.4 in to as much as 19.2 in over its period of record while Richmond has ranged from 4.6 in to 19.3 in.



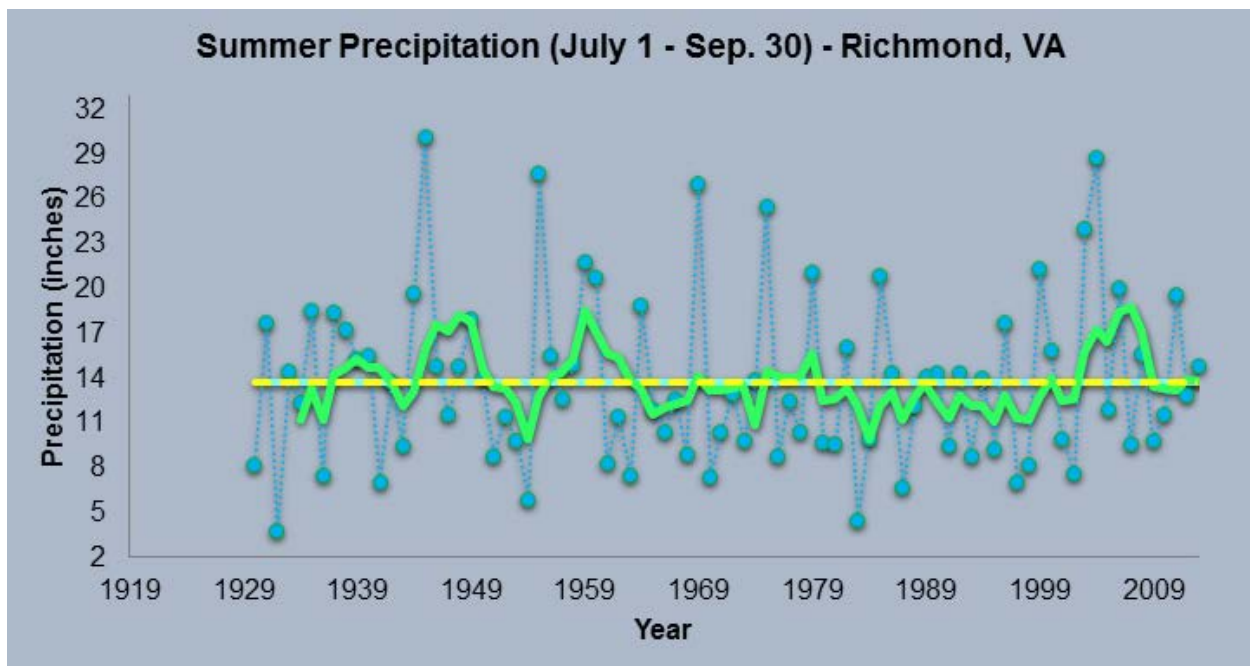


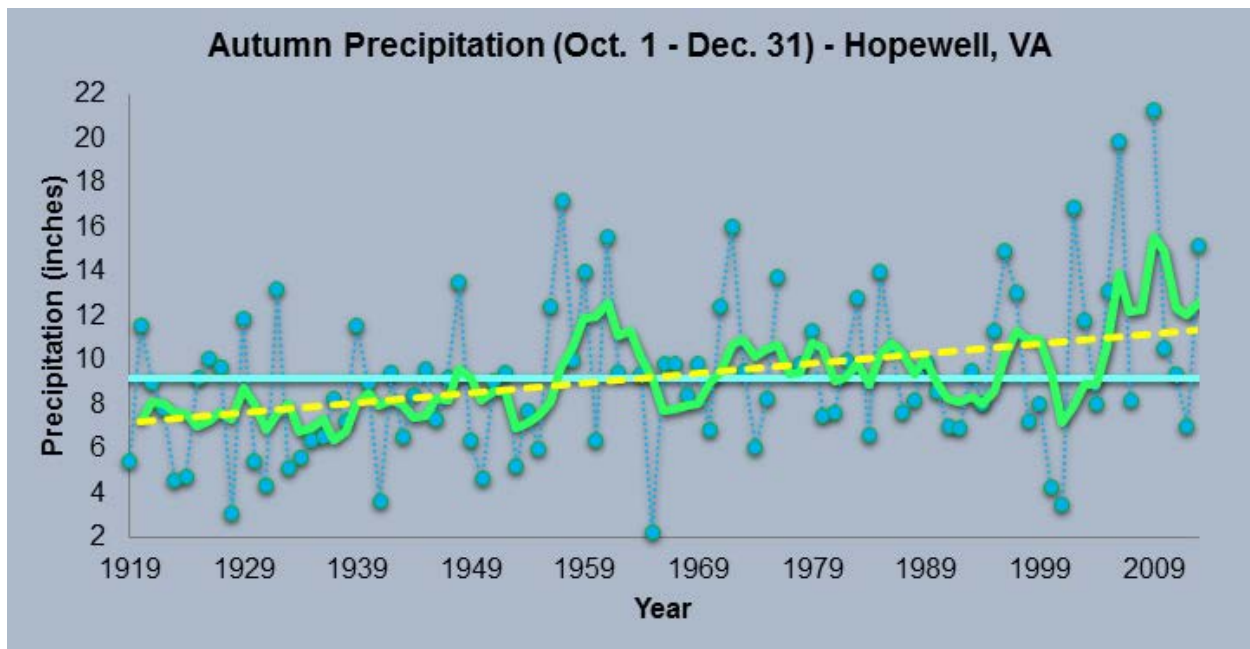
Spring Precipitation Trends: Hopewell shows a slight decrease (approx. 1 in over the past ~100 years), whereas Richmond displays no trend in spring precipitation. Hopewell has seen as much as 19.5 in and as little as 5.0 in during the spring while Richmond has seen between 5.6 and 21.0 in.



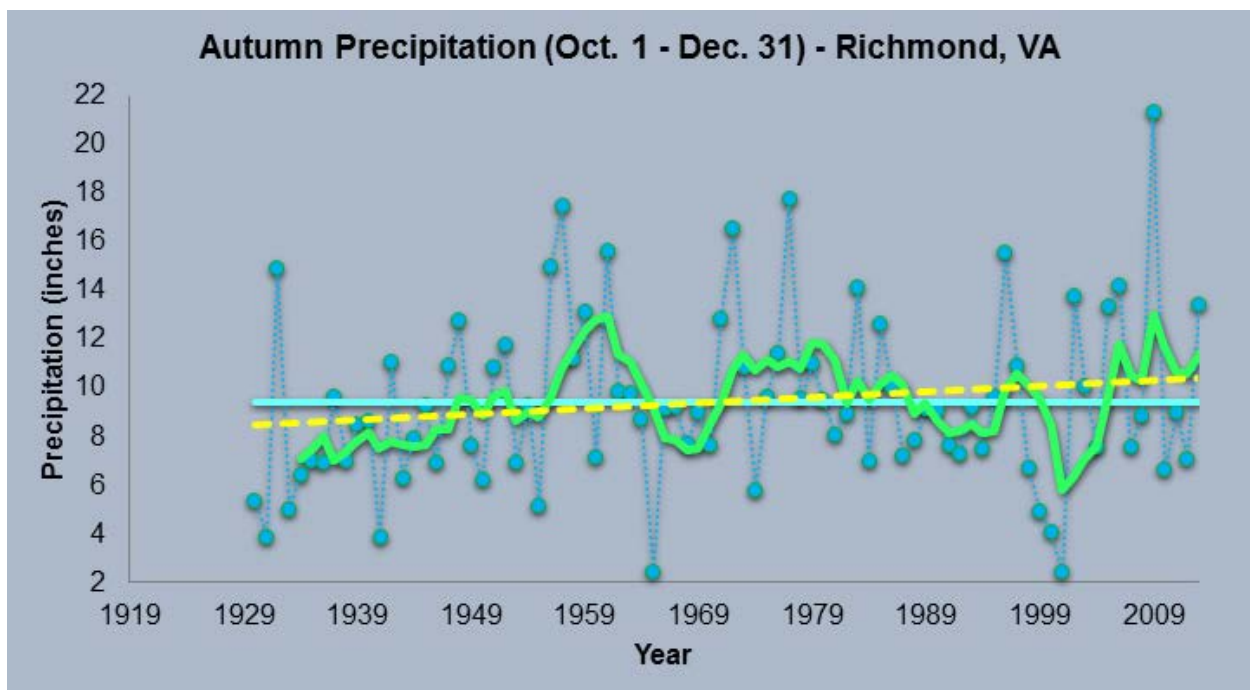


Summer Precipitation Trends: A small increase in summer precipitation is noted at Hopewell (about 2 in in ~100 years), but no trend exists in summer precipitation at Richmond . Hopewell’s summer precipitation has ranged between 2.2 to 32.3 in. while Richmond has seen a minimum of 3.8 in to a maximum of 30.3 in.





Autumn Precipitation Trends: Both stations show an increase in autumn precipitation with Hopewell demonstrating a more rapid rise (approx. 4.5 in over the past 100 years). The average sum of precipitation during the autumn is 9.2 in (min of 2.2 and max of 21.3 in) at Hopewell compared to an average of 9.4 in (min of 2.5 and max of 21.4 in) at Richmond.



The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 325/131143, 367/131143, January 2016

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