Examining Precipitation Across the Garden State From 1900 to 2020

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Executive Summary

This study provides a comprehensive overview of precipitation within New Jersey from 1900 to 2020. An examination of statewide and regional means and trends is based on daily observations from National Weather Service Cooperative Stations. In addition to presenting several "traditional" means of evaluating precipitation, such as annual and seasonal values and variability, some rather unique approaches to delve into the state's precipitation climatology are explored. This assessment is aimed widely, hoping that those within the agency will find information to assist them in their water-related monitoring and regulatory roles. A more complete understanding of the means and extremes of New Jersey precipitation will permit better-informed decisions to be made with regard to planning and responses to flooding, including flash and riverine events. It will also prove valuable to drought monitoring and associated water management. Finally, knowing how precipitation has been distributed over the past up to the present provides a valuable baseline when evaluating observed and projected precipitation patterns in upcoming years and decades.

Study results highlight the spatiotemporal complexity of precipitation patterns in New Jersey over the past 12 decades. Some findings are statewide in nature while others are more focused within the six NJDEP drought regions in which station data were examined. Some show changes over the full period of record, while others focus on more recent decades. Among the more interesting findings are the following:

1) During the 1900-2020 interval, NJ annual precipitation trended upwards at about a 7% per century pace. This is adding the equivalent of more than a February's normal amount of precipitation to the annual total. Over this period, increases in spring and fall totals have led the way.
2) Significant increases in annual precipitation over the study period were observed in the four northernmost drought regions. The southwest, coastal south, and northeast regions experienced significant decreases in the percent of precipitation contributed by daily precipitation events less than 1.00 inch. The coastal south region had a significant increase in the percent of annual precipitation received in events of 1.00"-2.00", while the northwest had a significant increase in events exceeding 2.00".
3) Throughout the study period, trends examined in 30-year increments have risen and fallen, often in unison among regions or at least regions not showing opposite tendencies. The most notable exception to this in the last half century being the lack of a 1970s increase in the coastal south region, when all other regions had increased precipitation.
4) Rain (or the melted equivalent of snow) of 0.10" or more falls on average between once and twice per week throughout the year. Record low annual counts of days with 0.10" or more at key study stations range from 51-63 days and high counts from 92-120 days. There is some suggestion that counts above the four study thresholds of 0.10", 0.50", 1.00", and 2.00" have increased in recent decades but interannual variations dominate over the study period. This also holds for the distribution of precipitation totals on days when measurable precipitation is observed.
5) Since 1950, NJ precipitation has increased in all seasons. Unlike for the 1900-2020 interval, the increase has been led by summer. Increased interannual variability has accompanied these trends, particularly in summer and fall. The two record wet years

going back to 1900 occurred in 2011 and 2018. The mid-1960s drought was particularly evident in summer totals and least seen in winter.

6) Looking closer to present, a comparison of the 1981-2010 and recent 1991-2020 normals finds that NJ has gotten wetter statewide. The coast leads the way, followed rather closely by the south. Meanwhile, the north barely got wetter.
7) In recent decades, much as seen over the full 120-year record, there is no clear pattern in the distribution of precipitation by daily amounts across the six drought regions. Heavier daily totals are contributing more within the northwest and central regions, while the southwest shows the opposite. There are no signs of a recent change in precipitation distribution in the other three regions.
8) Over the past two decades, a more rapid pace toward accumulating multi-month precipitation totals of 10.00" and 20.00" has been observed in the warm half of the year compared to the last half of the 20th century.

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Introduction

New Jersey's middle latitude position on the eastern coast of a continent leaves it exposed to a wide variety of weather and climate extremes during each of four well-defined seasons. This includes heat and cold, snow and ice, and considerable variability in precipitation. The latter, be it in abundance or by its absence, is the focus of this report. A more complete understanding of the means and extremes of New Jersey precipitation will permit better-informed decisions to be made with regard to planning and responses to flooding, including flash and riverine events. It will also prove valuable to drought monitoring and associated water management. Knowing how precipitation has been distributed over the past and at present provides a valuable baseline when evaluating projected precipitation patterns in the years and decades ahead.

The Office of the New Jersey State Climatologist (ONJSC) has been tasked with providing such a precipitation overview to the New Jersey Department of Environmental Protection (NJDEP). In addition to presenting several "traditional" means of examining precipitation, such as annual and seasonal values and variability throughout the 20th century to present using rankings and regressions, some rather unique approaches to evaluating the state's precipitation climatology are explored, for instance employing Gini coefficients and Lorenz curves. This assessment is aimed widely, hoping that those within the agency will find information to assist them in their water-related monitoring and regulatory roles.

National Weather Service (NWS) Cooperative Observing Station (Coop) records serve as the source of information for this study, with attention paid to individual station observations for the periods of 1900-2019,1950-2019, 1980-1999, and 2000-2019. Statewide assessments from 1900-2020 and 1950-2020 are also presented. The bulk of the analyses were conducted prior to 2020 data being fully available. Thus, most of the study only goes through 2019. However, as the report was being finalized, statewide data through 2020 were available through NOAA's Climate at a Glance (NCEI, no date) and used in one section of the report.

This report is divided into multiple sections, beginning with a discussion of the data employed in the study, moving onto analytic methods employed, a long results section, brief concluding remarks, a list of contributors to the report, references, and appendices.

Data

Aside from statewide assessments to be presented, for the majority of this study, New Jersey is divided into the six NJDEP drought regions (figure 1) (Hoffman, 2001; NJGIN, no date). Within each region, suitable primary Coop stations were identified with the greatest longevity and quality of daily precipitation observations extending back to 1900 (Tier 1) or 1950 (Tier 2) through 2019. For five of the 40 stations used to generate complete data coverage (Appendix A) it was necessary to move just outside of a region to find a representative station with sufficient coverage. Most primary stations have over 80% daily coverage from 1900-2019. All Tier one stations had 88% or greater coverage when one additional station was used to thread with the main station to fill in data gaps. The term "thread" is used to explain how data from multiple stations is used to generate a temporally complete data record when no single station has a complete record covering the time period being studied. The New Brunswick station is an outlier in that the two main stations utilized are actually one, this the result of an unfortunate station identification number change at the national center when a minor station relocation occurred (that after ten years relocated back to the original location, keeping the new station ID). It took no more than two threaded substitutes to bring data completeness to better than 99% at all but two of the eleven Tier 1 and 2 study stations, the Coastal North Tier 1 station being the most challenging.

All station observations were quality controlled at the National Centers for Environmental Information (NCEI) (Durre et al, 2010), with study data accessed via the Applied Climate Information System database that is maintained by the Northeast Regional Climate Center.

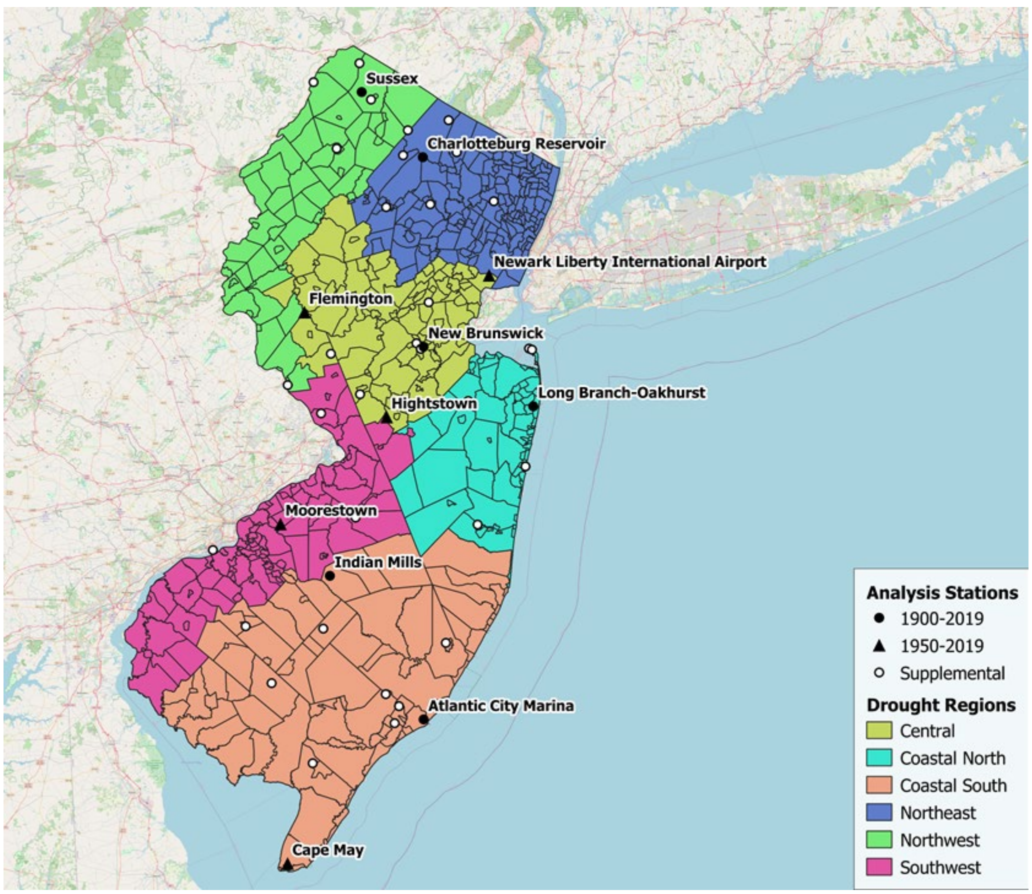


Figure 1. *Stations used for this analysis situated in six NJDEP drought regions. Filled circles identify Long-Term (Tier 1:1900-2019) stations and triangles Short-Term (Tier 2: 1950-2019) Open circles identify supplemental stations used to fill missing data in either Tier 1 or 2 stations. New Brunswick is the only station that is classified as Tier 1 or 2 and used as a supplemental station.*

***Table 1**. NWS Coop stations representing the six study regions. Long-term (Tier 1) stations are listed first for each region, with shorter term (Tier 2) stations listed next. There was no suitable tier two station for the Coastal North. The primary station is listed first in each row, with the average percent of coverage in parentheses. Given that each station except Newark Liberty had incomplete coverage, the primary threaded station used to fill in gaps in the primary station is listed as "threaded station #1". A full listing of threaded stations and percentages is found in Appendix A.*

Region	Station	Date-Range	Threaded Station #1
Northwest 1	Sussex 3 WNW (88%)	1900-2019	Newton (10%)
Northwest 2	Flemington (98%)	1950-2019	Wertsville (2%)
Northeast 1	Charlotteburg Reservoir (53%)	1900-2019	Oak Ridge Reservoir (41%)
Northeast 2	Newark Liberty (100%)	1950-2019	
Central 1	New Brunswick 3 SE (53%)	1900-2019	New Brunswick Experimental (43%)
Central 2	Hightstown (99%)	1950-2019	Princeton Water Works (<1%)
Coastal North 1	Long Branch-Oakhurst (84%)	1900-2019	Sandy Hook (4%)
Southwest 1	Indian Mills (98%)	1900-2019	Pemberton (<1%)
Southwest 2	Moorestown (87%)	1950-2019	Philadelphia Airport (13%)
Coastal South 1	Atlantic City Marina (99%)	1900-2019	Atlantic City (1%)
Coastal South 2	Cape May (99%)	1950-2019	Belleplain State Forest (1%)

Methodology

A variety of approaches are used to depict New Jersey precipitation climatology and its variability since 1900. Ranging from common rankings and regressions to the more innovative, such as Gini coefficients and Lorenz curves, the methods employed are aimed to provide information for those seeking insights into the distribution of precipitation across the state and, in particular, how conditions have varied over time. Significance testing utilizes Kendall-Tau and p-values. The Kendall's Tau-B correlation method is used to analyze time series trends of ordinal data. The results of this test vary on a scale of -1 to +1. Values close to +1 indicate strong agreement between two values, while values close to -1 indicate strong disagreement.

Another output of the test is a p-value. This is a two-sided p-value for a hypothesis test whose null hypothesis is an absence of association, tau=0. This method is calculated using the Python library SciPy (https://docs.scipy.org/doc/scipy/reference/generated/scipy.stats.kendalltau.html).

Less familiar to analyses of precipitation are Gini coefficients and Lorenz curves, thus a somewhat detailed description follows. The Gini coefficient is a metric used to describe how evenly a variable is distributed. The Gini coefficient became popularized in economics, where it is commonly used to describe distribution of wealth among a population. To calculate the Gini coefficient of wealth inequality, as is common in economics, each member of a population is ranked by wealth. Then, cumulative wealth is calculated, from the sample with the least wealth to the sample with the most wealth. This information is plotted on a grid system such that the X-axis shows the ranked population from the sample with the least wealth to the sample with the most wealth, and the Y-axis shows the percent of total wealth provided by each person, cumulatively. The resulting curve is called the Lorenz curve. If every person in the sample has the same amount of wealth, the Lorenz curve is a 1:1 line. If some people in the sample have more wealth than others, there is a difference between the 1:1 line and the Lorenz curve. The area between the Lorenz Curve and the 1:1 line represents the Gini coefficient. A Gini coefficient of 0 represents a sample in which wealth is evenly distributed (perfect equality); a Gini coefficient of 1 indicates a sample in which one person has all the wealth and the rest of the sample has none (perfect inequality).

Recent studies have applied the Gini coefficient and Lorenz curves to describe precipitation distributions (Bombardi et al., 2020, Teale and Robinson, 2020). Here, this method is applied to describe the proportion of annual precipitation that is delivered in daily precipitation events (for examples, see figures 25 and 32). Each precipitation day is ordered by precipitation depth, and cumulative precipitation is then calculated from the driest to the wettest day. If every precipitation day delivers the same amount of precipitation, the Lorenz curve is a 1:1 line and the Gini Coefficient is 0. If a large proportion of the annual precipitation is delivered in a relatively small number of large events, the Gini coefficient approaches 1. Inspection of the Lorenz curves reveals the relative contribution from each part of the precipitation distribution. For instance, analysis of the Lorenz curve indicates the proportion of annual precipitation delivered in the smallest events, or the proportion of annual precipitation delivered in the heaviest percentile of precipitation days.

In this report, the Gini coefficient is calculated annually for the six Tier 1 stations across NJ from 1900-2019. This depicts how precipitation is distributed within each year for the last 120 years, as well as how intra-annual precipitation distribution varies across NJ. Lorenz curves are calculated for each year 1900-2019, for the same six stations. These curves are plotted chronologically from 1900-2019, with color indicating the year. This figure allows within-year precipitation distributions from recent years to be compared to those of earlier years.

The 25th and 75th percentiles of annual Lorenz curves are calculated for multiple time periods: 1950-1999, 1980-1999, and 2000-2019. The 20th century time periods are each plotted with the 21st century time period to show if the curves overlap, or if major shifts in intra-annual precipitation distribution occurred between the time periods. This is calculated and analyzed for NJ as a whole, and for the six Tier 1 stations located across NJ.

Study Results

The study results are divided into five sections.

1) New Jersey-wide precipitation (1900-2020)
   - An assessment of New Jersey precipitation covering the 1900-2020 period. This includes statewide annual and seasonal figures and tables.
2) Regional Precipitation (1900-2019)
   - An assessment of precipitation within each of the six drought regions from 1900-2019 using Tier 1 station observations. Annual analyses are shown graphically for:
     a) Annual precipitation totals
     b) Number of days of precipitation above prescribed amounts
     c) Percentage of days with rain above thresholds
     d) Percentage of annual precipitation from < 1”, 1” to 2”, and >2” events and Gini coefficients
     e) Lorenz curves for annual precipitation
3) New Jersey-wide precipitation (1950-2020)
   - An assessment of New Jersey precipitation covering the 1950-2020 period. This includes statewide annual and seasonal figures and tables
4) Regional precipitation (1950-2019)
   - An evaluation of precipitation in the six drought regions from 1950-2020 much like for section two and including pairing a Tier 2 station with a Tier 1 site in five of the six regions.
5) Comparison of climate normals: 1981-2010 vs 1991-2020
   - A comparison of the newly released 1991-2020 normals for New Jersey precipitation with the recently retired 1981-2010 normals.

1) New Jersey-wide precipitation (1900-2020)

Statewide annual and seasonal totals from 1900 through 2020 are based on an interpolated analysis of dozens of stations from within NJ and from border regions of adjacent states (Vose et al., 2018). Station numbers have varied over time but in New Jersey are typically close to three dozen. An inverse distance squared interpolation method onto a 5 km square grid is used to ensure that there are no regional biases due to the uneven distribution of observing stations states (Vose et al., 2018).

New Jersey annual precipitation averaged 45.56” over the 121-year study period (Figure 2). It ranged from a maximum of 67.76” in 2018 to 29.27” in 1965 (Table 2). A linear regression covering the entire interval shows a significant increase of precipitation of 3.27” or approximately 7% per century (r= 0.1844, p=0.043). Four of the ten wettest years fall within the past 30 years and one of the ten driest occurred during this period. One of the ten wettest was found in the first half of the 20th century, with five of the ten driest occurring during this interval.

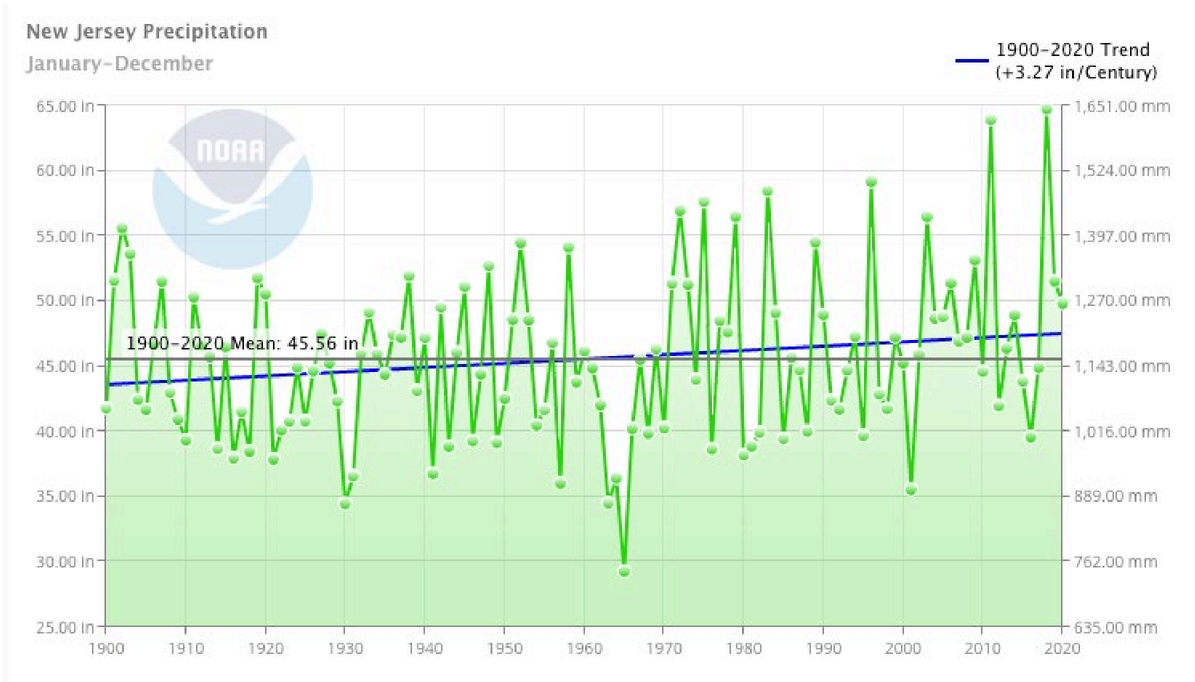


Figure 2. *New Jersey annual precipitation from 1900-2020 and a linear regression for the period of record (blue line). The trend per century is shown in the top right. Data and graph from Climate at a Glance (NCEI).*

***Table 2**. Ten wettest (left) and ten driest (right) years observed in New Jersey from 1900-2020.*

Rank	Precip.	Year
1	67.76	2018
2	63.95	2011
3	59.18	1996
4	58.50	1983
5	57.66	1975
6	56.95	1972
7	56.49	1979
8	56.48	2003
9	55.64	1902
10	54.54	1989

Rank	Precip.	Year
1	29.27	1965
2	34.48	1930
3	34.53	1963
4	35.55	2001
5	36.04	1957
6	36.43	1964
7	36.60	1931
8	36.79	1941
9	37.88	1921
10	37.96	1916

Precipitation is quite evenly distributed throughout the year, the 1900-2020 mean ranging from 10.29” in winter (December-February) to 13.09” in summer (June-August). Figures 3 to 6 show times series of seasonal precipitation and tables 3 to 6 show top 5 maximum and minimum totals for each season. Over the 121-year study period, winter exhibits very little change in precipitation, declining 0.13” per century. There has not been a top 5 seasonal total since the winter of 1978/1979, while the last top 5 driest winter was in 2000/2001. Spring (March-May) precipitation has trended upwards at 1.17” per century, with no top 5 totals since 1984 and no bottom 5 since 1965. Much like winter, summer showed little change, edging up 0.22” per century. Despite this, three of the five wettest summers have occurred since 2009, while the last bottom five total was in 1966. Even more so than the spring transition season, fall exhibits a significant increase in precipitation over the study period (r=0.2121, p=0.019). The upward trend of 2.02" per century represents an approximate 20% increase. Three of the five wettest falls have occurred since 2005, with the last bottom five total in 2001 and before that in 1941.

To sum up, NJ annual precipitation is trending upwards at about a 7% increase per century, the 3.27" trend total exceeding that of average February precipitation. Essentially all of the increase is due to increases in the fall and spring transition seasons.

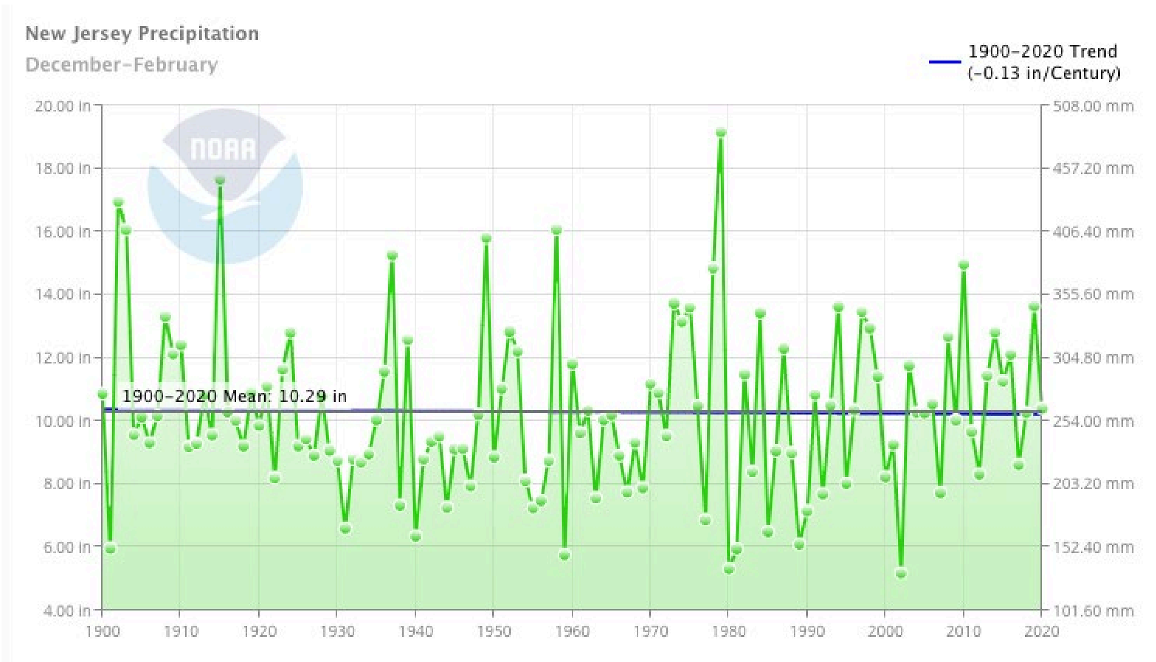


Figure 3. *New Jersey winter (Dec-Feb) precipitation from 1899/1900-2019/20 and a linear regression for the period of record (blue line). See figure 2 for more information.*

Table 3. *Five wettest (left) and five driest (right) winters observed in New Jersey from 1899/1900-2019/20.*

Rank	Precip.	Year
1	19.17	1978/79
2	17.66	1914/15
3	16.96	1901/02
4	16.08	1957/58
5	16.07	1902/03

Rank	Precip.	Year
1	5.18	2001/02
2	5.32	1979/80
3	5.76	1958/59
4	5.95	1980/81
5	5.97	1900/01

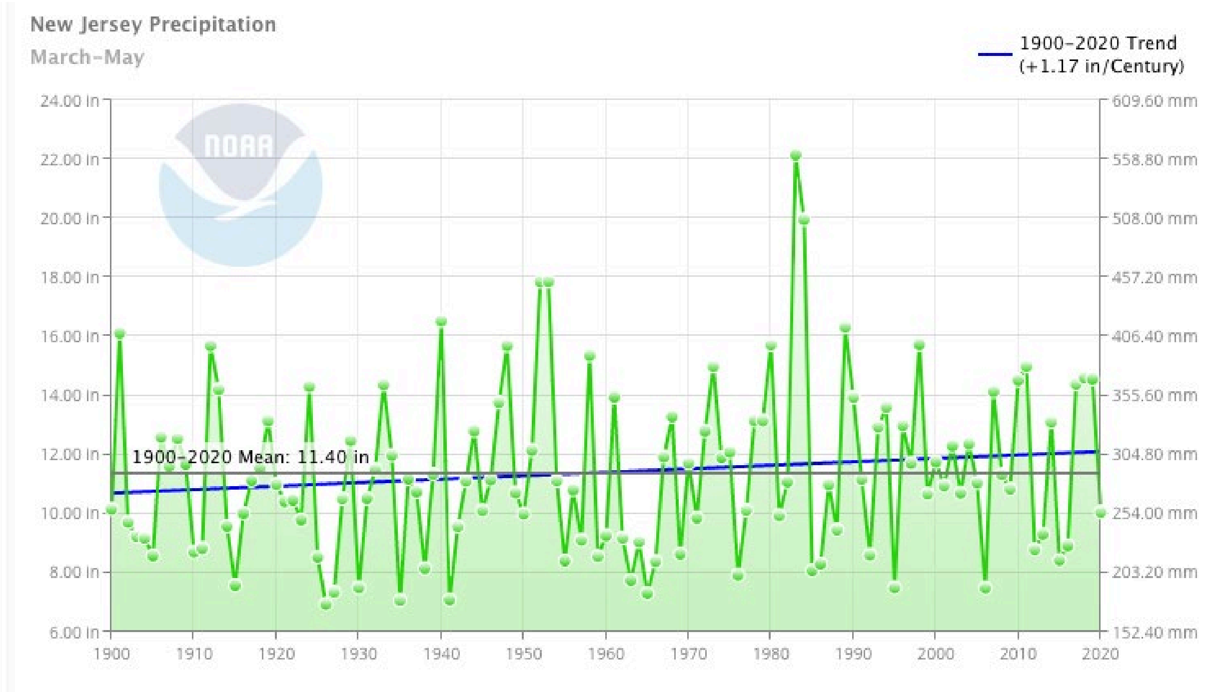


Figure 4. *New Jersey spring (Mar-May) precipitation from 1900-2020 and a linear regression for the period of record (blue line). See figure 2 for more information.*

Table 4. *Five wettest (left) and five driest (right) springs observed in New Jersey from 1900-2020*

Rank	Precip.	Year
1	22.15	1983
2	19.96	1984
3	17.87	1953
4	17.86	1952
5	16.53	1940

Rank	Precip.	Year
1	6.94	1926
2	7.07	1935
3	7.09	1941
4	7.31	1965
5	7.35	1927

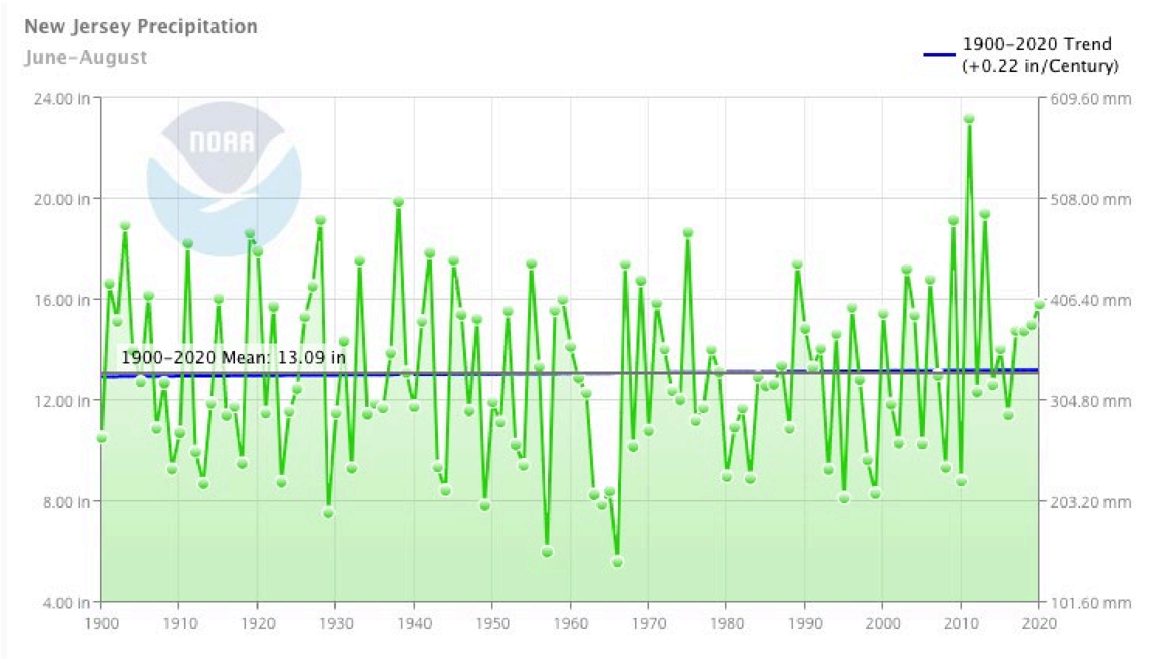


Figure 5. *New Jersey summer (Jun-Aug) precipitation from 1900-2020 and a linear regression for the period of record (blue line). See figure 2 for more information.*

Table 5. *Five wettest (left) and five driest (right) summers observed in New Jersey from 1900-2020.*

Rank	Precip.	Year
1	23.21	2011
2	19.91	1938
3	19.43	2013
4	19.19	1928
5	19.18	2009

Rank	Precip.	Year
1	5.61	1966
2	6.01	1957
3	7.56	1929
4	7.86	1949
5	7.89	1964

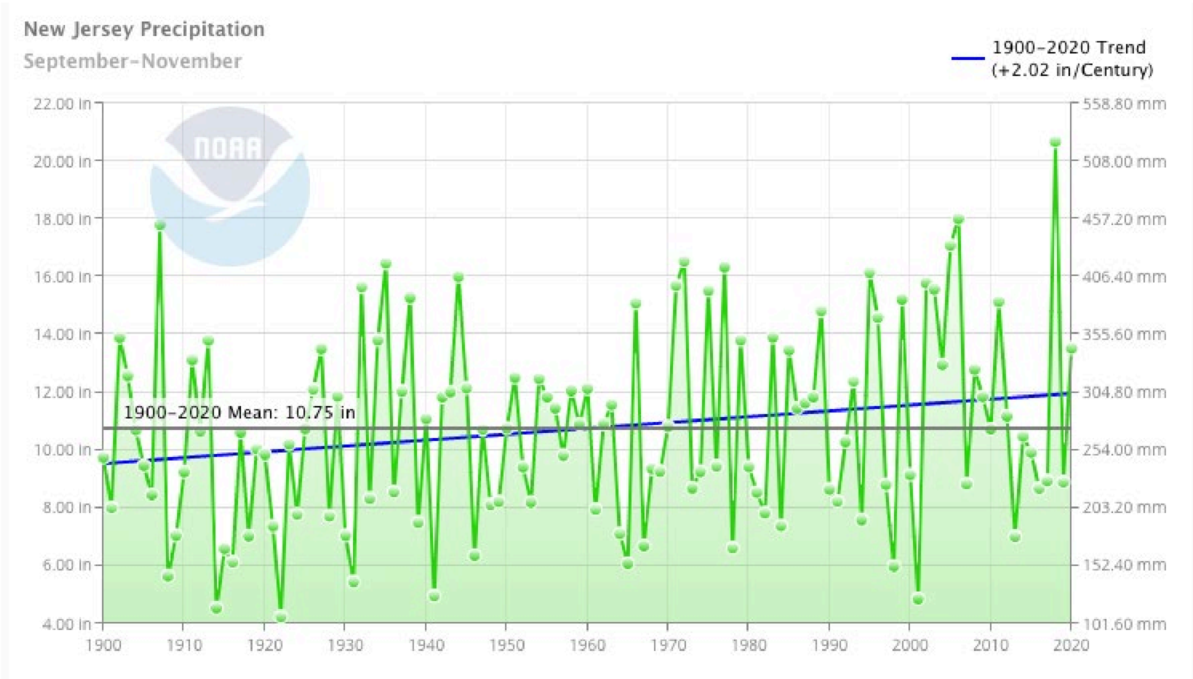


Figure 6. *New Jersey fall (Sep-Nov) precipitation from 1900-2020 and a linear regression for the period of record (blue line). See figure 2 for more information.*

Table 6. *Five wettest (left) and five driest (right) falls observed in New Jersey from 1900-2020.*

Rank	Precip.	Year
1	20.68	2018
2	18.01	2006
3	17.81	1907
4	17.09	2005
5	16.54	1972

Rank	Precip.	Year
1	4.24	1922
2	4.54	1914
3	4.86	2001
4	4.96	1941
5	5.45	1931

2) Regional precipitation (1900-2019)

This section examines long-term records of precipitation from six Tier 1 stations in New Jersey's six drought regions. As noted earlier, one station is considered dominant in each region with any gaps in its coverage from 1900 to 2019 filled with surrogate stations within or immediately adjacent to the region.

Annual precipitation totals

For each station, annual precipitation totals were generated, trends of 30-year running intervals calculated, and an overall linear regression generated. Results are shown in multiple figures and tables.

Generally, annual totals have increased at all stations/regions over the study period. However, a simple linear trend only begins to document annual, decadal, and longer behaviors across the state. Charlotteburg (Northeast) is wettest, with a long-term annual average of 50.18" (1894-2020) and Atlantic City Marina (South Coast) driest, averaging 40.94" (1874-2020). Annual precipitation has ranged from 81.90" in Charlotteburg to 26.05" at Atlantic City Marina. (Table 7). Differences between annual totals for the driest and wettest years have varied by a factor ranging from 2.4 (New Brunswick and Long Branch) to 3.0 (Charlotteburg).

As seen in the statewide annual time series in the previous section, all stations/regions experienced an overall increase in precipitation during the study interval. Trend analyses for total annual precipitation exhibited significant increases over the period of record at Sussex, New Brunswick, and Long Branch (each at $p<0.05$) and Charlotteburg ($p<0.1$). However, figures 7 to 12 show that embedded within this upward trend are lengthy intervals where precipitation was on a downward trajectory, changing little, or increasing quite rapidly. See Appendix B1 for significance values for these and other analyses to follow in this section. Table 8 also shows this variability, documenting trends and their significance for each 30-year running period. Each station/region has its own unique pattern of variability over the 120 years, though commonalities are also noted between stations over the years or at particular intervals.

A wet early start to the 20th century was followed by a downward trend in annual totals in the early decades. An upward trend followed into the 1940s at Sussex and Atlantic City but was generally not seen at the other four locations. All stations exhibited a decline in 30-year averages covering the 1940s into the late 1960s, as the 1950s were rather dry and the mid 1960s had a major drought. The decline was most pronounced in the northwest and south. Trends began to rise throughout most of NJ as the dry 1960s transitioned to a wet 1970s.
This was particularly evident at Charlotteburg, which showed some of the largest and most statistically significant upward trends during this period. Only the south coast did not see an upward trend in precipitation in the 1970s. There, an upward trend began in the 1980s, continuing to be statistically significant to present. Other locations saw trends in 30-year values level off in the 1980s into the 1990s. It was not until the past twenty or so thirty-year intervals that there has been an upward trend at the other stations, particularly at Long Branch, while least at Charlotteburg.

To sum up the annual precipitation evaluation at the six stations/regions, all exhibit significant year-to-year variability with notable extremes, northern areas are wetter, however southern ones have seen a stronger upward trend in recent decades. Significant increases in annual precipitation over the 1900-2019 period were observed in the four northernmost regions (Northwest, Central, Coastal North, and Northeast). Throughout the 120-year period, trends in 30-year increments have risen and fallen, often somewhat in unison among stations or at least not showing opposite tendencies. The most notable exceptions to this in the past half century being the lack of a 1970s increase in the coastal south region, while Charlotteburg has not been a part of the increase in the early part of this century.

Table 7*. Annual precipitation ranked at tier 1 stations for the ten wettest and driest years on record from 1900-2019.*

	Sussex		Charlotteburg		New Brunswick		Long Branch		Indian Mills		Atlantic City Marina	
Rank	Wet Years (in)	Driest Years (in)	Wet Years (in)	Driest Years (in)	Wet Years (in)	Driest Years (in)	Wet Years (in)	Driest Years (in)	Wet Years (in)	Driest Years (in)	Wet Years (in)	Driest Years (in)
1	2011 (79.48)	1964 (29.56)	2011 (81.9)	1965 (27.51)	2011 (66.11)	1965 (27.51)	2011 (74.47)	1965 (31.12)	2018 (75.03)	1965 (29.4)	1958 (67.17)	2001 (26.05)
2	2018 (68.4)	1917 (31.47)	2018 (74.27)	2001 (32.25)	1975 (65.85)	1930 (32.9)	2018 (71.96)	1988 (33.96)	1958 (64.44)	1955 (34.17)	2009 (64.63)	1985 (27.54)
3	1996 (67.24)	2001 (33.45)	2003 (71.82)	1930 (32.9)	2018 (65.23)	1963 (33.8)	1983 (64.15)	1985 (34.5)	2011 (62.6)	1957 (34.83)	1948 (62.18)	1900 (28.13)
4	2003 (64.43)	1965 (33.53)	1983 (68.02)	1963 (33.31)	1983 (61.82)	1923 (35.18)	2014 (63.93)	2001 (35.33)	2019 (61.12)	2001 (35.72)	1903 (61.11)	1965 (30.05)
5	1972 (63.71)	1946 (34.01)	1972 (67.99)	1923 (35.18)	1996 (61.45)	1957 (35.19)	1919 (63.63)	1921 (35.73)	1911 (59.95)	1985 (35.88)	1953 (55.91)	1904 (30.14)
6	1942 (63.25)	1963 (34.45)	2019 (66.71)	1957 (35.24)	2003 (60.85)	1931 (35.77)	1989 (63.6)	1963 (35.83)	1979 (59.6)	1964 (35.98)	1935 (55.04)	1918 (30.14)
7	1938 (62.08)	2016 (34.81)	1996 (66.65)	1931 (35.77)	1989 (60.47)	1941 (36.14)	2008 (63.31)	1922 (36.16)	1996 (59.58)	1943 (36.07)	2018 (53.56)	1976 (30.29)
8	1975 (61.04)	1908 (34.94)	1979 (63.36)	1941 (36.14)	1911 (59.38)	1976 (36.16)	1938 (62.89)	1931 (36.36)	2003 (58.65)	1921 (36.14)	2014 (52.42)	1981 (30.52)
9	1902 (61.00)	1943 (35.11)	1990 (61.57)	1943 (36.71)	1979 (59.11)	1943 (36.71)	1913 (62.51)	1946 (36.95)	1907 (58.63)	1930 (36.15)	1972 (51.68)	1930 (31.18)
10	2006 (60.67)	1966 (35.14)	1975 (60.72)	2013 (37.24)	1972 (57.25)	1914 (36.75)	1979 (61.88)	1930 (37.12)	1972 (58.6)	1980 (36.39)	1933 (51.27)	1931 (31.18)

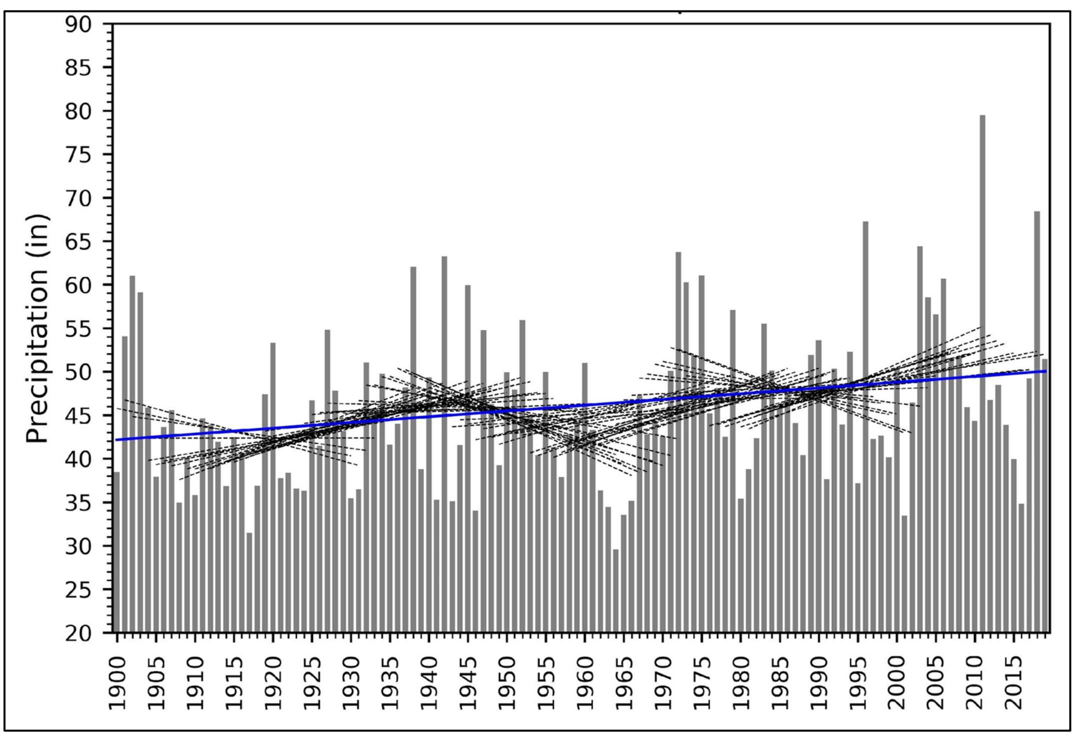


Figure 7. *Annual precipitation at Sussex: 1900-2019. Dotted lines indicate 30-year regressions, the blue line represents the full 120-year regression.*

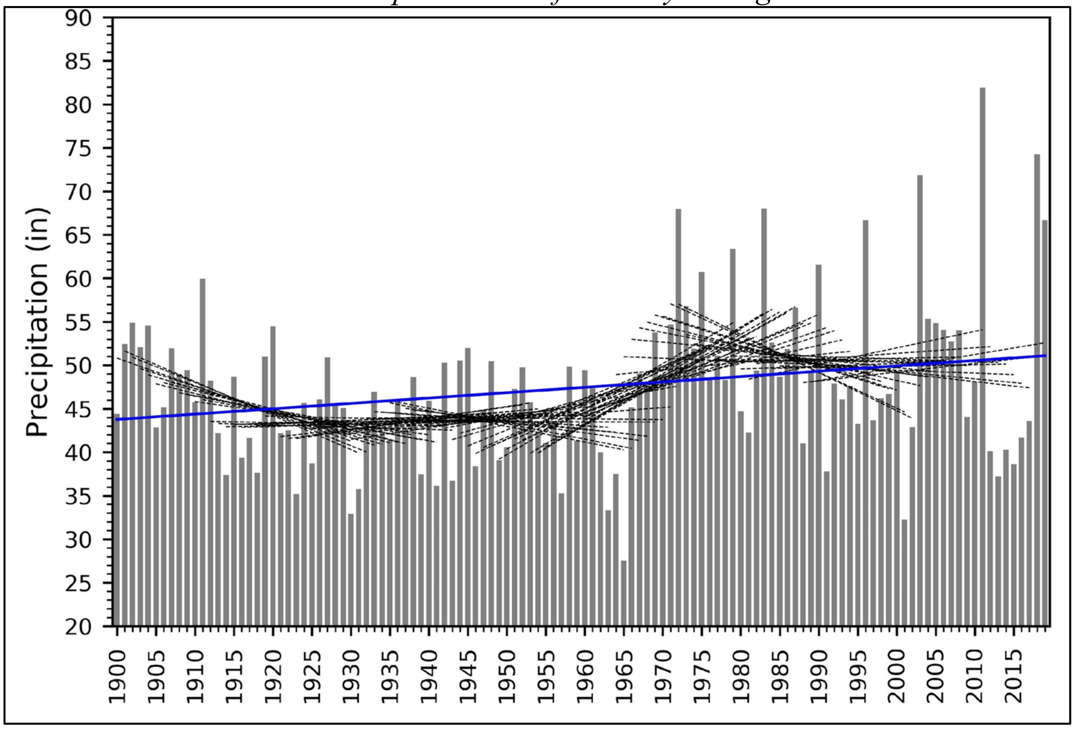


Figure 8. *Annual precipitation at Charlotteburg: 1900-2019. See fig. 7 for further information.*

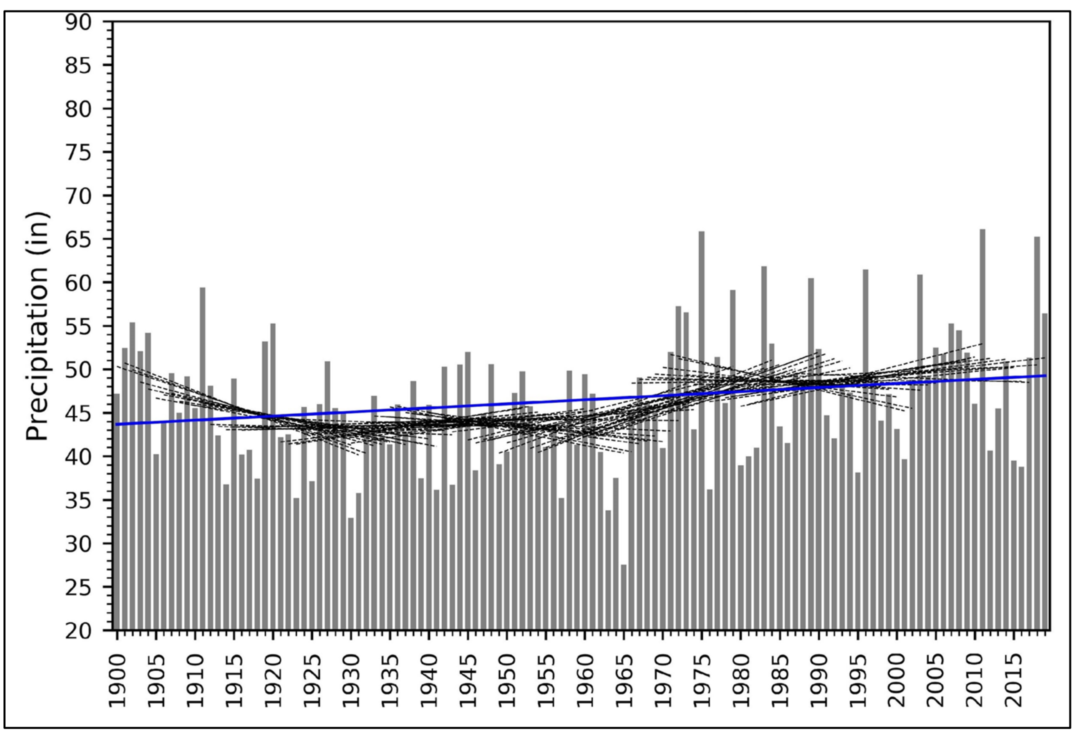


Figure 9. *Annual precipitation at New Brunswick: 1900-2019. See fig. 7 for further information*

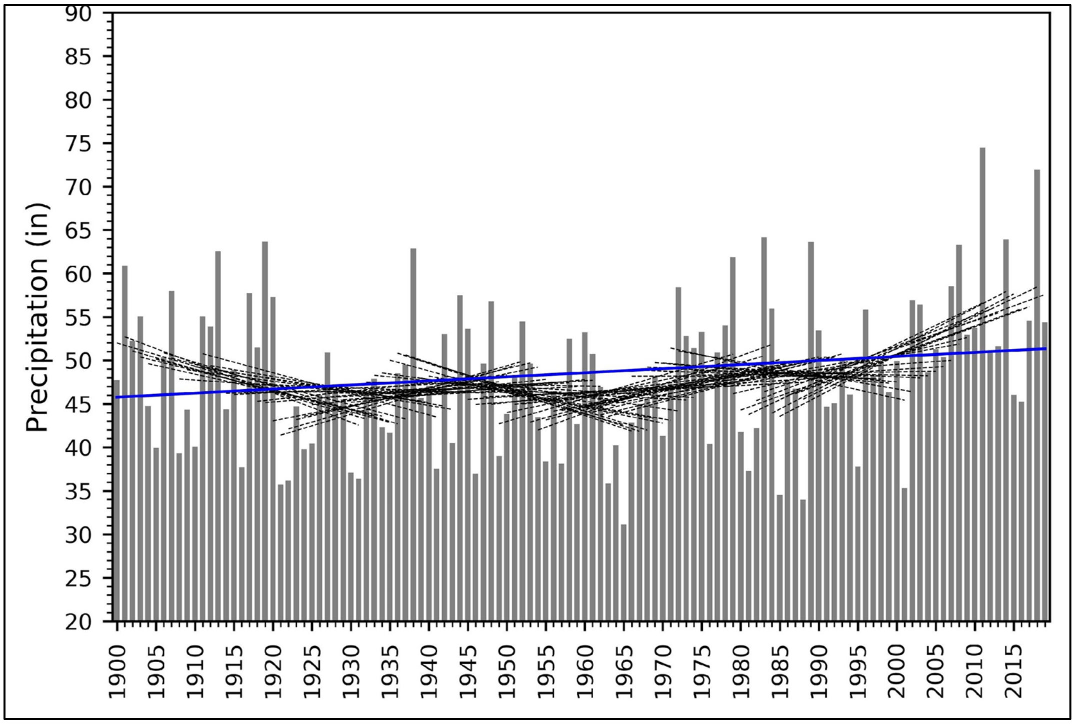


Figure 10. *Annual precipitation at Long Branch: 1900-2019. See fig. 7 for further information.*

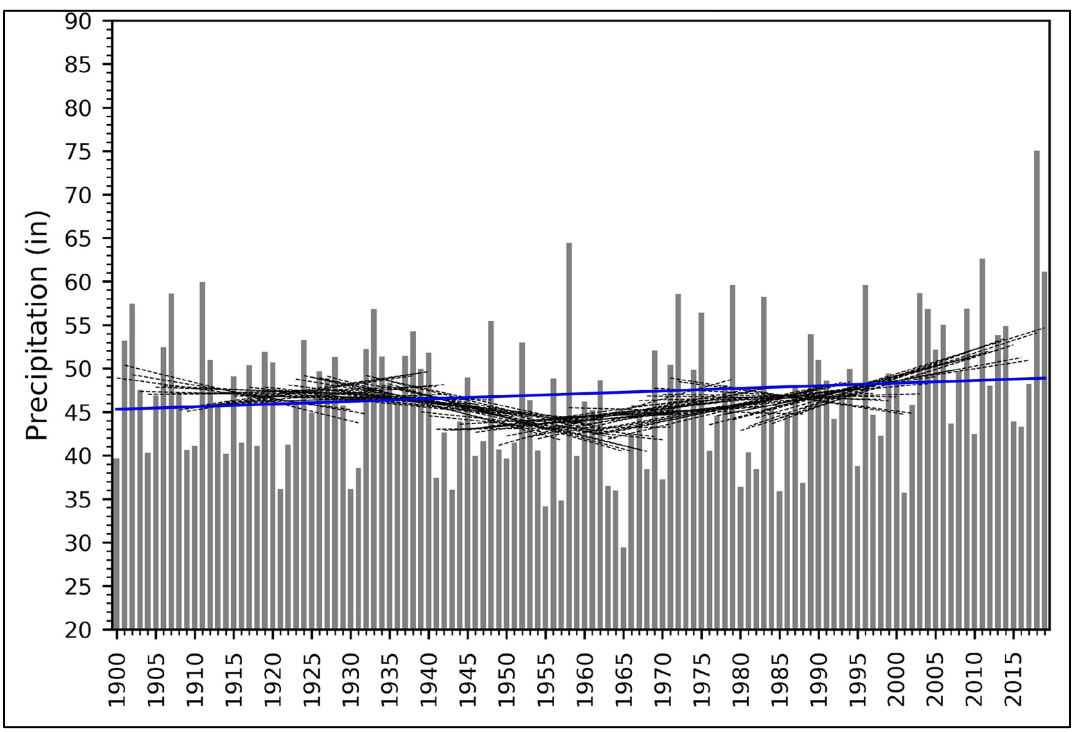


Figure 11. *Annual precipitation at Indian Mills: 1900-2019. See fig. 7 for further information.*

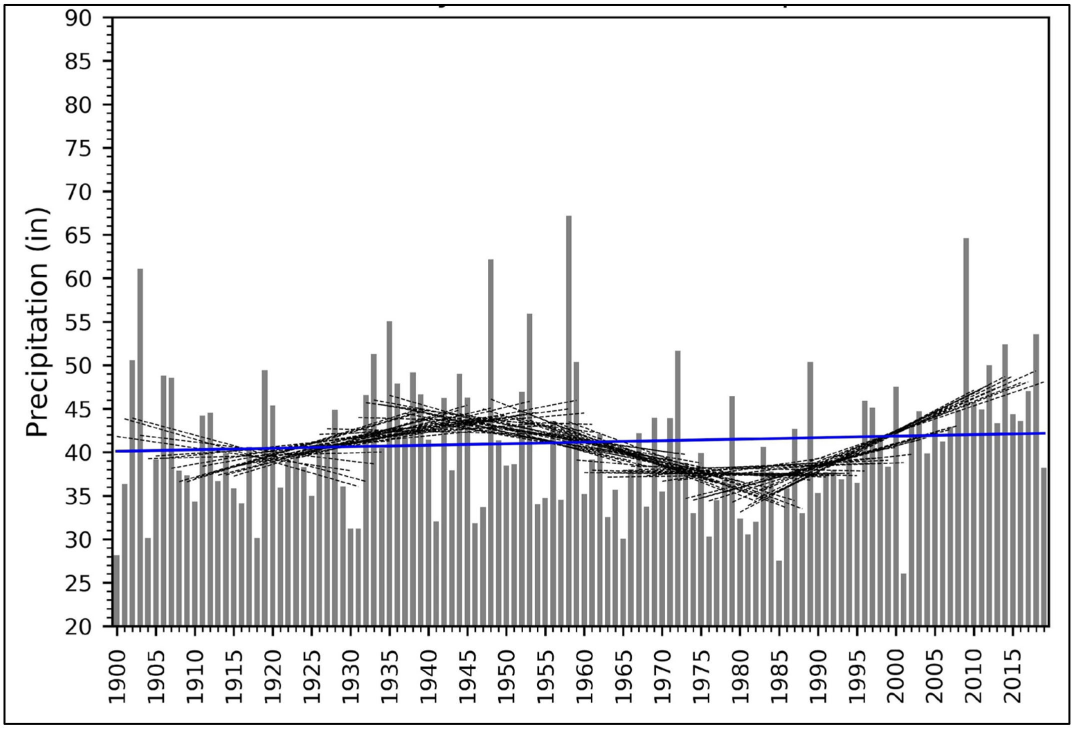
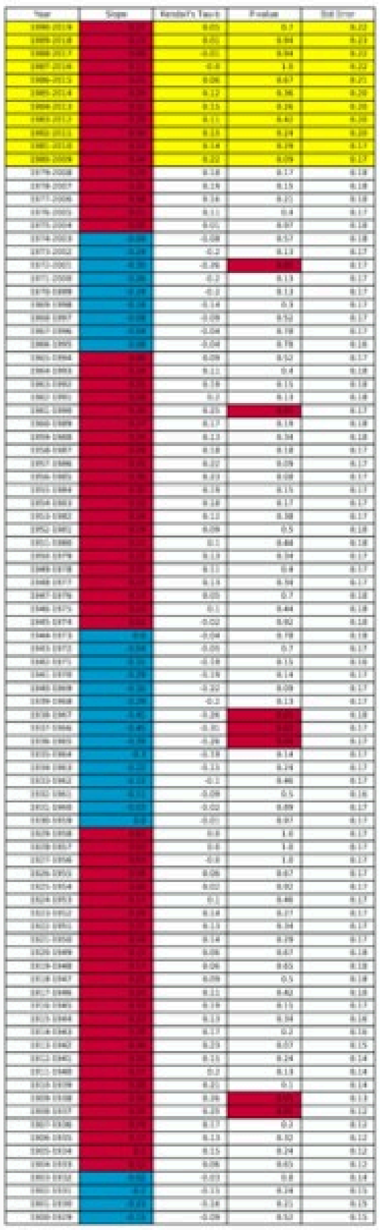


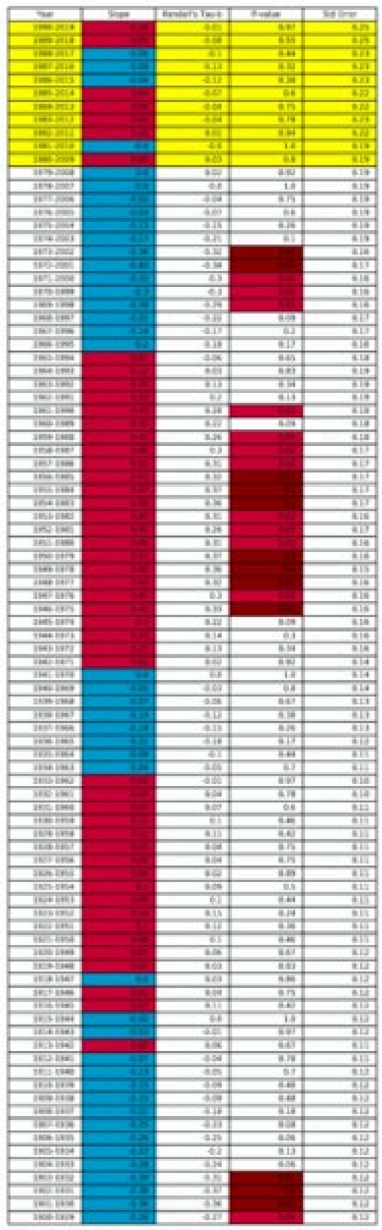
Figure 12. *Annual precipitation at Atlantic City Marina: 1900-2019. See fig. 7 for further information.*

***Table 8**. Thirty-year year time series from 1900-1929 to 1990-2019 (left column) are evaluated for each Tier 1 station, examining slope (second column from the left) and potential significance to a trend using Kendall's tau-b (third column), P-value (fourth column), and standard error (fifth column). The ten most recent 30-year periods are highlighted in yellow. Increasing slopes are highlighted in red and decreasing slopes in blue. The dark red in the P-value indicates significance at the 99% level and the normal red is significant at the 95% level. See appendix C for enlarged versions of each station time series.*

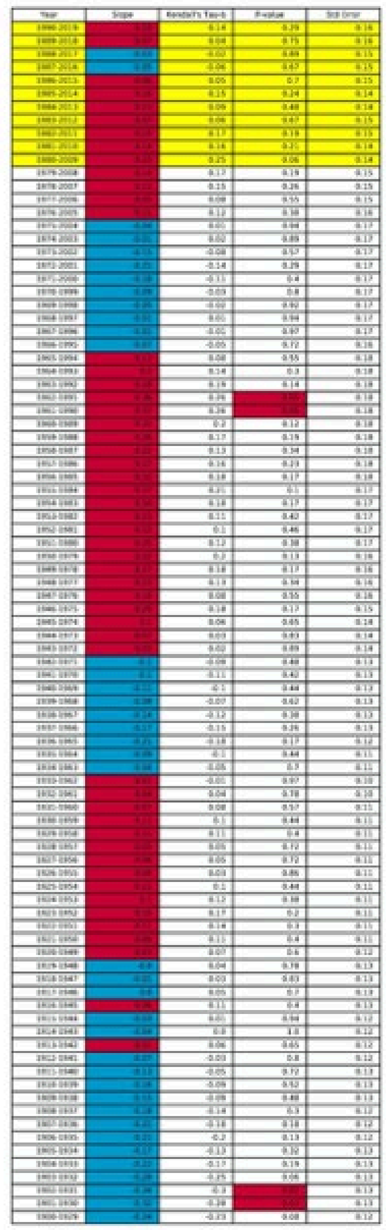
Sussex

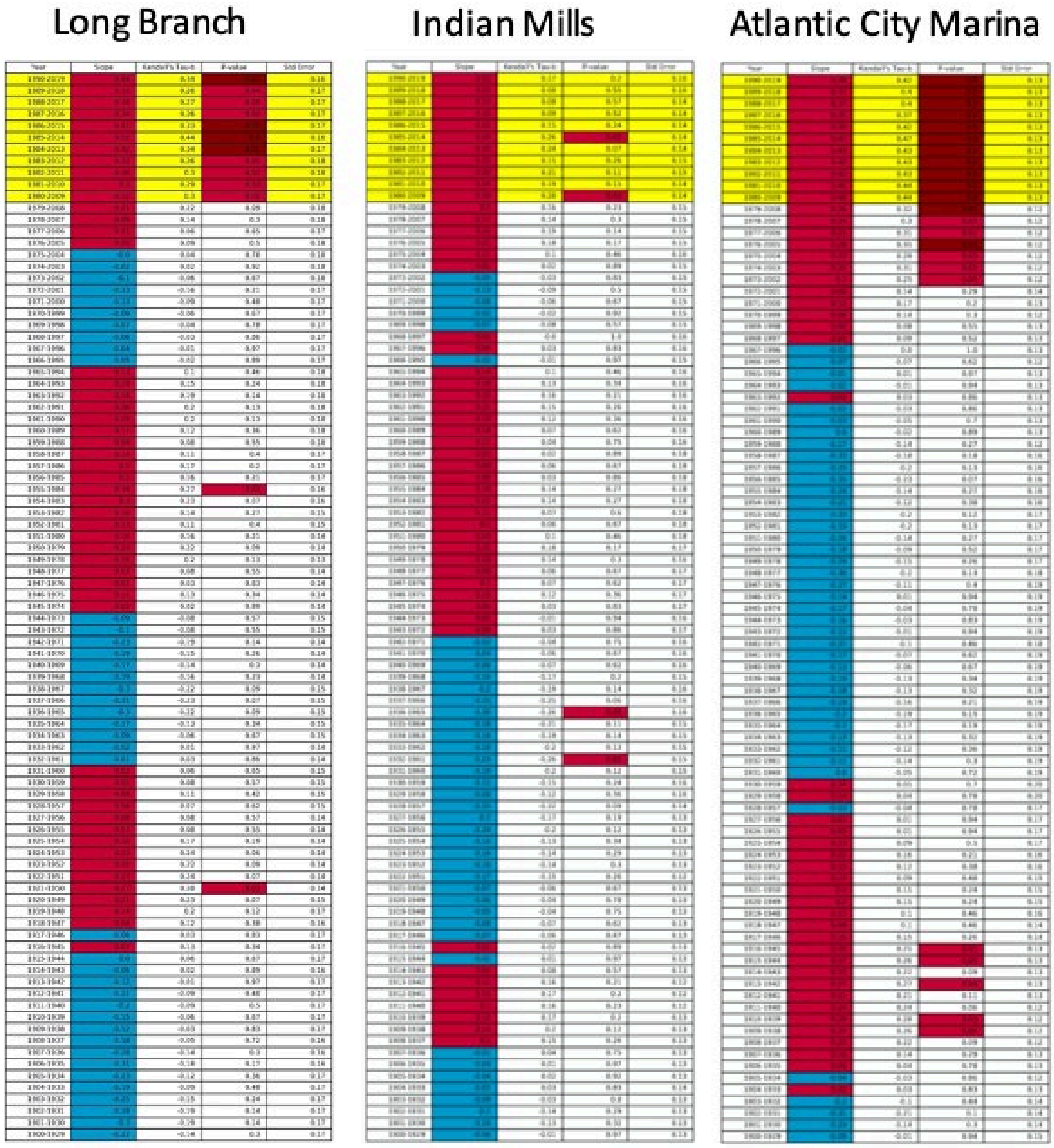


Charlotteburg



New Brunswick





Number of days of precipitation above prescribed amounts

The number of days each year when precipitation exceeds four prescribed thresholds is next examined for the 1900-2019 interval. For each Tier 1 station, days equal to or exceeding 0.10”, 0.50”, 1.00”, and 2.00” were calculated and trends were also determined for each running 30-year increment (figures 13-18). Days falling below 0.10” were excluded as they are less consequential to the state’s hydrologic regime.

In general, the number of days each year with 0.10” or more ranges from 70-80 days across NJ. More occur in the north and fewer along the south coast. Extremes range from 120 days in Charlotteburg in 1972 to 51 days at Atlantic City Marina in 2001 (table 9).

Results in the 0.10" or greater category were highly variable between stations. Sussex had mid-20th century and recent decades peaks; Charlotteburg peaked early in the 20th century and in the 1970s; New Brunswick had minor peaks at the beginning of each century; Long Branch showed little variability, with a small minimum in the 1960s; Indian Mills declined up through the 1960s, before rising in recent decades; and Atlantic City Marina showed higher counts in the first half of the 20th century, a decline in the 1960s, and some degree of leveling off since then.

Variations in annual counts and 30-year trends in 0.50" or greater totals are more subtle than at the 0.10" level. There is general agreement among the six stations, with a slight increase in days over the course of the 120 years. State-wide consistency was also exhibited in 1.00" or greater counts. All showed some increase in counts, particularly since the 1970s, most notably at Atlantic City Marina, though the increase there did not begin until more recent decades.

It is rare for a station to have more than several 2.00" or greater daily totals in a year, thus it is difficult to discern any changes over the course of the last 120 years. There is some suggestion of increases in recent decades at Sussex and in the three southernmost regions. This is not noted at Charlotteburg or New Brunswick.

The results from this section show that 0.10" of rain (or melted snow) or more falls on average between once and twice per week throughout the year. Record low counts range from 51-63 days and high counts from 92-120 days. There is some suggestion (no statistical significance) that counts above each of four study thresholds have increased in recent decades but interannual variations dominate over the study period.

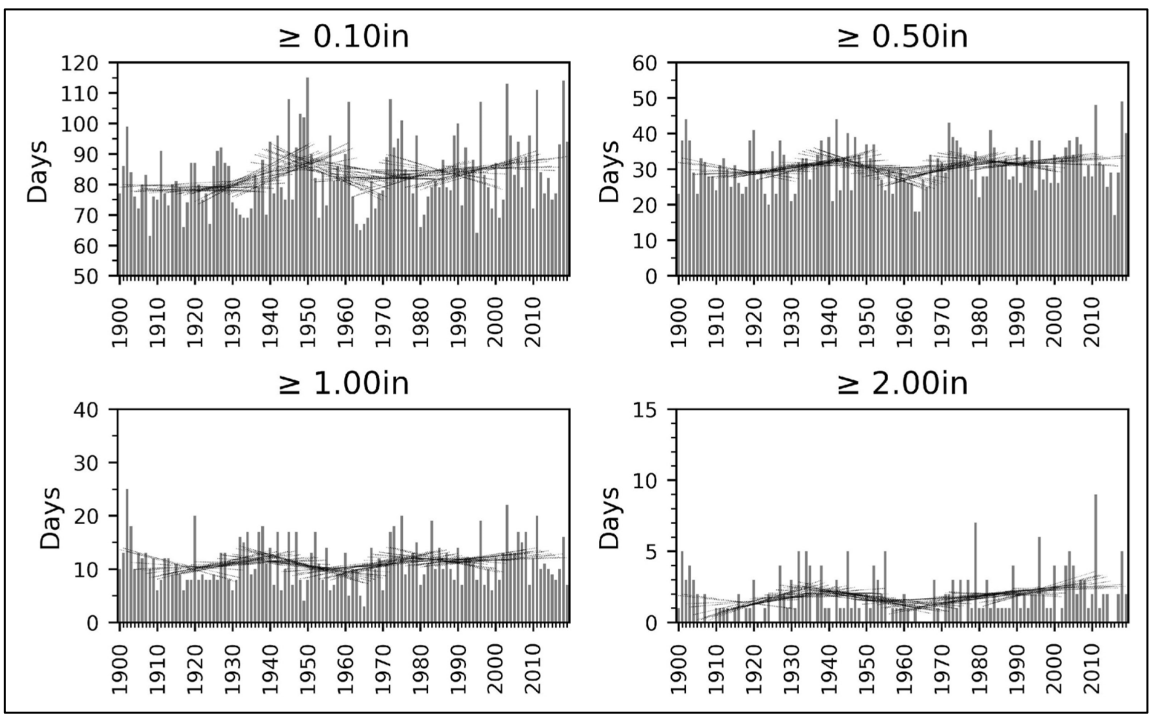


***Figure 13**. Time series of the annual number of days with precipitation above prescribed thresholds at Sussex for the 120-years of record. Multiple lines indicate 30-year regressions.*

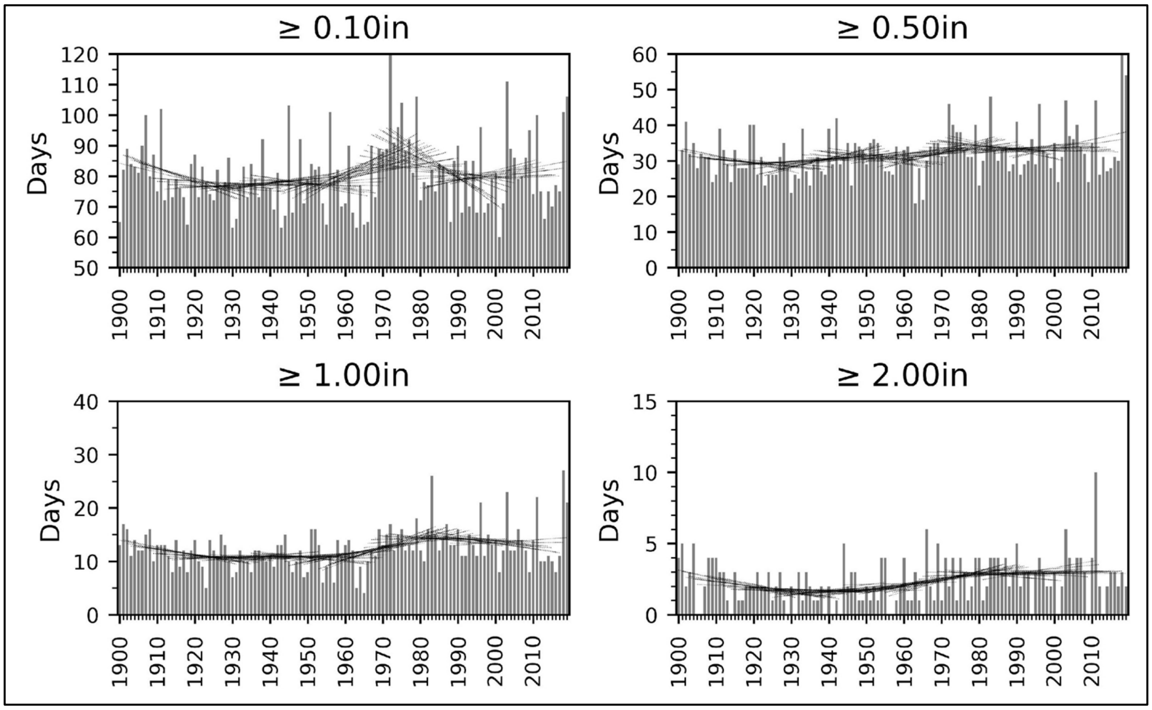


***Figure 14**. Time series of the annual number of days with precipitation above prescribed thresholds at Charlotteburg. See Fig. 13 for more information.*

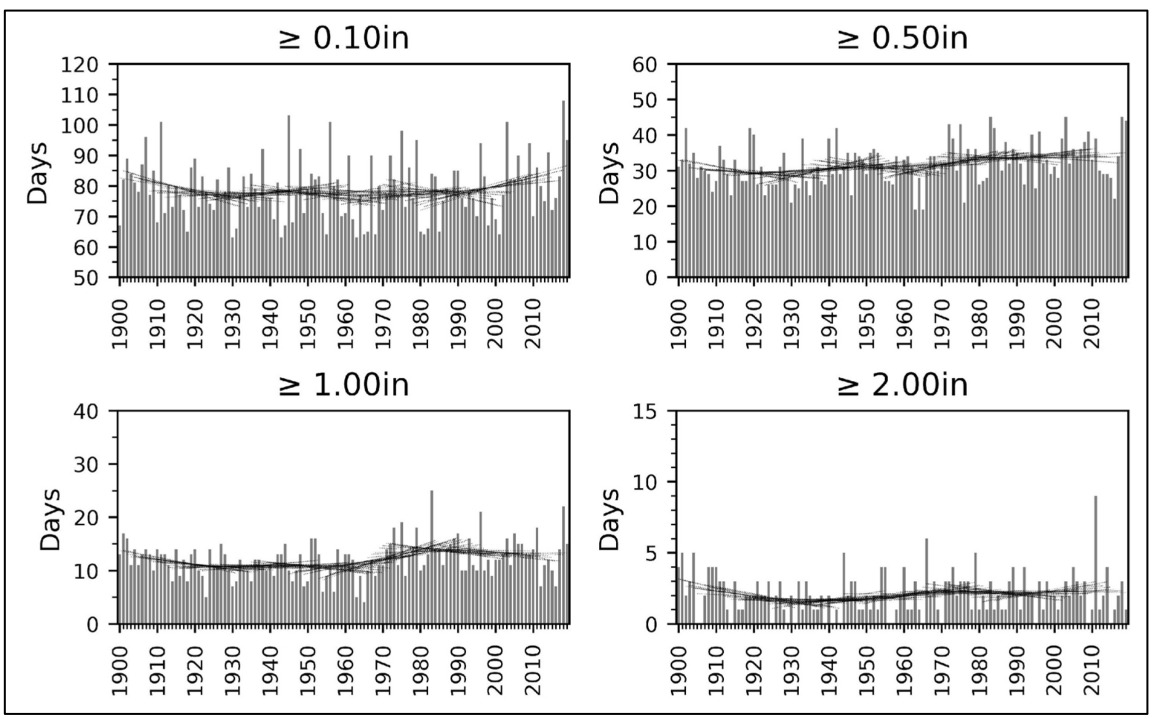


***Figure 15**. Time series of the annual number of days with precipitation above prescribed thresholds at New Brunswick. See Fig. 13 for more information.*

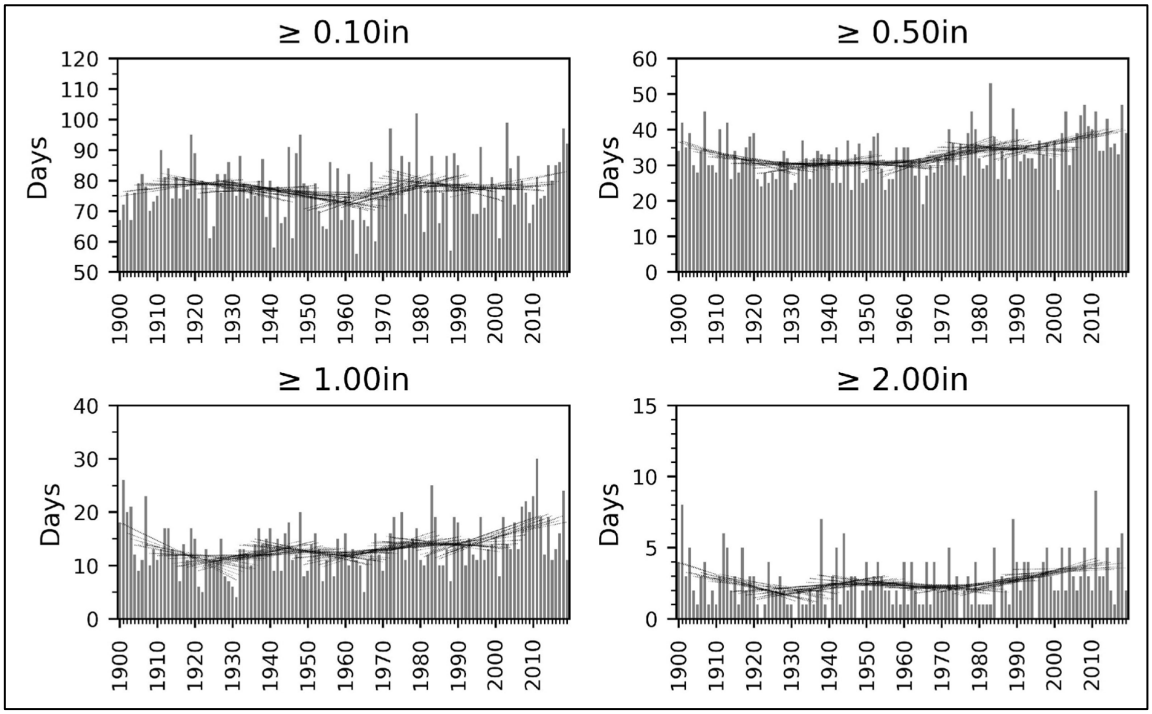


***Figure 16**. Time series of the annual number of days with precipitation above prescribed thresholds at Long Branch. See Fig. 13 for more information.*

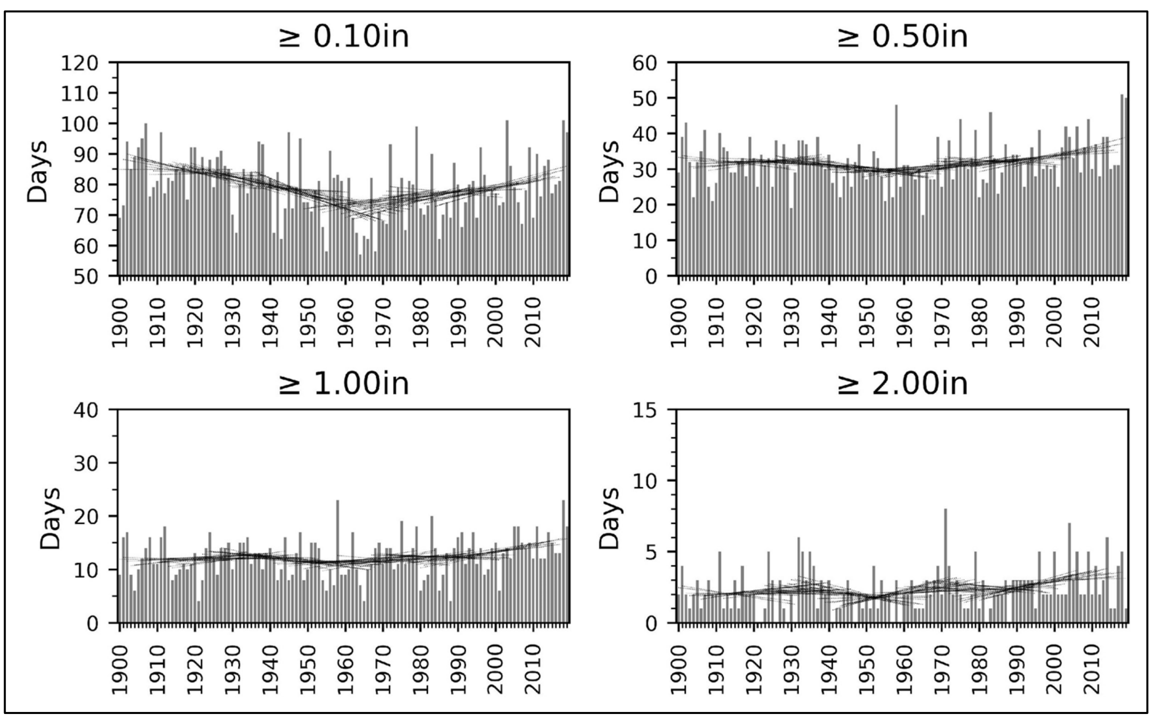


***Figure 17**. Time series of the annual number of days with precipitation above prescribed thresholds at Indian Mills. See Fig. 13 for more information.*

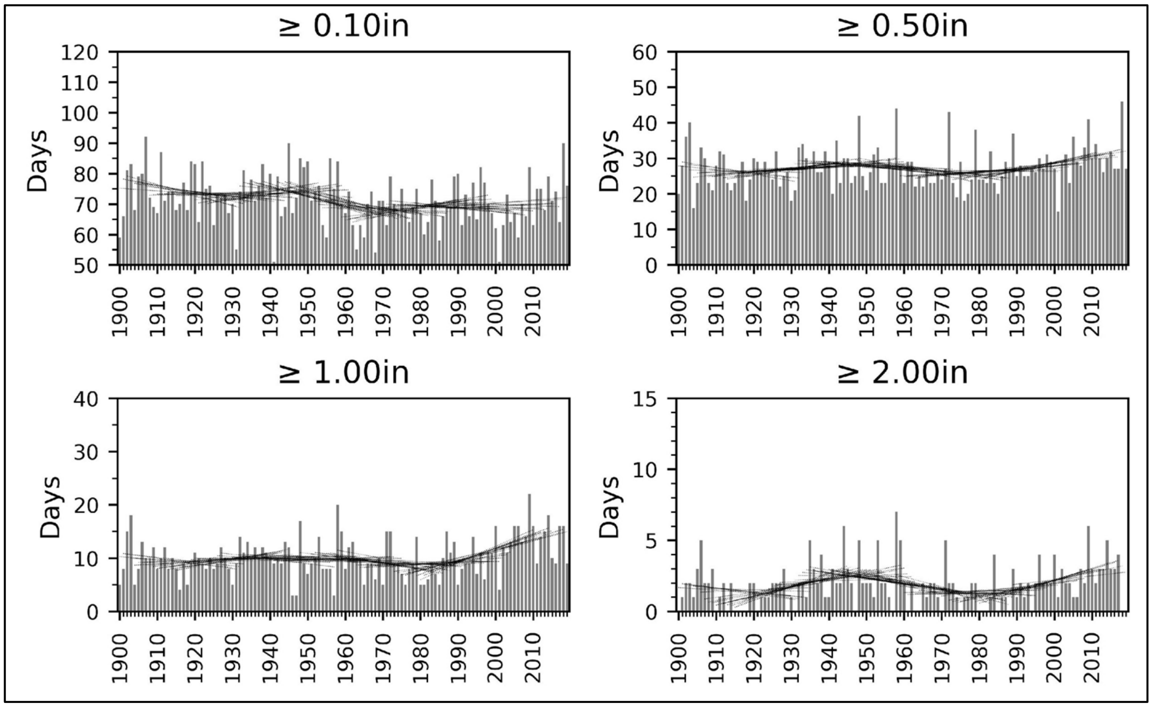


Figure 18. *Time series of the annual number of days with precipitation above prescribed thresholds at Atlantic City Marina. See Fig. 13 for more information.*

Table 9. *Top 10 most and least days in a year with precipitation of 0.10" or greater at Tier 1 stations from 1900-2019.*

	Sussex		Charlotteburg		New Brunswick		Long Branch		Indian Mills		AC Marina	
Rank	Most Days	Least Days	Most Days	Least Days	Most Days	Least Days	Most Days	Least Days	Most Days	Least Days	Most Days	Least Days
1	1950 (115)	1908 (63)	1972 (120)	2001 (60)	2018 (108)	1930 (63)	1979 (102)	1963 (56)	2003 (101)	1964 (57)	1907 (92)	2001 (51)
2	2018 (114)	1995 (64)	2003 (111)	1930 (63)	1945 (103)	1943 (63)	2003 (99)	1988 (57)	2018 (101)	1968 (58)	1945 (90)	1941 (51)
3	2003 (113)	1964 (65)	2019 (106)	1943 (63)	2003 (101)	1963 (63)	2018 (97)	1941 (58)	1907 (100)	1955 (58)	2018 (90)	1968 (54)
4	2011 (111)	1980 (66)	1979 (106)	1963 (63)	1956 (101)	1955 (64)	1972 (97)	1968 (60)	1979 (99)	1985 (62)	1911 (87)	1963 (55)
5	1945 (108)	1917 (66)	1975 (104)	1918 (64)	1911 (101)	1965 (64)	1919 (95)	1924 (61)	1945 (97)	1943 (62)	1948 (85)	1931 (55)
6	1972 (108)	1965 (67)	1945 (103)	1955 (64)	1975 (98)	1981 (64)	1948 (95)	2001 (61)	1911 (97)	1966 (62)	1956 (85)	1985 (58)
7	1996 (107)	1963 (67)	1911 (102)	1965 (64)	1907 (96)	1968 (64)	2019 (92)	1946 (61)	2019 (97)	1965 (63)	1919 (84)	1900 (59)
8	1961 (107)	1924 (67)	1956 (101)	1988 (65)	1979 (95)	2001 (64)	1996 (91)	1981 (63)	1906 (95)	1963 (64)	1950 (84)	1955 (59)
9	1948 (103)	2001 (69)	2018 (101)	1966 (65)	2019 (95)	1980 (65)	1945 (91)	1955 (64)	1948 (95)	1941 (64)	1922 (84)	2006 (59)
10	1949 (102)	1934 (69)	2011 (100)	1900 (65)	2009 (94)	1918 (65)	1911 (90)	1966 (65)	1937 (94)	1931 (64)	1958 (84)	1965 (59)

Percentage of days with rain above thresholds

The following is an evaluation of the distribution of precipitation totals on days when precipitation occurs. In other words when it precipitates just how much falls? Unlike the previous section, only days when any measurable (0.01") precipitation fell are considered. Values are expressed as percentages of the annual precipitation falling at and above 0.10", 0.50", 1.00", and 2.00" (figures 19-24).

The 0.10" or greater figures for each station permit an examination of the percentage of days with precipitation that fall under this mark. Generally, 30-40% of precipitation days total less than 0.10". The percentage of these small accumulation days decreased at Sussex into the 1960s and has held steady since. Charlotteburg and New Brunswick exhibit little change throughout the study period. Long Branch had a smaller percentage of low precipitation days early in the record and in the 1990s and 2000s. There is some concern that the very low totals early on were due to a failure to report lower amounts. Indian Mills saw a notable decline in the percent of days with low totals from the 1970s onward, while Atlantic City Marina had little change over time.

About 20-30% of precipitation days see at least 0.50" fall. This percentage has changed little over time at the northern three stations. It has increased about 5% over the past several decades at Long Branch and Indian Mills, while there has been a slight rise from the low to mid 20% range at Atlantic City Marina. Close to 10% of precipitation days have 1.00" or more falling. The regional results through time are similar to those found for the greater than or equal to 0.50" category, though there has been a more notable increase in 1.00" or greater days at Atlantic City Marina than at the 0.50" threshold. As with day counts discussed earlier for 2.00" or greater amounts, the percentages of precipitation days exceeding 2.00" are too small to gain results having any statistical significance. They are in the several percent range, with all stations leaning to a more recent increase in percentage, particularly at the three southernmost stations and least of all at New Brunswick.

As expected, the overall results from this evaluation of the distribution of precipitation totals on days when measurable precipitation is observed vary little from those looking at day counts above 0.10", 0.50", 1.00", and 2.00" thresholds. Interannual variations dominate, particularly as thresholds increase, with some indication of greater totals on precipitation days in recent decades compared to earlier ones.

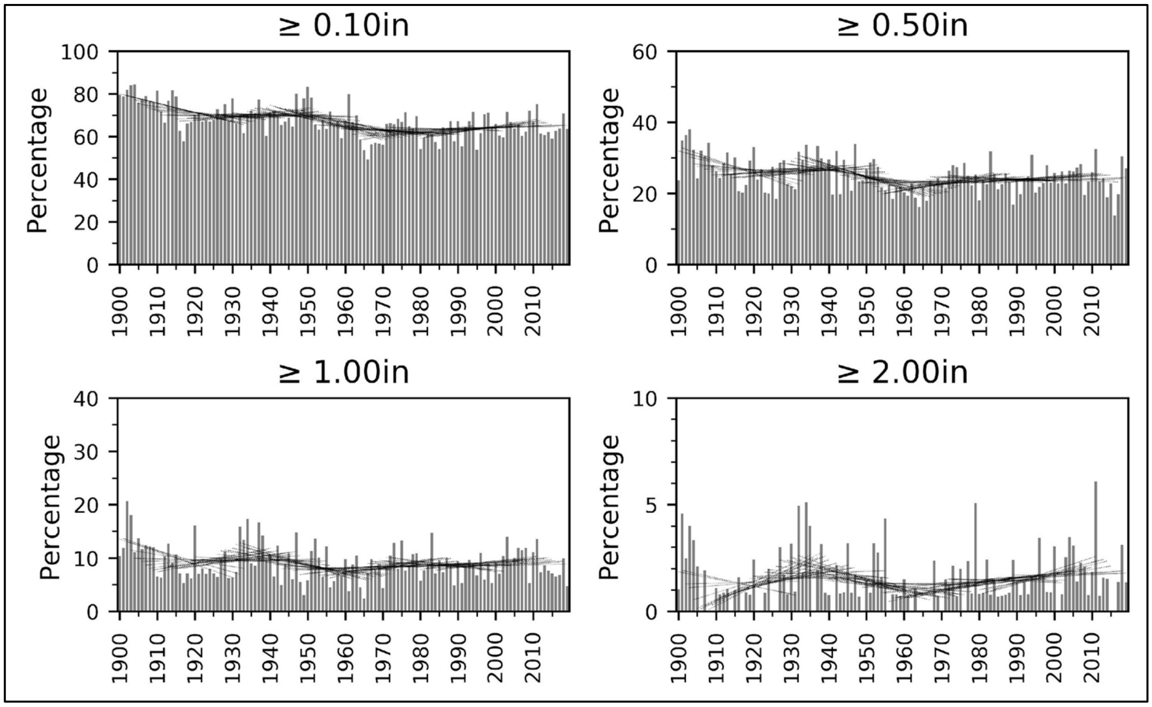


Figure 19. *Time series of the annual percentage of days with precipitation above prescribed thresholds at Sussex for the 120-years of record. Multiple lines indicate 30-year regressions.*

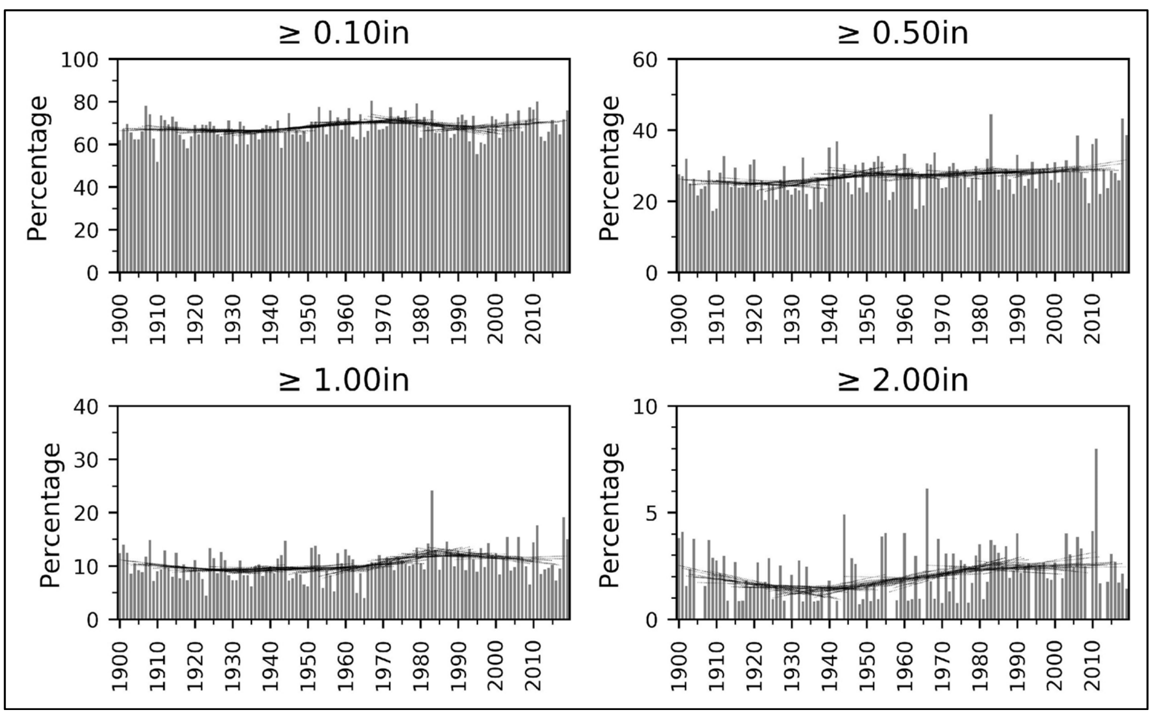


Figure 20. *Time series of the annual percentage of days with precipitation above prescribed thresholds at Charlotteburg. See Fig. 19 for more information.*

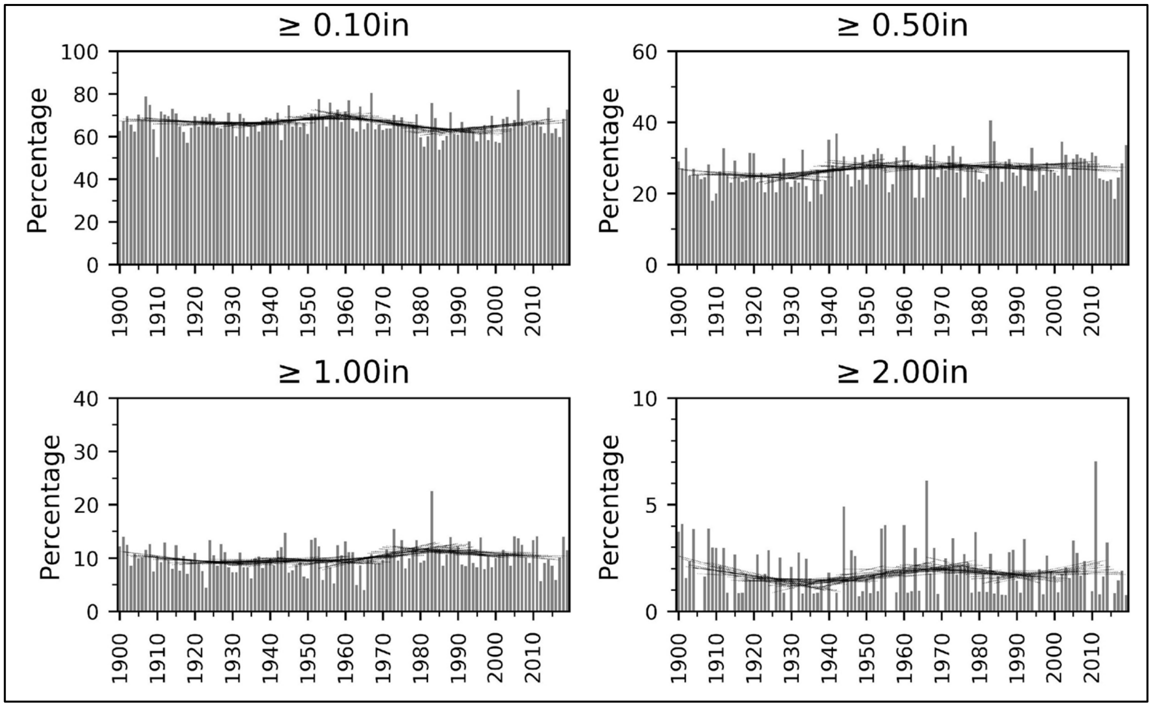


Figure 21. *Time series of the annual percentage of days with precipitation above prescribed thresholds at New Brunswick. See Fig. 19 for more information.*

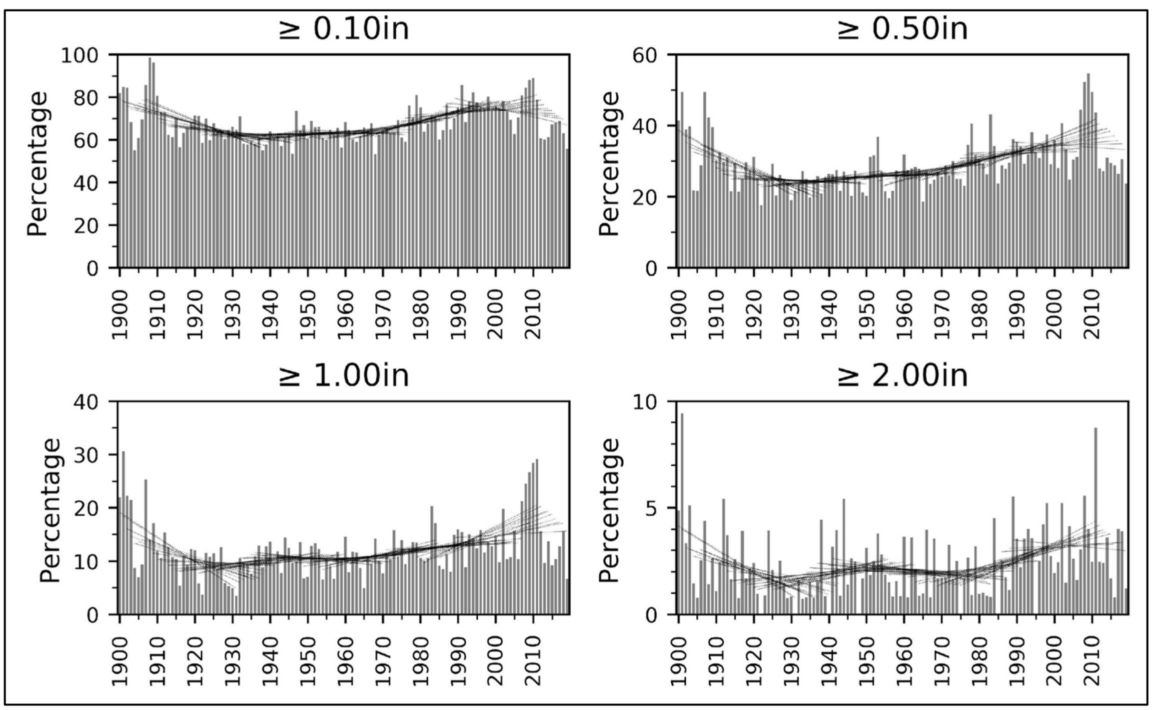


Figure 22. *Time series of the annual percentage of days with precipitation above prescribed thresholds at Long Branch. See Fig. 19 for more information.*

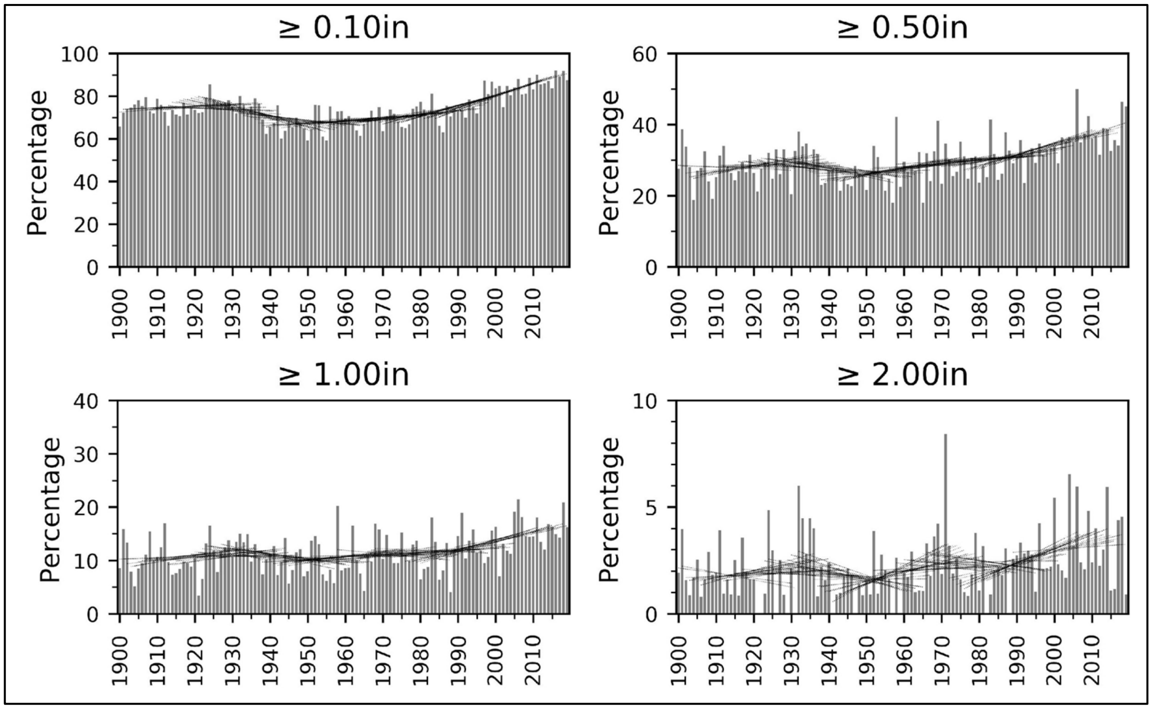


Figure 23. *Time series of the annual percentage of days with precipitation above prescribed thresholds at Indian Mills. See Fig. 19 for more information.*

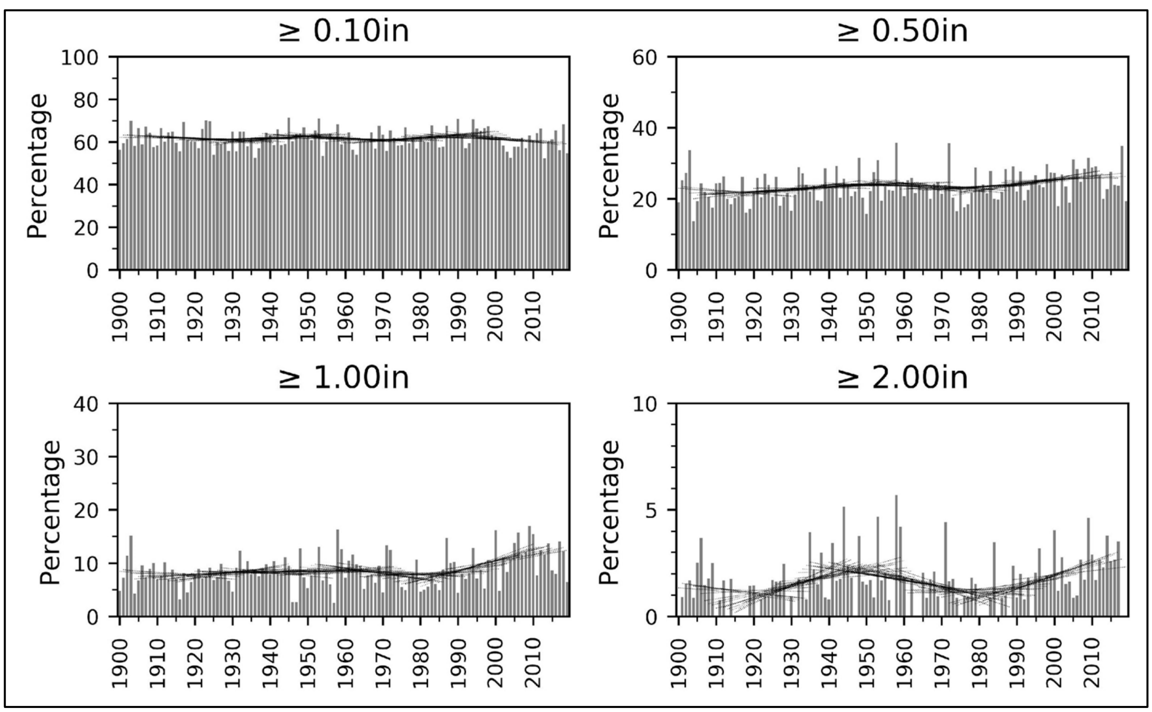


Figure 24. *Time series of the annual percentage of days with precipitation above prescribed thresholds at Atlantic City. See Fig. 19 for more information.*

Percentage of annual precipitation from <1", 1-2", >2" events and Gini coefficient

This section and the next further examine the distribution of precipitation by amount, including several novel ways of delving into the question of potential changes in the manner in which precipitation falls in New Jersey over the 1900-2019 interval. For each region's Tier 1 station, figures 25-30 display information on the annual percentage of precipitation falling in three ranges along with the total annual precipitation in the top portion of each figure. The bottom portion shows the Gini coefficient depicting the distribution of precipitation each year. More on this follows in Figure 31 where the distributions are plotted together for all stations. The key to this value is the higher the coefficient the larger the proportion of annual precipitation that was delivered via few large events.

Indian Mills and Atlantic City Marina experienced significant decreases in the percent of precipitation contributed by daily precipitation events less than 1.00 inch ($p<0.05$) along with Charlotteburg ($p<0.1$). Atlantic City Marina was the only station to see a statistically significant change (slight increase) in the percent of annual precipitation received in events of 1-2 inches. Sussex was the only station to see a statistically significant change (slight increase) in the percent of annual precipitation received in events exceeding 2 inches.

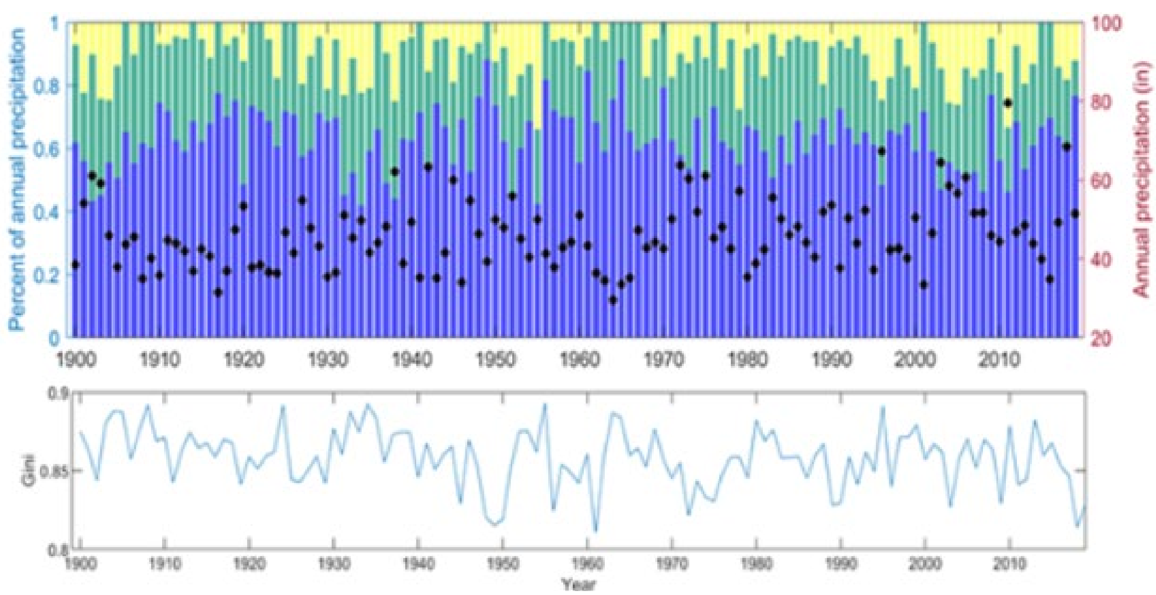


***Figure 25**. Precipitation by magnitude and Gini coefficient for Sussex. Top, left axis: Proportion of annual precipitation from daily events less than 1 in (blue), 1-2 in (green), and ≥2 in (yellow). Top, right axis: Annual precipitation (black markers). Bottom: Gini coefficient for each year 1900-2019.*

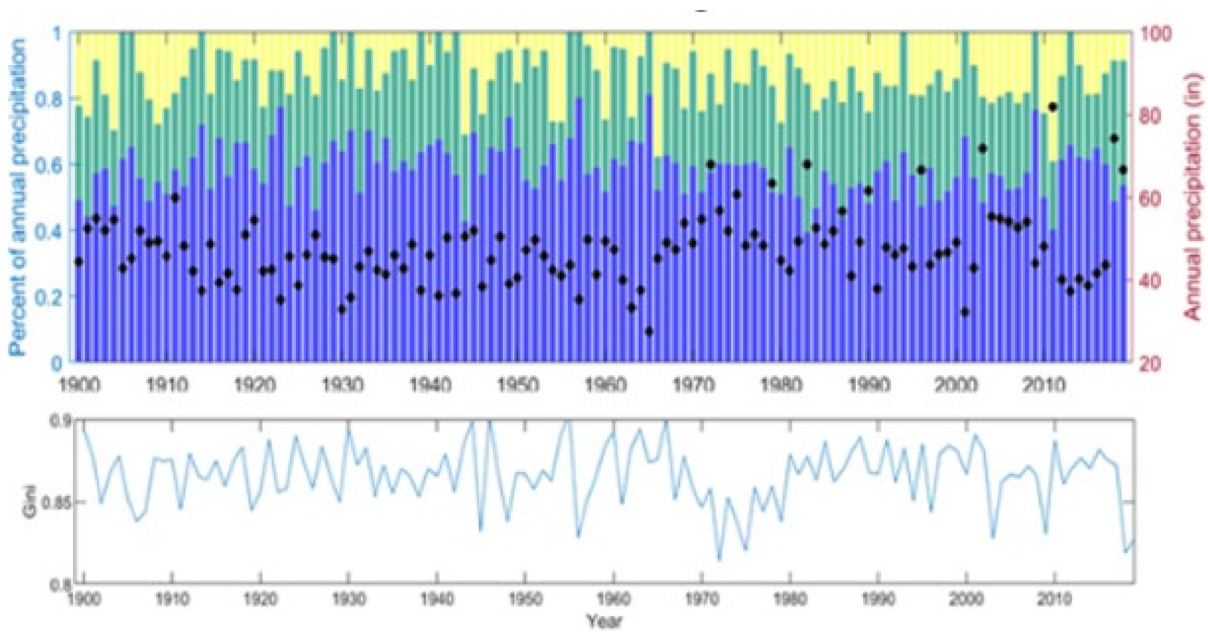


Figure 26. *Precipitation by magnitude and Gini coefficient for Charlotteburg. See Figure 25 for further explanation.*

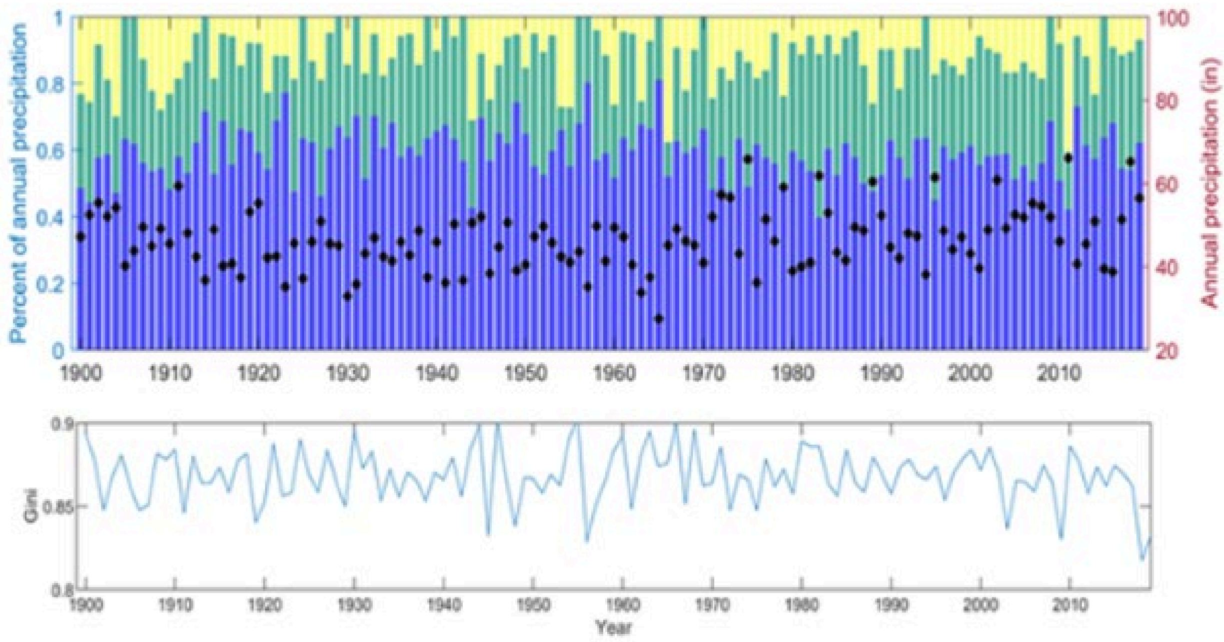


Figure 27. *Precipitation by magnitude and Gini coefficient for New Brunswick. See Figure 25 for further explanation.*

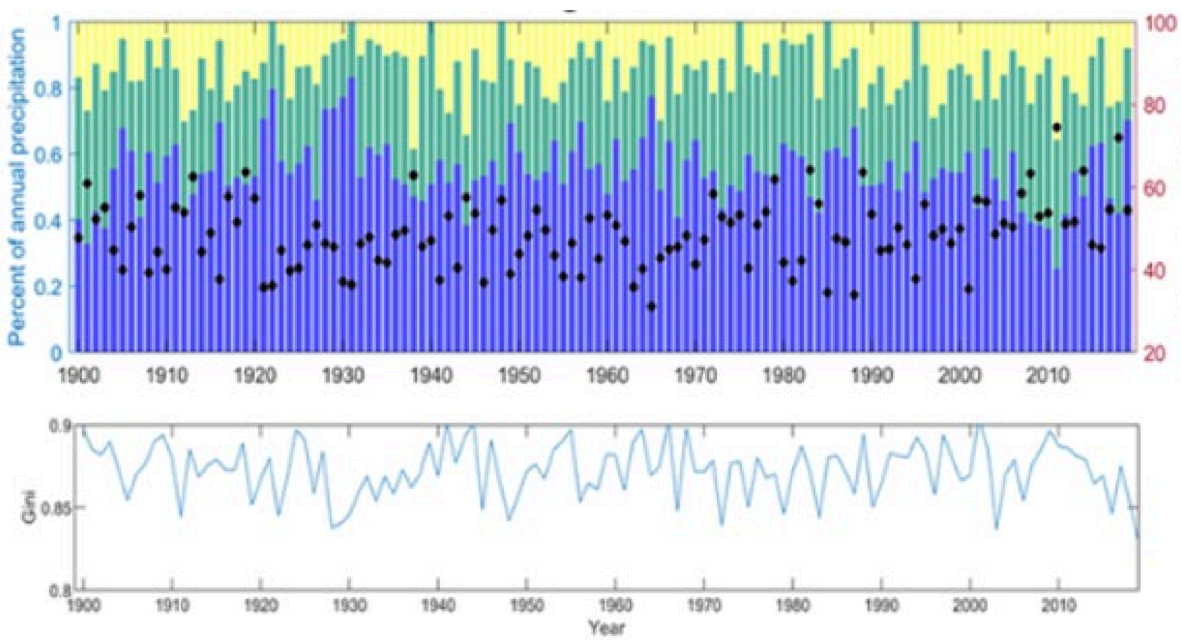


Figure 28. *Precipitation by magnitude and Gini coefficient for Long Branch. See Figure 25 for further explanation.*

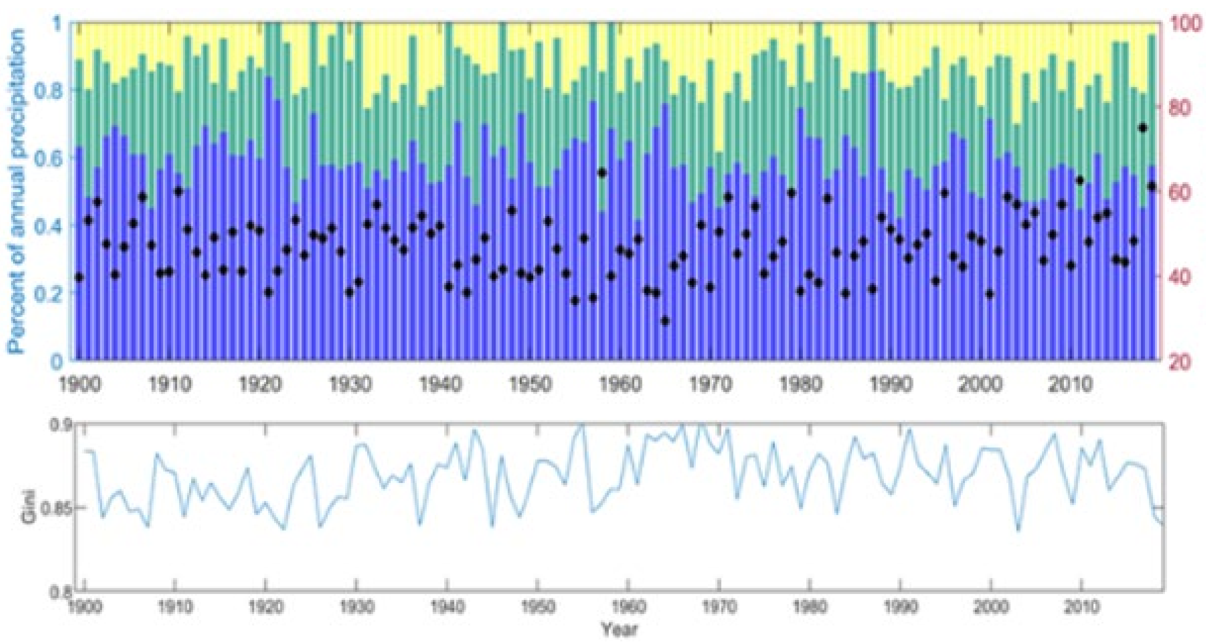


Figure 29. *Precipitation by magnitude and Gini coefficient for Indian Mills. See Figure 25 for further explanation.*

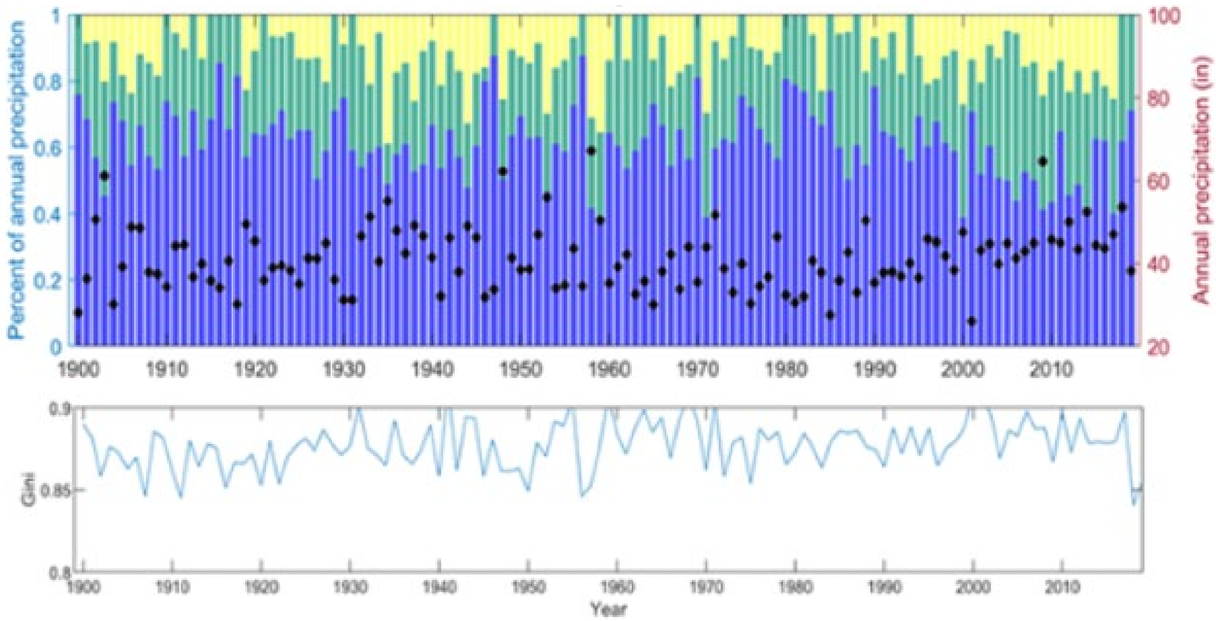


***Figure 30**. Precipitation by magnitude and Gini coefficient for Atlantic City Marina. See Figure 25 for further explanation.*

Rather than examine the Gini coefficients for each station as depicted in the above figures, they were grouped into one figure and plotted by year and also by 10-year sliding averages for each station (Figure 31). Sliding averages were generated by calculating the average for a 10-year period, which is plotted at the mid-point in the 10-year window. Again, high Gini coefficients indicate years in which a large proportion of annual precipitation was delivered in large events; lower Gini coefficients indicate years in which light and moderate precipitation events contributed substantially to annual precipitation totals. Changes in how precipitation was delivered to each station can be seen by inspecting the time series. The intra-annual precipitation distributions at each station seem to be driven by similar forces over decadal time periods (generally similar ups and downs) but the extent to which heavy and light precipitation events impact the annual precipitation distribution varies by region. For example, the Gini coefficient of precipitation received at the Sussex location (green) is relatively high in the first years of the time series and declined through the 1920s. This suggests that the proportion of precipitation delivered in the largest daily precipitation events decreased through the first two decades of the century. After an increase in Gini coefficient through the 1920s and 1930s, indicating that more of the annual precipitation was being received through the heaviest daily precipitation events than in previous years, the metric undergoes a large decline and stays low, relative to the first few decades, for the rest of the time series, with some quasi-decadal increases and decreases. This suggests that at the Sussex station, annual precipitation is distributed across precipitation days more equally in the latter part of the time series than in the early 20th century.

The other five stations tended to have higher Gini coefficients than in Sussex. Exceptions were early in the record at Indian Mills and in the 1970s at Charlotteburg. The highest values were most often found at Atlantic City Marina, particularly during the 1960s (joined by Indian Mills) and early this century. In terms of statistical significance, the decreasing coefficient at Sussex from 1900-2019 is significant, while it increases significantly at Atlantic City Marina and Indian Mills over this time

Summing up this section, Indian Mills, Atlantic City Marina, and Charlotteburg experienced significant decreases in the percent of precipitation contributed by daily precipitation events less than 1.00 inch. Atlantic City Marina had a significant increase in the percent of annual precipitation received in events of 1-2 inches, while Sussex had a significant increase in events exceeding 2 inches. The distribution of precipitation on annual timescales varies considerably between regions. The Central and Northeast regions show similarities in Gini coefficients from 1900 through 2019 other than a departure from 1960-1980. The Gini coefficients in the Southwest and Coastal South regions increase from 1900 through 2010, indicating that a greater percentage of annual precipitation is delivered in the largest precipitation events. In contrast, the Gini coefficient of the Northwest region decreases over the same time period, indicating that moderate precipitation events are increasing in impact on annual precipitation totals as opposed to light or heavy precipitation events.

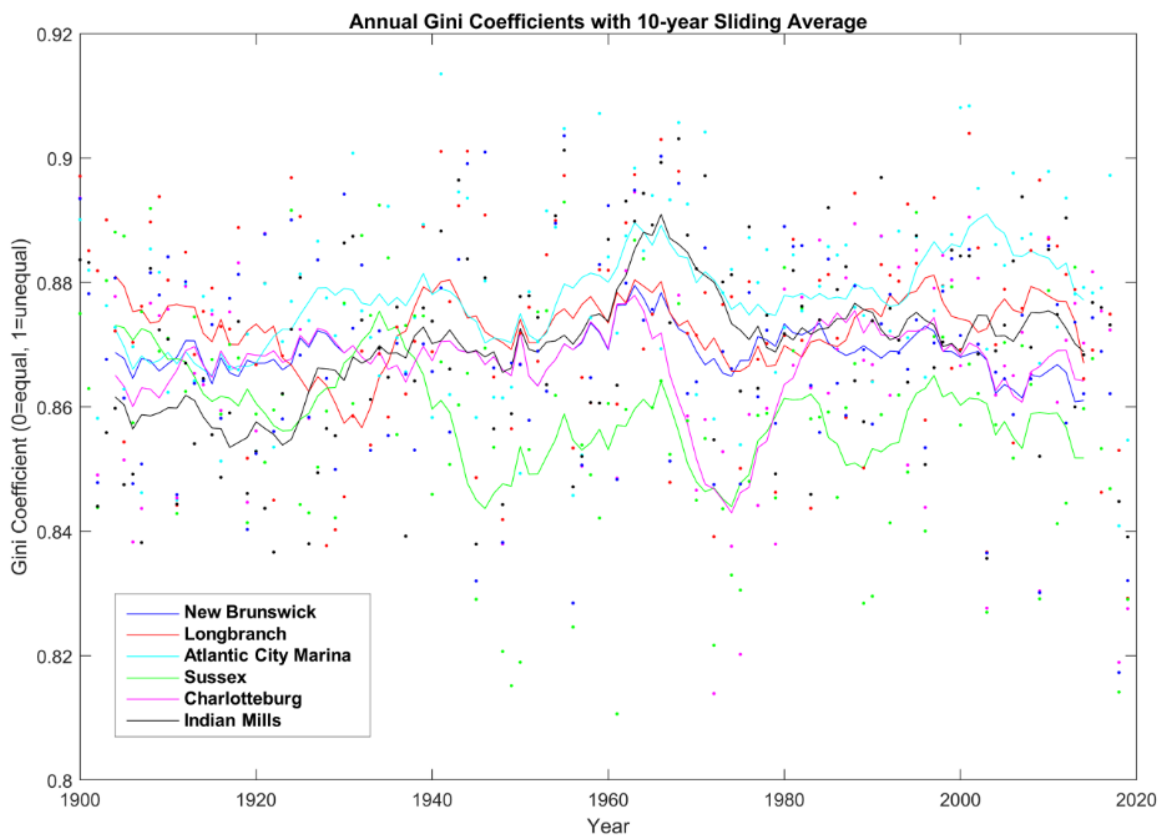


Figure 31. *Annual Gini coefficient for each year (points), with 10-year sliding average (lines). Stations are indicated by colors as shown in legend.*

Lorenz curves for annual precipitation

For a further examination of the distribution of precipitation by different daily amounts, Lorenz curves are employed. They show the cumulative percent of precipitation delivered by each daily precipitation event when ranked from smallest to largest. A Lorenz curve that closely approximates a 1:1 line indicates that the light and moderate daily precipitation events had substantial contributions to the annual precipitation total. A deep curve indicates that a relatively small proportion of annual precipitation is received from the lighter end of the precipitation distribution and a large proportion of annual precipitation is delivered in a limited number of heavy daily precipitation events.

By plotting the annual Lorenz curves from 1900-2019, changes within the annual precipitation distribution can be ascertained (figure 32). Here, the color of the curve indicates year, with indigo representing 1900, the mid-20th century years shown in blues, and recent years shown in yellows. This color scale allows an assessment of how recent precipitation distributions (plotted last (therefore on top) and in yellow) compared to those of previous years. For example, the annual Lorenz curves at the Sussex station show that the yellow curves, the more recent years, are below the blue curves from the 20th century. This shows that in the 20th century, the moderate precipitation events (1-2 inches) up to the 60th percentile (0.6) contributed approximately 15-20% of the annual precipitation. In contrast, daily precipitation events of the same percentile after 2000 contributed approximately 7%-15% of the annual precipitation. This means that more of the annual precipitation was delivered in the heaviest percentiles of daily precipitation in the 21st century than in the 20th. A similar pattern is observed at New Brunswick. This pattern is reversed at the Indian Mills station, where the placement of 21st century Lorenz curves above curves from earlier years indicates that precipitation has been distributed more equally across precipitation days in recent years than it was earlier in the time series. More recent annual Lorenz curves at Charlotteburg, Long Branch, and Atlantic City Marina are within historical boundaries.

Thus, once again, there is no clear pattern in the distribution of precipitation by daily amounts across the six drought regions. Heavier daily totals are contributing more to recent decades in the northwest and central regions, while Indian Mills shows the opposite. There are no clear signs of a change in precipitation distribution in the other three regions.

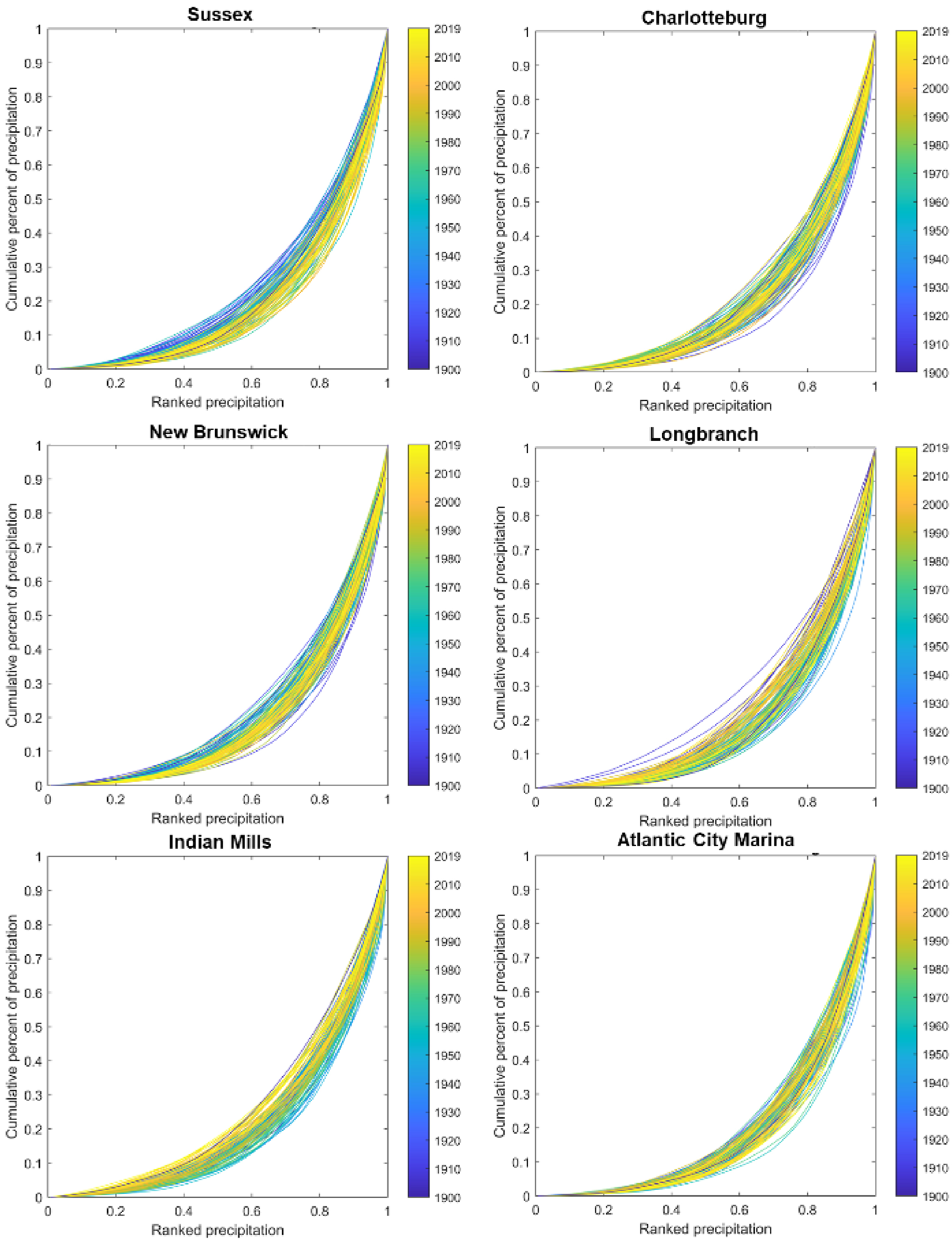


Figure 32*. Lorenz curves for annual precipitation, 1900-2019, for each region. Years are indicated by color.*

3) New Jersey-wide precipitation (1950-2020)

The purpose of sections 3 and 4 of the report is to focus on precipitation variability across New Jersey during the past 70 years. As previously in section 1 for 1900-2020, a statewide assessment is presented in this section. Section 4 will examine the six drought regions, subdivided into 1950-1999, 1980-1999, and 2000-2019 intervals to evaluate potential changes among the different decades. For five of the six study regions, in addition to the Tier 1 stations used in the 1900-2019 portion of the report, a Tier 2 station has been added (a suitable second station is unavailable for the coastal north region). This provides a more complete assessment of conditions within a region, including potential differences between the region station pairs. This was made possible by the availability of more stations in the second half of the 20th century to present than earlier in the century.

Looking statewide, the annual mean from 1950-2020 is 46.20” (figure 33). The time series clearly shows the drought years of the 1960s and the two record wet years of 2011 and 2018. The overall increasing trend is at a rate of 8.11” per century. Each season has exhibited an increasing trend in precipitation over the past 71 years (figures 34-37). Unlike the 1900-2020 trend where almost all of the upward annual trend was driven by fall and spring increases, summer had the most pronounced trend in recent decades, at a 3.71” per century rate. Also apparent in summer and fall was increased interannual variability over the past 30 years compared to earlier in the study period. When evaluating statistical significance, only the annual increasing trend tests as significant, while summer just misses the mark. In the case of annual precipitation, the two-tailed p-value is less than 0.05, making for a statistically significant relationship ($r=0.2449$, $p=0.040$) between year and annual precipitation.

Delving more into each season, winter averaged 10.26”, with a 1979 maximum. Winter precipitation did not see a mid 1960s minimum that was seen in the annual (and other seasons) record. Precipitation has increased at a 1.33” per century rate. Spring averaged 11.74” and exhibited a mid-1960s minimum and pronounced maximums in consecutive years (1983 and 1984). The smallest upward trend of all seasons was found at 0.69” per century. Summer was the wettest season, averaging 12.92”. There was a notable four consecutive year minimum period from 1963-1966. The maximum in 2011, partially driven by rains from Hurricane Irene and an overall record wet (of any month) August, was part of the high interannual variability seen this century. However, the totals for the 2017-2020 summers were quite consistent and somewhat above average. Fall averaged 11.25” and increased at a rate of 2.33” per century. The season exemplifies the increased variability over the past 30 years, with 2001 being the 71-year minimum and 2018 the maximum.

To summarize, New Jersey precipitation has increased in all seasons over the past 71 years, led by summer. Increased interannual variability has accompanied these trends, particularly in summer and fall. The two record wet years going back to 1900 occurred in 2011 and 2018. The mid-1960s drought was particularly evident in summer totals and least seen in winter.

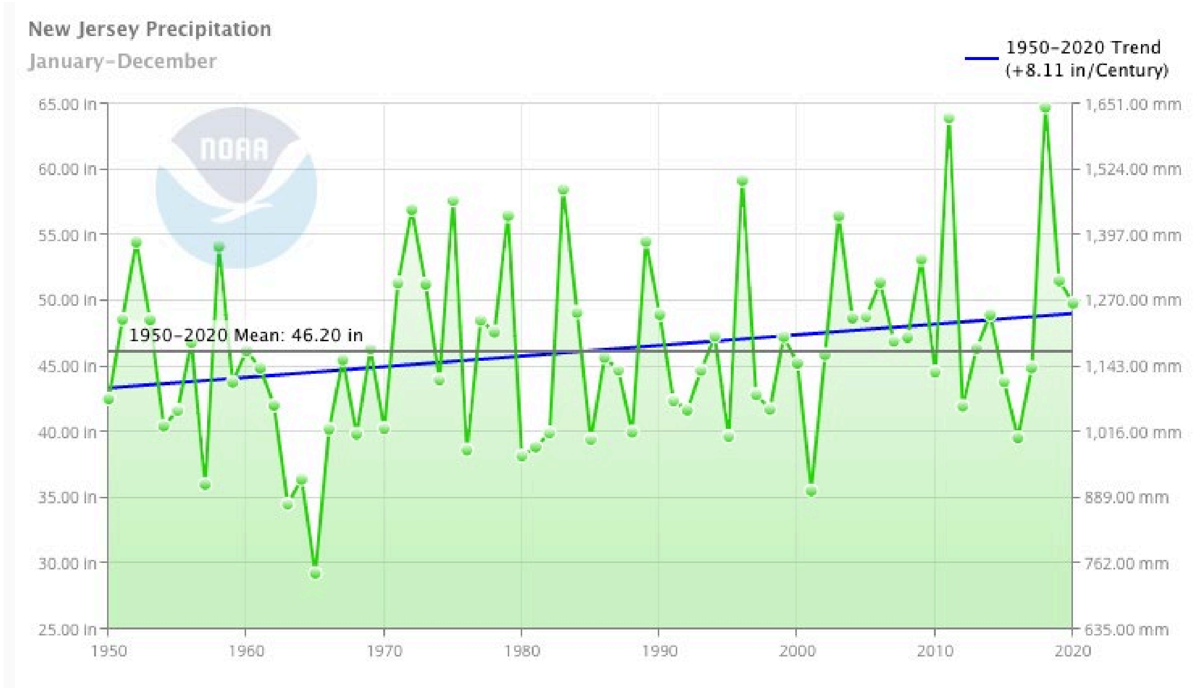


Figure 33. *New Jersey annual precipitation from 1950-2020 and a linear regression for the period of record (blue line). The trend per century is shown in the top right. Data and graph from Climate at a Glance (NCEI).*

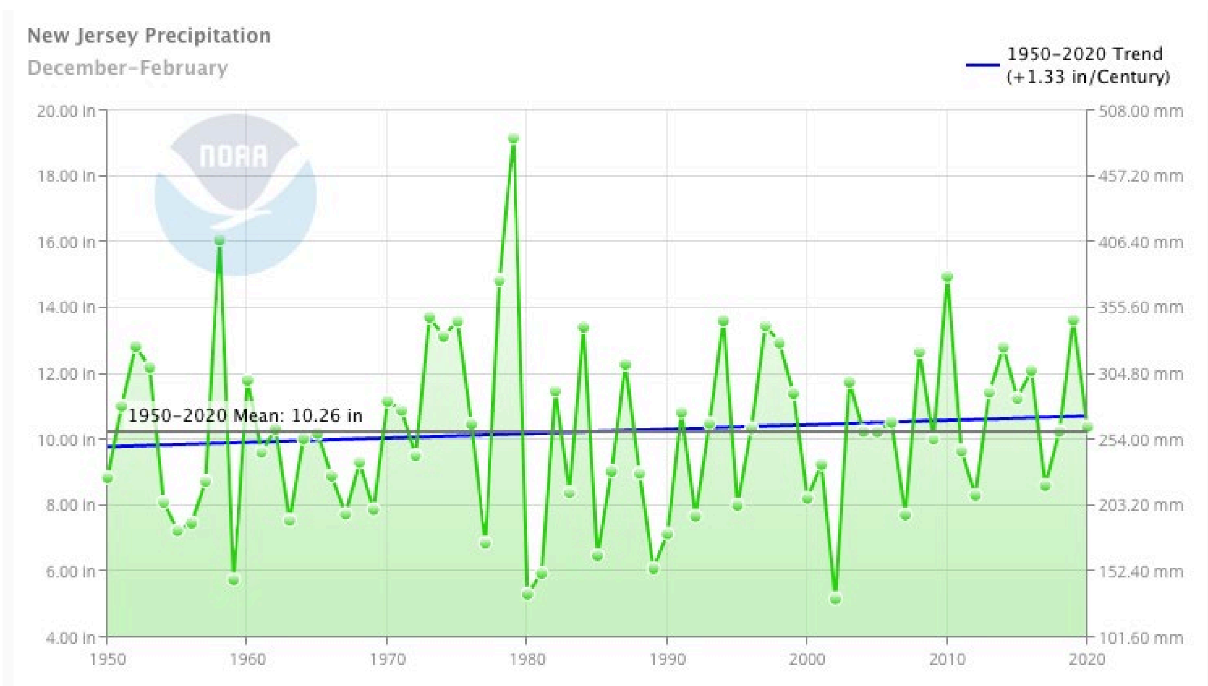


Figure 34. *New Jersey winter precipitation from 1949/50-2019/20 and a linear regression for the period of record (blue line). See figure 33 for more information.*

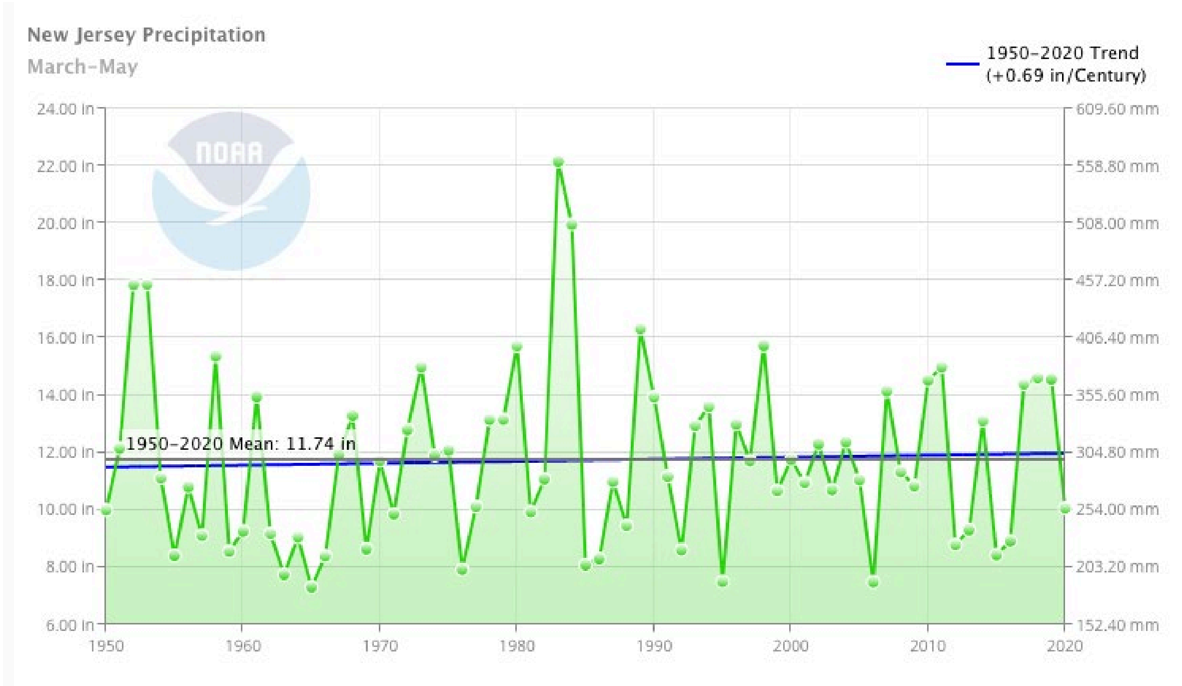


***Figure 35**. New Jersey spring precipitation from 1950-2020 and a linear regression for the period of record (blue line). See figure 33 for more information.*

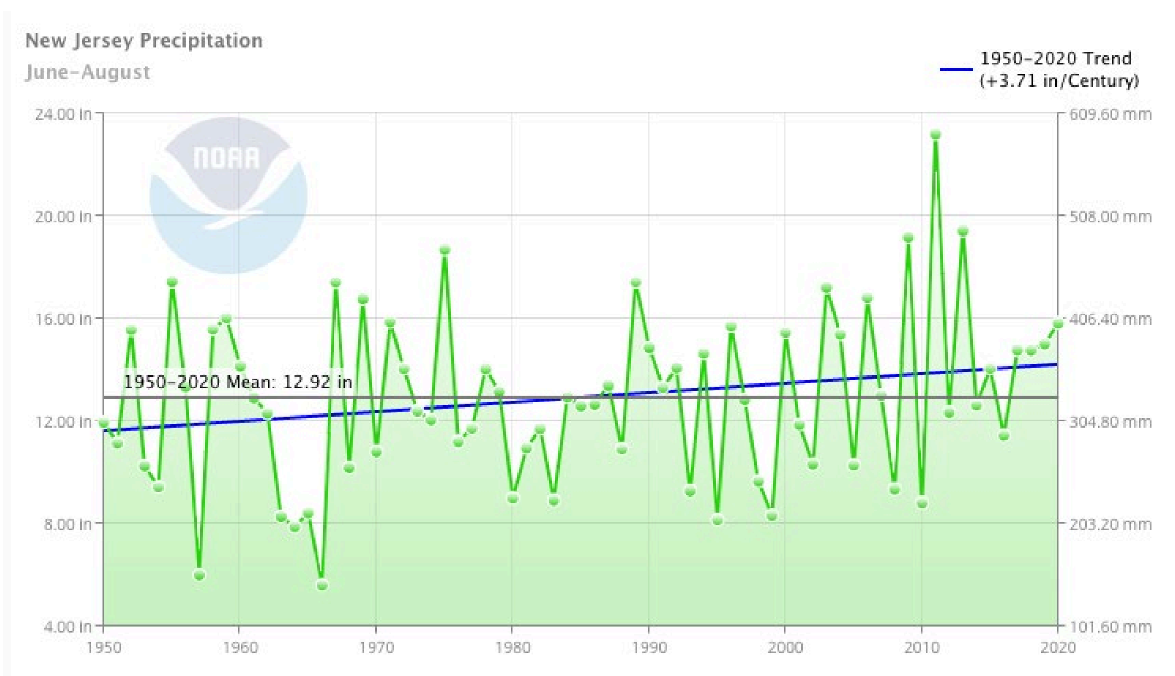


***Figure 36.** New Jersey summer precipitation from 1950-2020 and a linear regression for the period of record (blue line). See figure 33 for more information.*

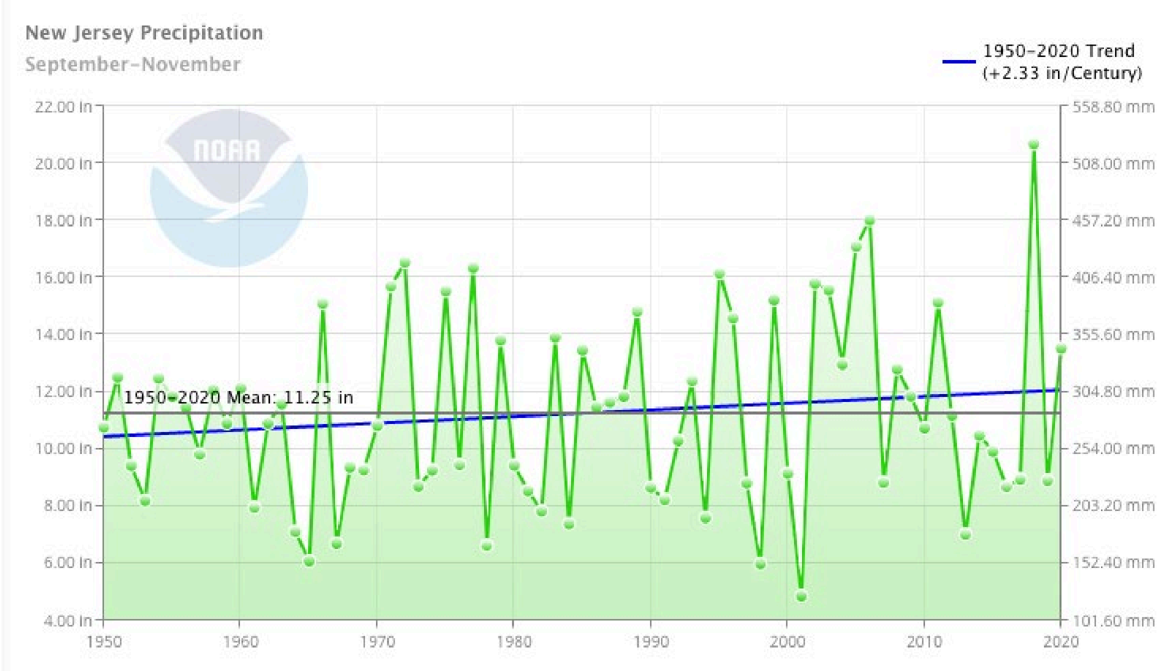


Figure 37. *New Jersey fall precipitation from 1950-2020 and a linear regression for the period of record (blue line). See figure 33 for more information.*

4) Regional precipitation (1950-2019)

As introduced at the beginning of section 3, section 4 looks at precipitation within each of the six regions over the 1950-2019 70-year period. As reported previously for the 120-year historic record, within each region stations are examined for annual totals, counts of days above selected thresholds, and percentage of days with measurable precipitation above these thresholds. Unique to this section are analyses of the number of days it takes to accumulate values of 0.50”, 2.00”, 10.00”, and 20.00”. For each day of the year, a running sum of precipitation is calculated until the total exceeds the base values. The median, 25th and 75th percentiles are plotted on figures that permit comparisons of analyses performed from 1950-1999 and 2000-2019, and also from 1980-1999 and 2000-2019. For example, for each January 1 between 1950-1999, the number of days moving forward that it takes to accumulate 10.00” is counted and the 50 years of counts are binned. This is next done for counts that begin on January 2, and so on through December 31. By plotting the 25th and 75th percentiles of the binned counts for each day of the year, seasonal variations in the time it takes to reach each precipitation mark can be evaluated. Also, by pairing results from two intervals on the same figure, differences between them can be discerned.

Northwest

Annual totals for the Sussex and Flemington stations have both increased over the study period (figure 38). The mid-1960s drought is evident at both, particularly at Sussex, with a wet 1970s and often wet 21st century noted at both stations. See Appendix B2 for significance values for these and days with precipitation analyses to follow in this section. Days with precipitation of at least 0.10”, 0.50”, and 2.00” have trended slightly upwards at both stations, while no discernable trend is noted at 1.00” and greater (figure 39). When precipitation occurs, the percentage of days exceeding the thresholds appear higher for the 0.50”, 1.00”, and 2.00” levels at Flemington compared to Sussex, suggesting more light precipitation days at Sussex (figure 40). No discernable trends at any threshold are noted at either station.

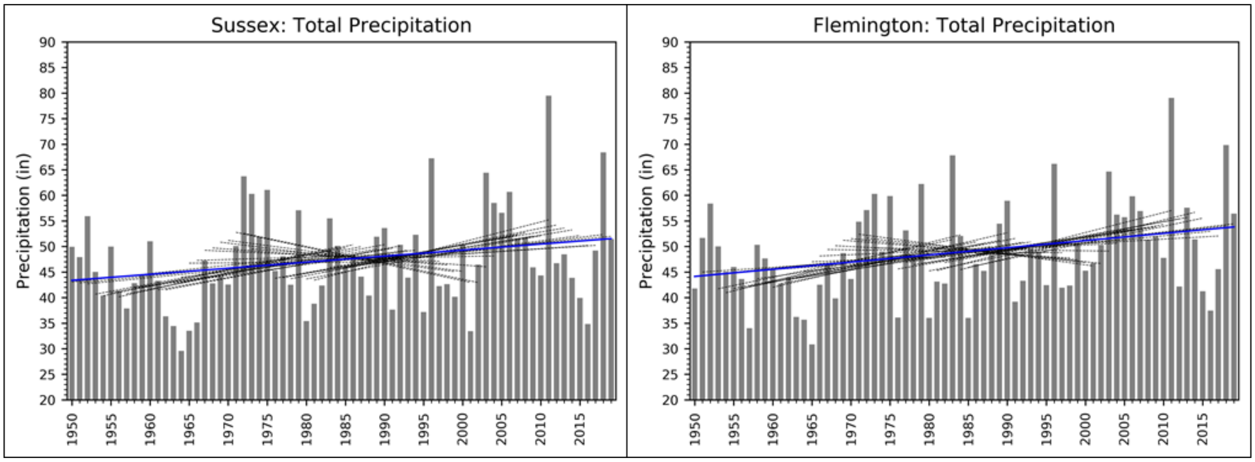
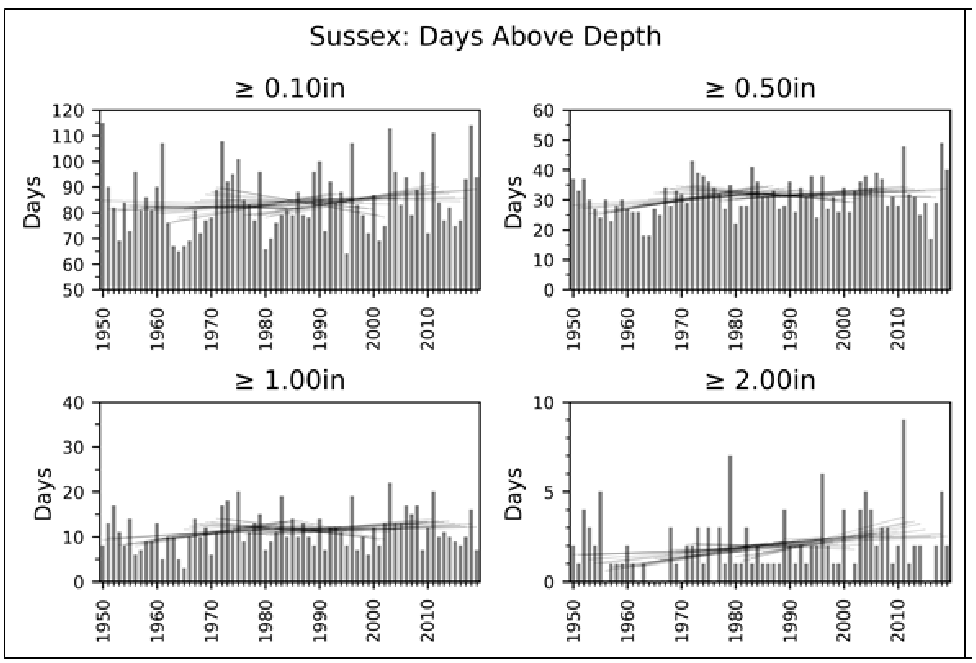


Figure 38*. Total annual precipitation between 1950-2019 at Sussex (left) and Flemington (right). The dotted lines are 30-year linear regressions while the solid line is the 70-year regression.*



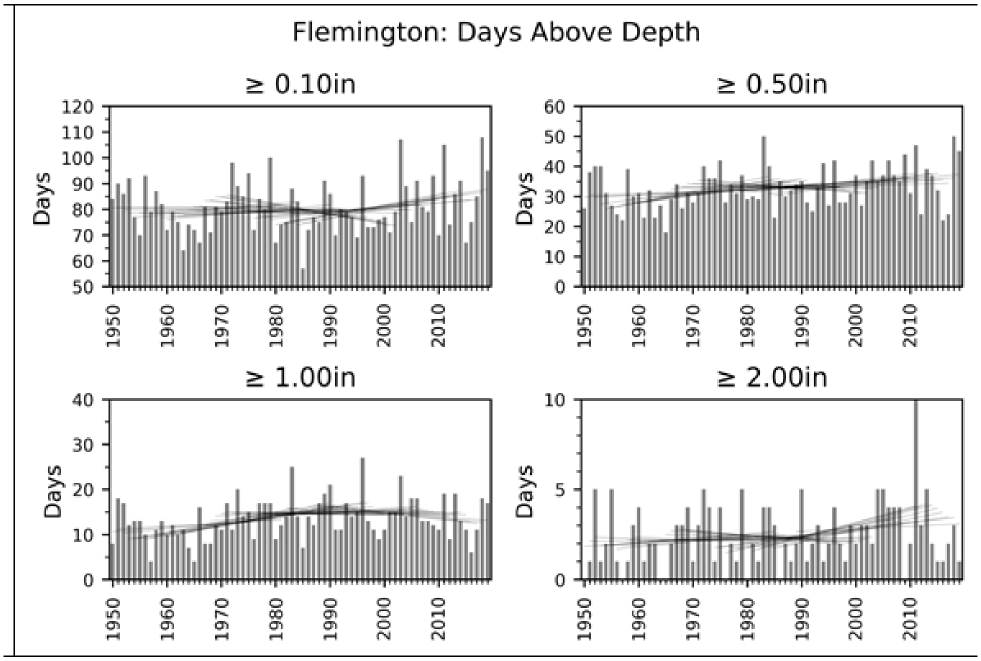
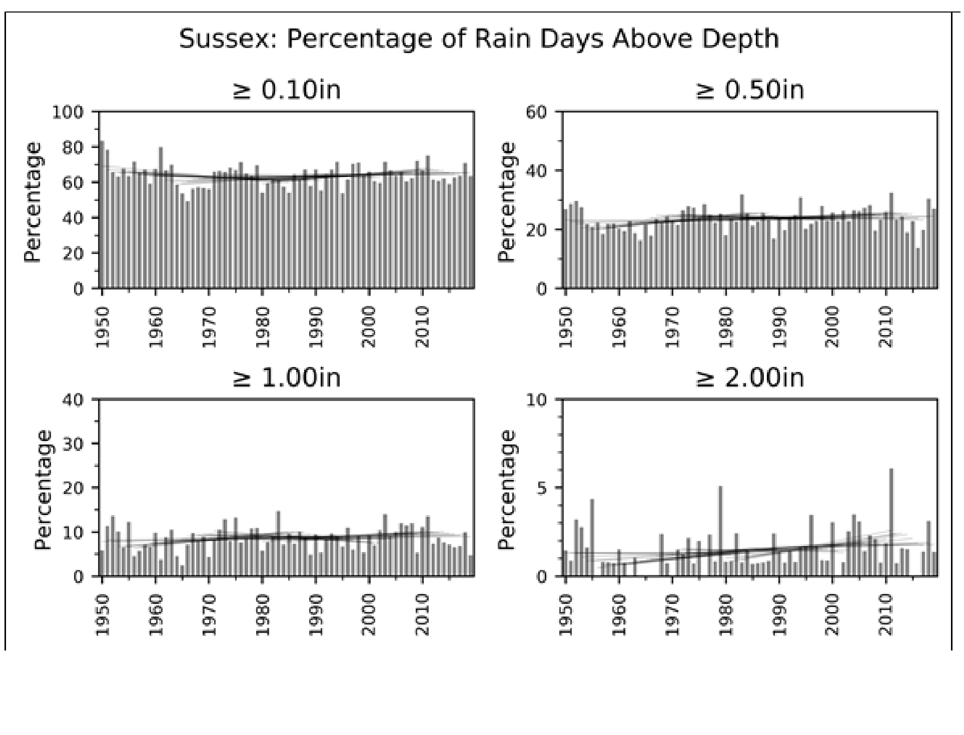


***Figure 39**. The number of days per year with daily precipitation equal to or exceeding four thresholds (bars) at Sussex (top) and Flemington (bottom). Solid lines show 30-year linear regressions, the dashed line is the 70-year trend.*



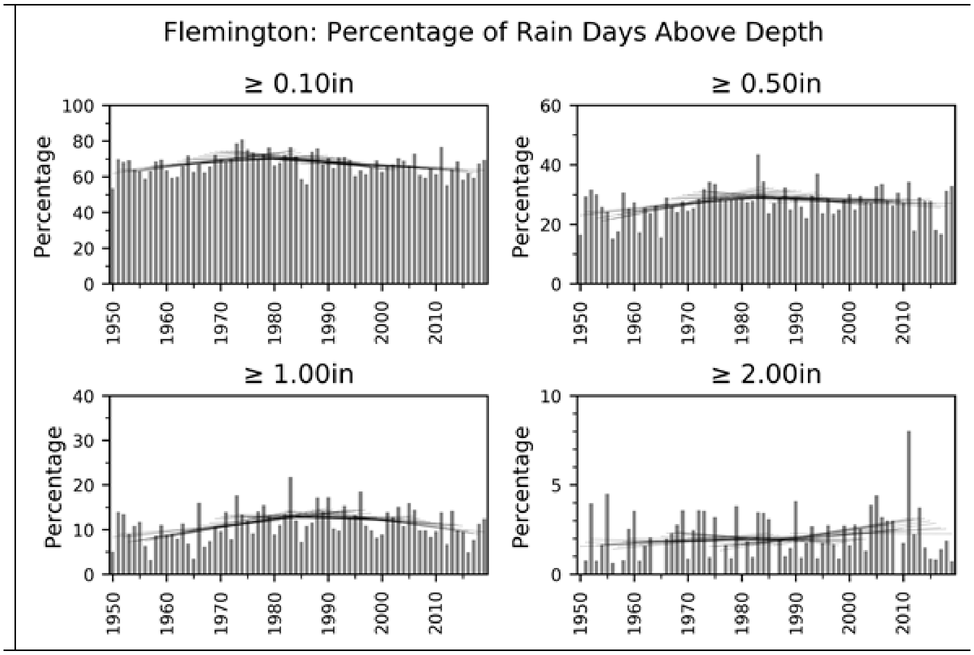
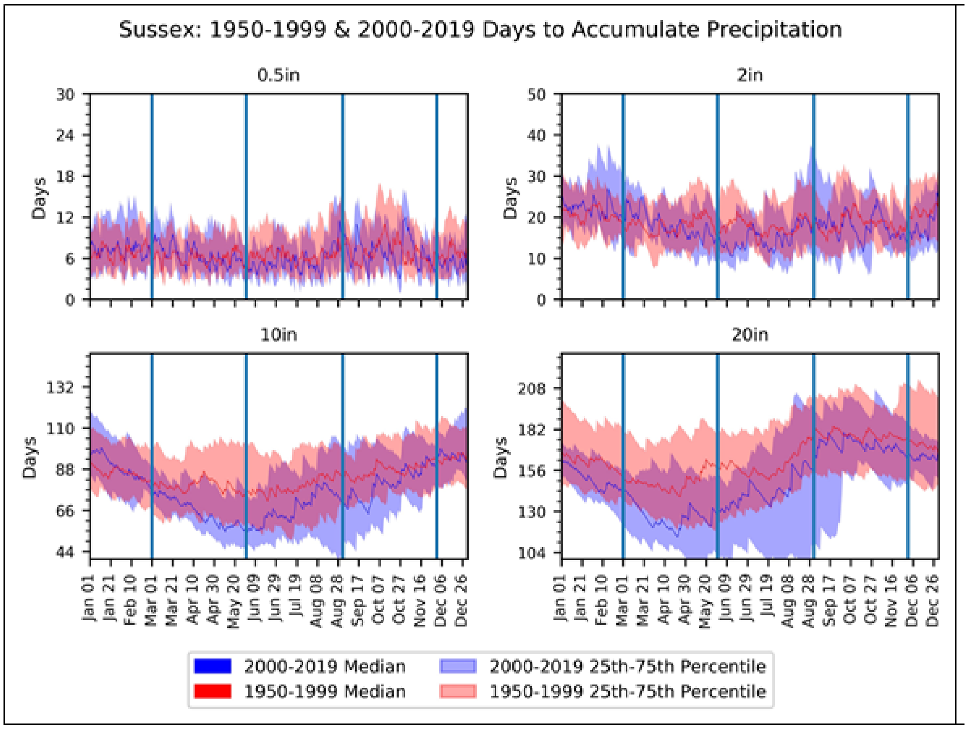


***Figure 40**. Percentage of precipitation days above various threshold depths at Sussex (top) and Flemington (bottom). Dotted lines show the 30-year trend.*

An examination of days to accumulate precipitation in the northwest finds little seasonally at the 0.50" and 1.00" levels (figure 41). It takes the fewest days to get to 10.00" and 20.00" in spring and summer. In late summer and fall it takes more days to reach 20.00" than at other times of the year, particularly at Sussex. Comparing 1950-1999 and 2000-2019, there is little difference at 0.50" and 2.00" at any time of the year. There are considerable differences at 10.00" and 20.00", particularly at Sussex. Daily medians and 25th and 75th percentiles show a slower achievement of these totals throughout the year in the 10–20-day range in the earlier period compared to the most recent two decades, particularly at the 75th percentile level for 10.00". The 25th percentile was reached fastest in late spring to early fall from 2000-2019. The same was seen at 20.00" from spring to early fall, especially at Sussex. This was less pronounced at Flemington but included the winter. The 1980-1999 period compares to 2000-2019 in an almost identical manner to that discussed here for the 1950-1999 comparison (figure 42).



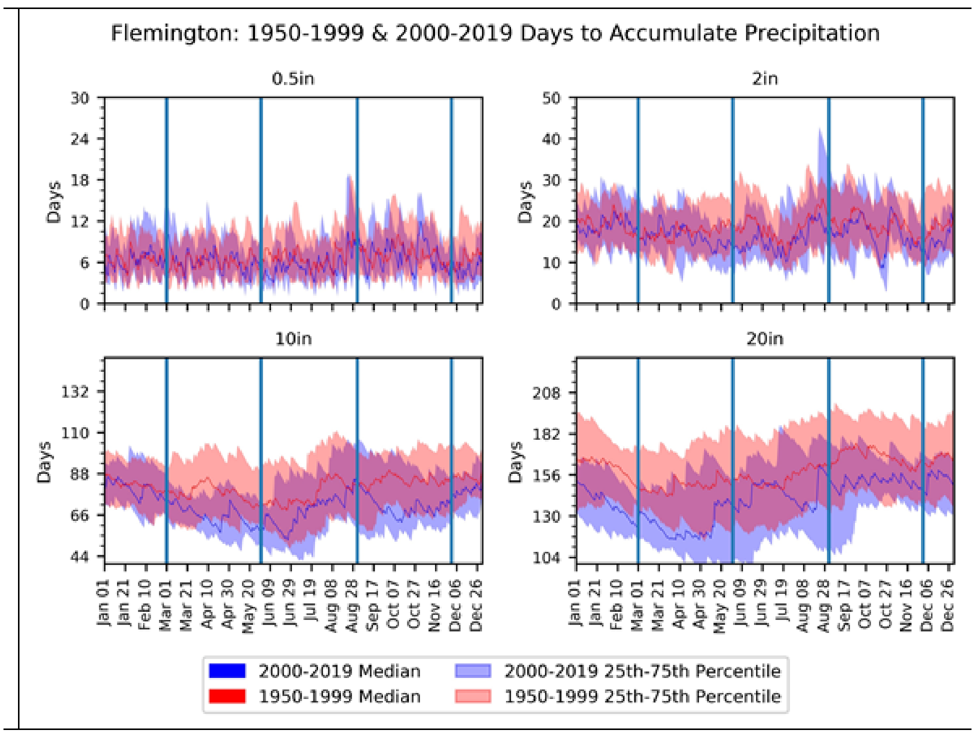
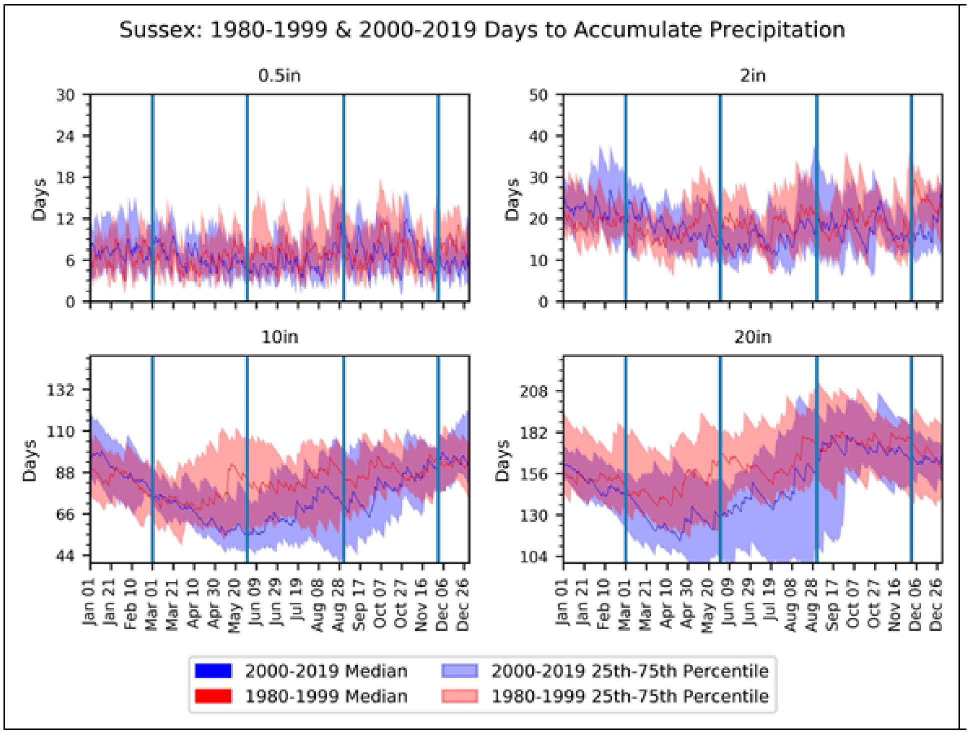


Figure 41. *The number of days it takes to accumulate multiple threshold values at Sussex (top) and Flemington (bottom). For each day of the year, a running sum of precipitation is calculated until the total exceeds the base value (e.g., 0.50", 1.00", etc…). The median, 25th and 75th percentiles are shown for both 2000-2019 and 1950-1999 periods. The solid vertical lines define the start of meteorological seasons.*



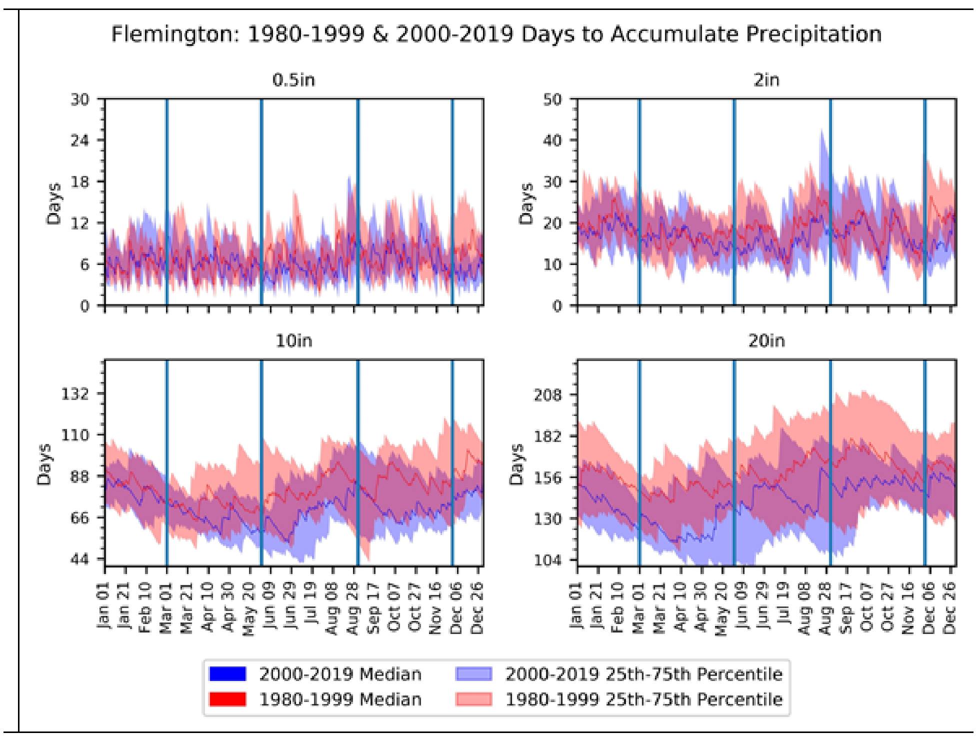


Figure 42*. Same as Figure 41 except for 2000-2019 and 1980-1999 periods.*

Northeast

While Newark receives about 5” less annual precipitation than Charlotteburg, the two Northeast stations show much the same interannual variability and an overall upward trend in precipitation (figure 43). The major portion of the upward trend was from the 1950s into the 1970s.Since then there has been a leveling off of values. This is also noted in the four depth categories (figure 44). There has been little change in the 0.10” and 0.50” percent of precipitation days categories over the 70 years at Charlotteburg (figure 45). At Newark, there was a slight upward trend in early decades at 0.50” before leveling off. This type of behavior was also seen at 1.00” for both locations and at Charlotteburg for 2.00”. Newark showed a decline at 2.00” since the 1970s but not to levels seen early in the period.

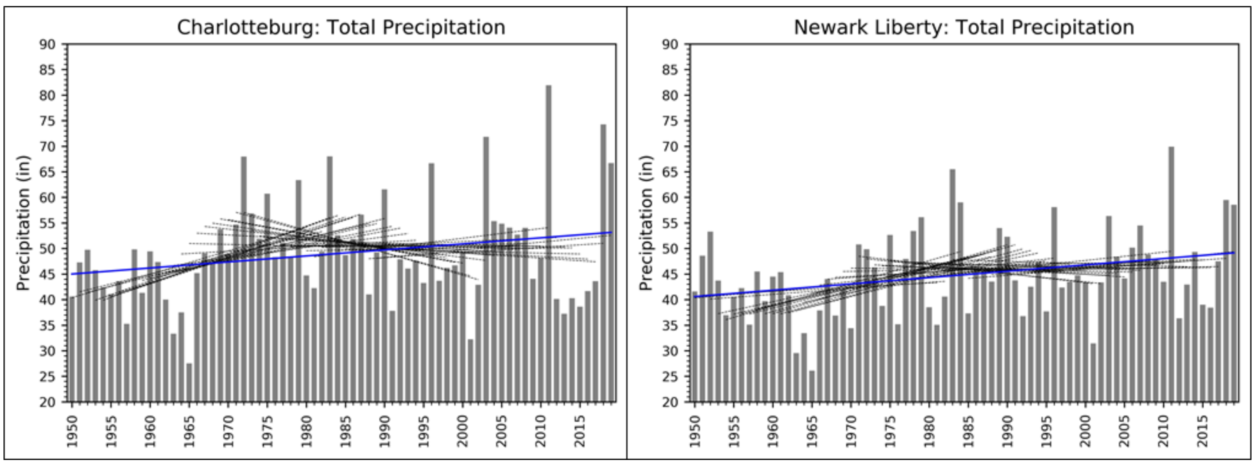
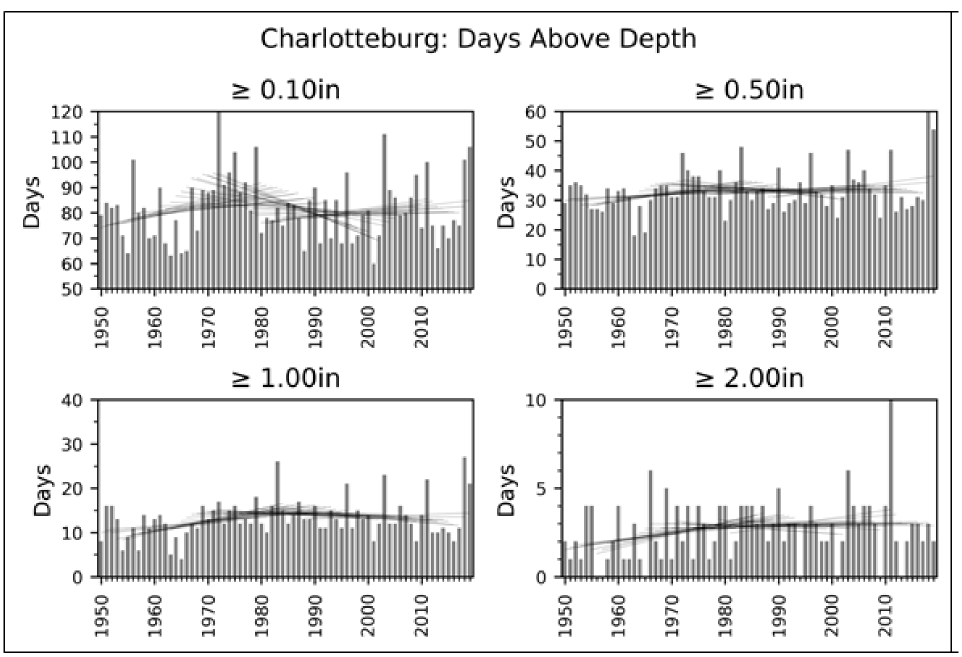


Figure 43*. Total annual precipitation between 1950-2019 at Charlotteburg (left) and Newark (right). See Figure 38 for further information.*



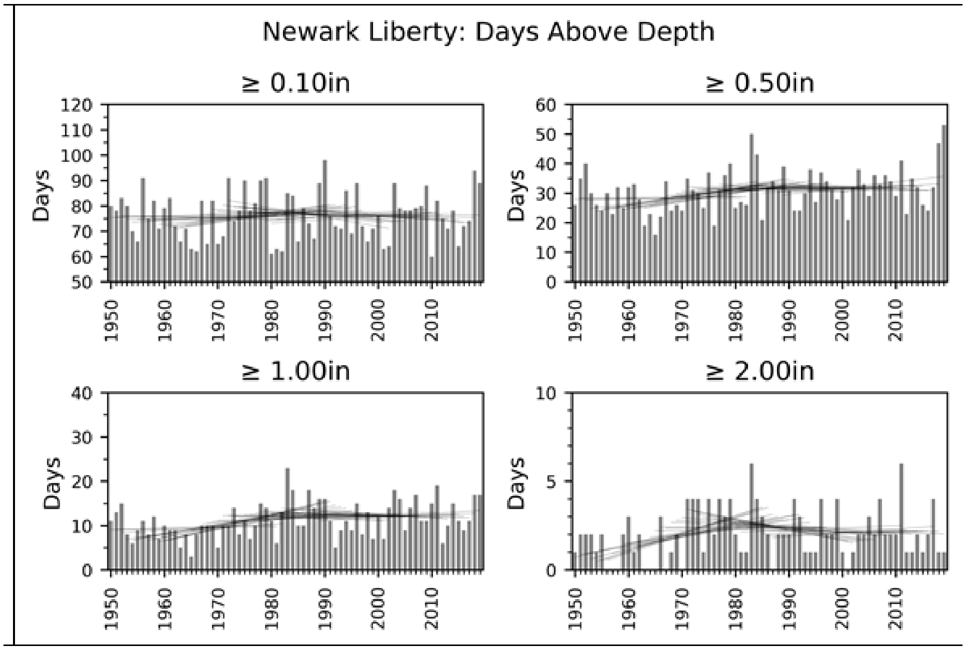
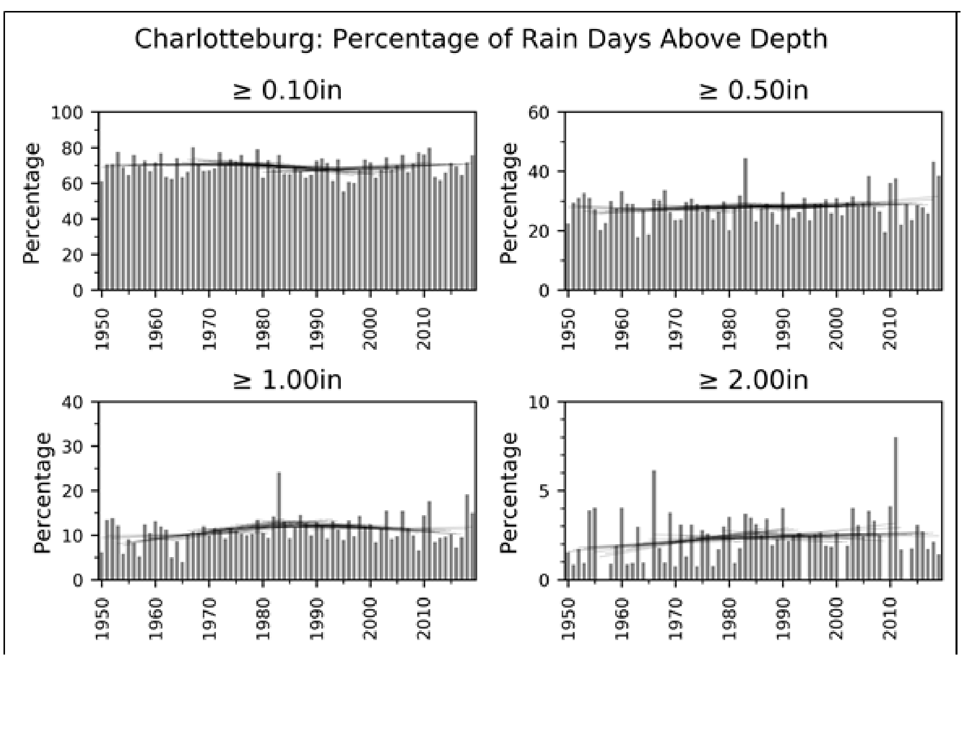


Figure 44. *The number of days per year with daily precipitation equal to or exceeding four thresholds (bars) at Charlotteburg (top) and Newark (bottom). See Figure 39 for more information.*



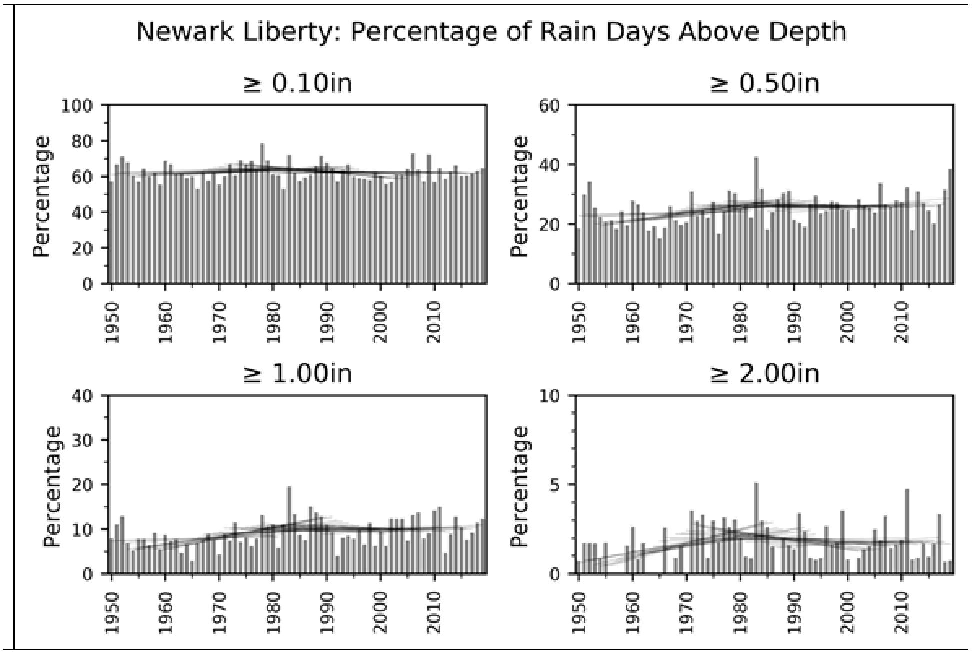


Figure 45. *Percentage of precipitation days above various threshold depths at Charlotteburg (top) and Newark (bottom). Dotted lines show the 30-year trend.*

The pace of accumulating 0.50” does not change much over the course of the year nor has any trend been noted over the study period (Figure 46). Both locations show a more rapid accumulation of 2.00” in the past 20 years compared to the previous 50 years, particularly in spring, early summer, and early winter. The pace of accumulating 10.00” and 20.00” is fastest in late spring and summer. It is appreciably slower, particularly at 20”, in fall and winter. This holds throughout the 70-year period. The past 20 years has also been faster to 10.00” from spring through fall, most pronounced at Charlotteburg in spring and fall. The 20.00” mark was reached more rapidly recently at both locations from spring through fall. This is quite pronounced at Newark, and even includes winter. The recent median at Newark in spring is as much as 30-40 days faster than in earlier decades. The patterns for the 1980-99 comparison with 2000-2019 are similar to those noted for 1950-99, though not quite as pronounced (figure 47).

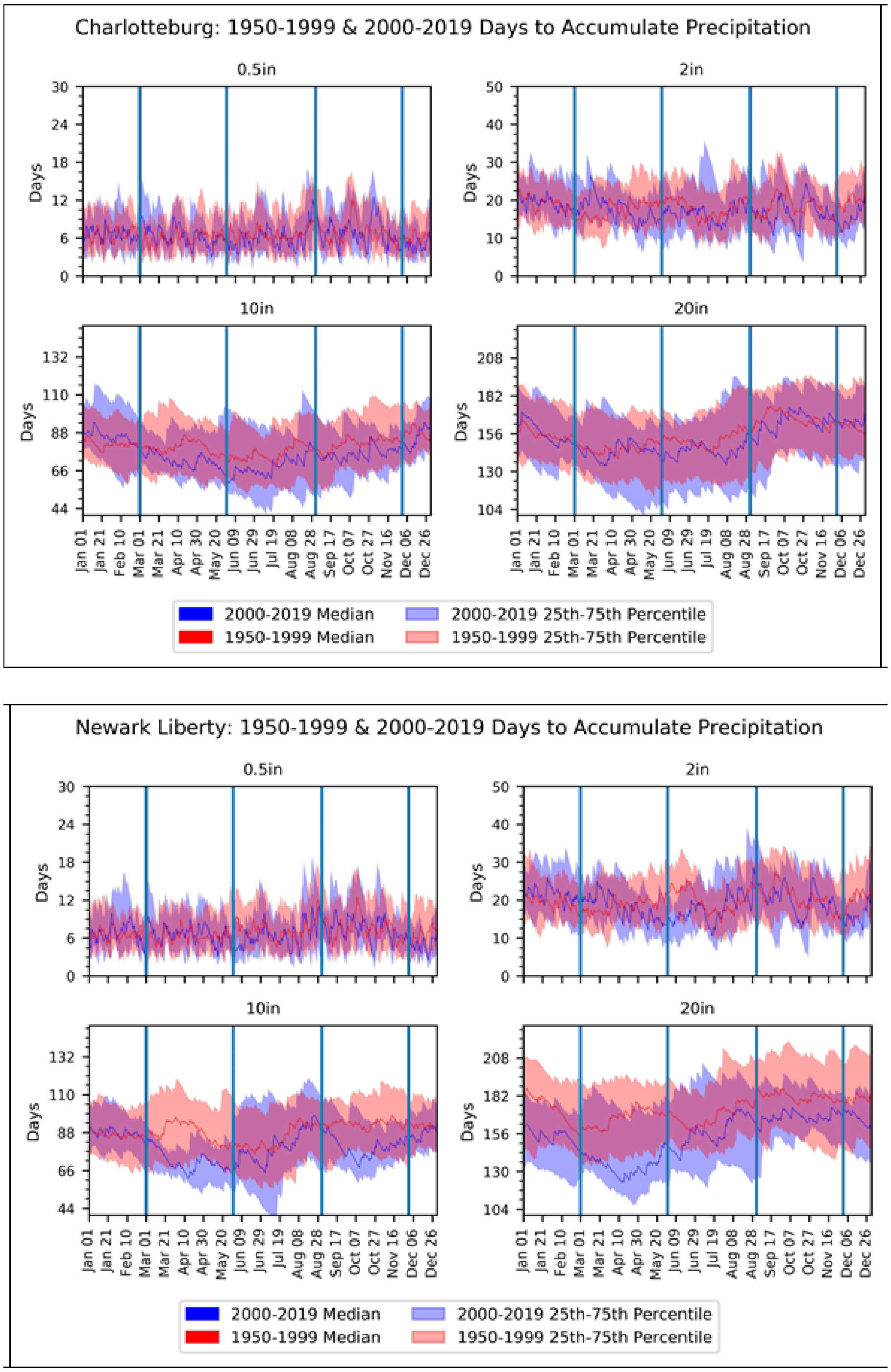


Figure 46. *The number of days it takes to accumulate multiple threshold values at Charlotteburg (top) and Newark (bottom) for both 2000-2019 and 1950-1999 periods. See Figure 41 for further information.*

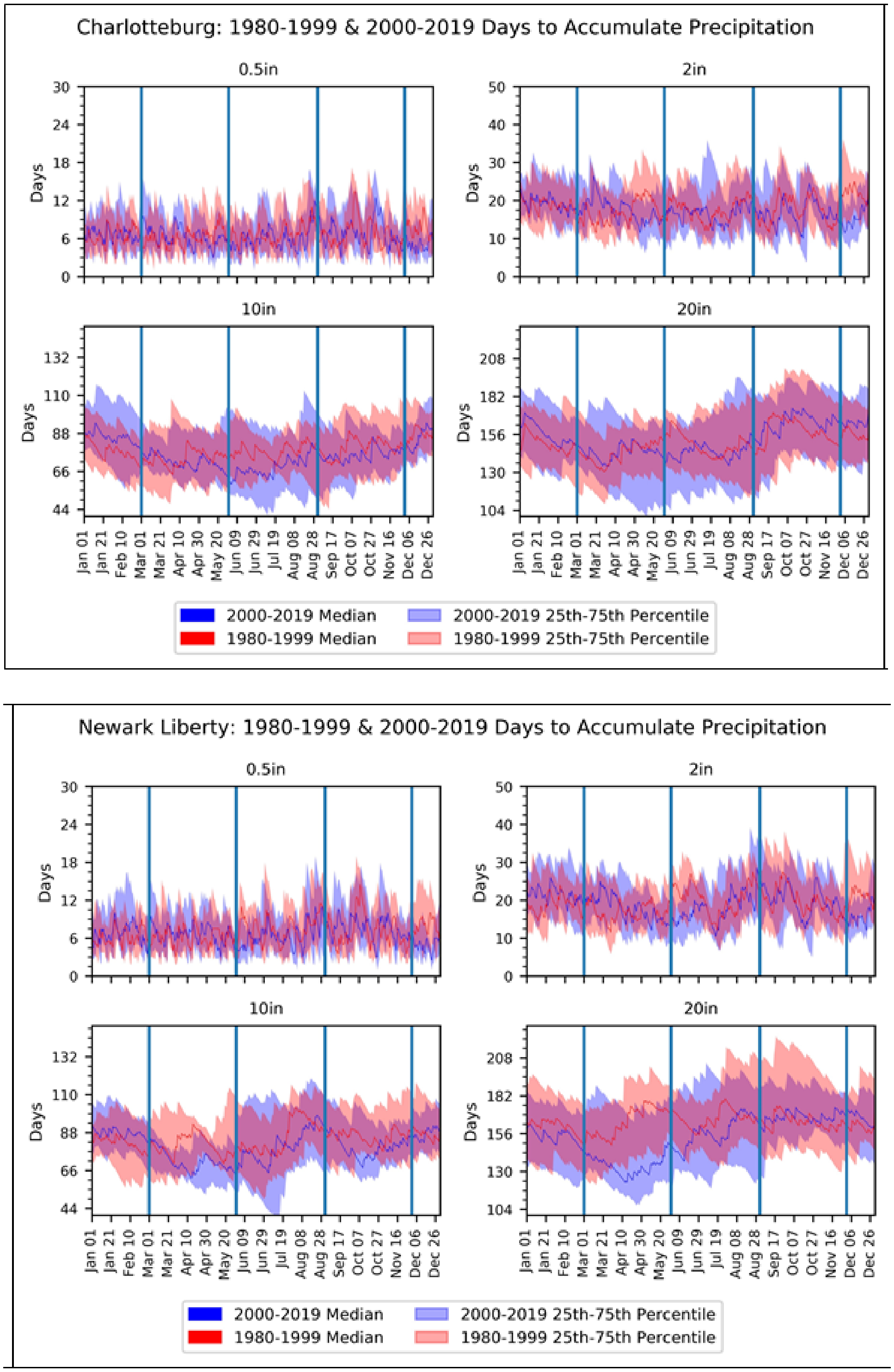


Figure 47*. Same as figure 46 except for 2000-2019 and 1980-1999 periods.*

Central

Annual totals are quite similar at both New Brunswick and Hightstown (Figure 48). Trend-wise they are similar too, with totals rising to the 1970s, leveling off in the 1980s and 1990s and rising in recent decades, though with some notable interannual variability. Days exceeding 0.10” increased in the past two decades, over 0.50” totals rose in early decades and subsequently remained rather stable (figure 49). A peak of 1.00” or greater days occurred in the 1970s, while 2.00” days showed no discernable trend. Percentage of days over 0.10” was highest early in the study period, showed no trend at 0.50”, saw a 1970s and 1980s peak at 1.00” or greater, and was flat at 2.00” or more (figure 50).

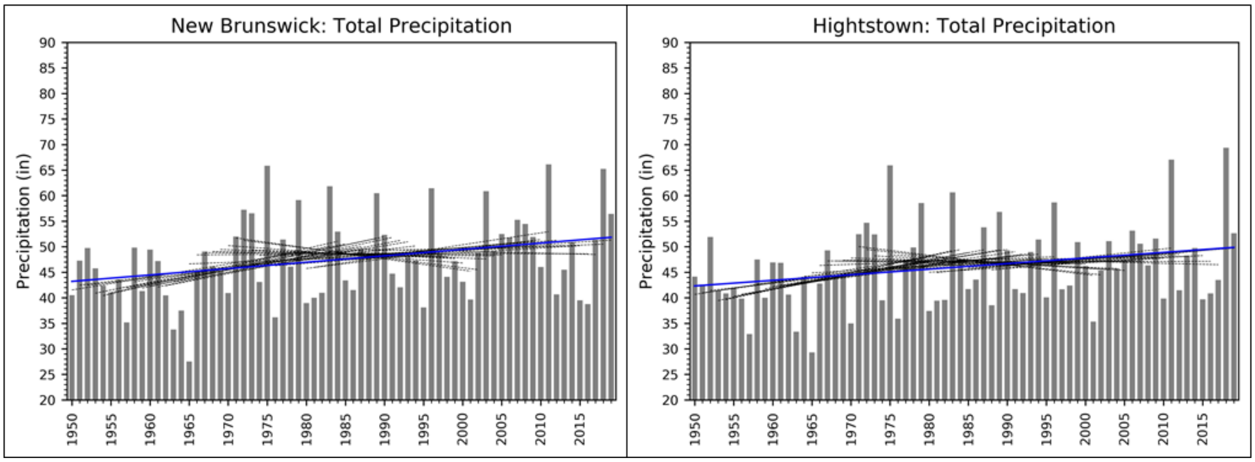
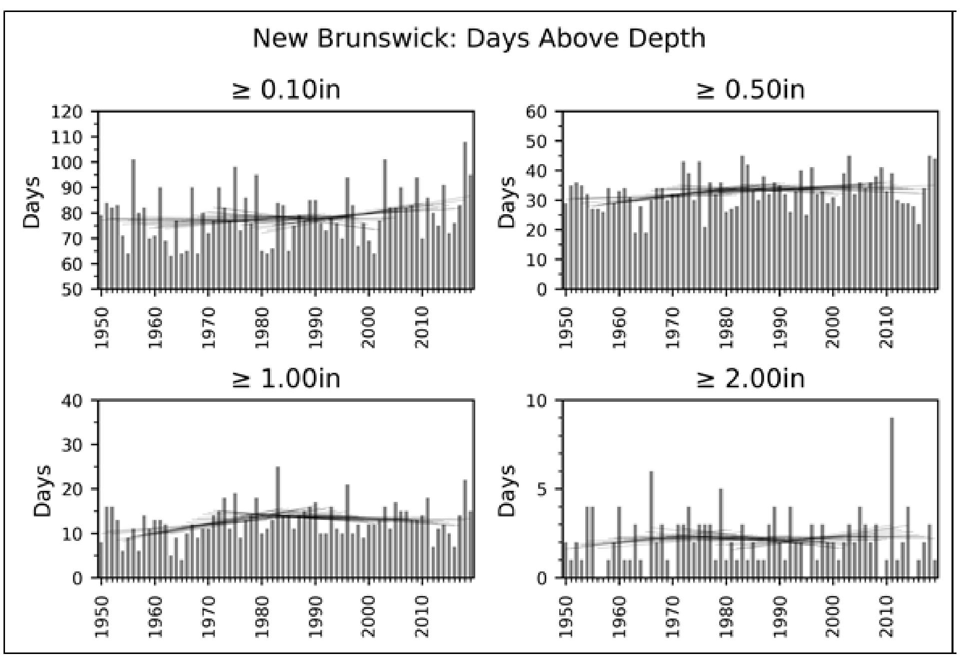


Figure 48. *Total annual precipitation between 1950-2019 at New Brunswick (left) and Hightstown (right). See Figure 38 for further information.*



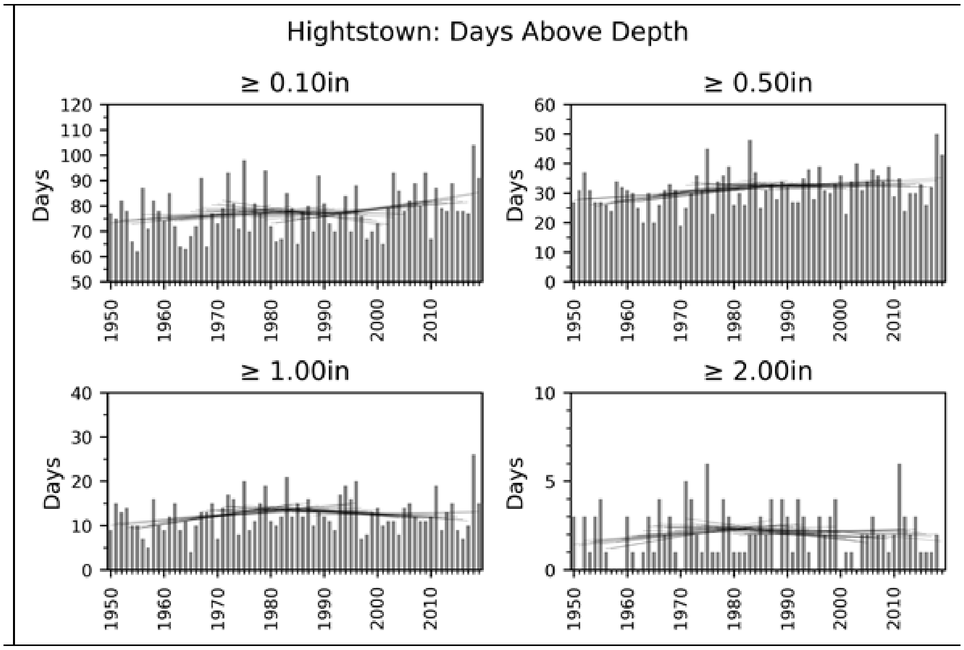
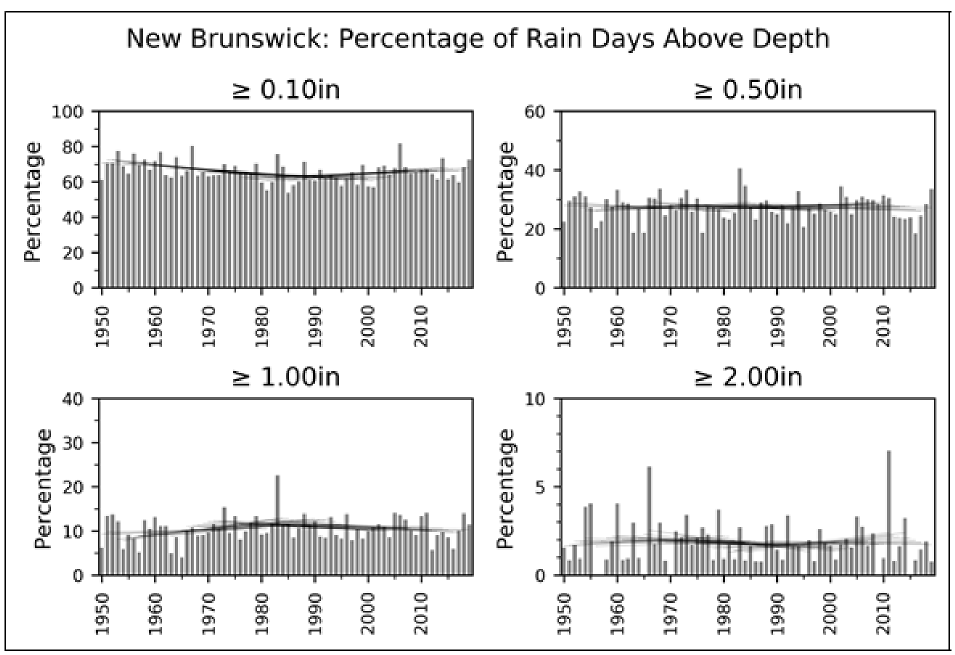


Figure 49. *The number of days per year with daily precipitation equal to or exceeding four thresholds (bars) at New Brunswick (top) and Hightstown (bottom). See figure 39 for more information.*



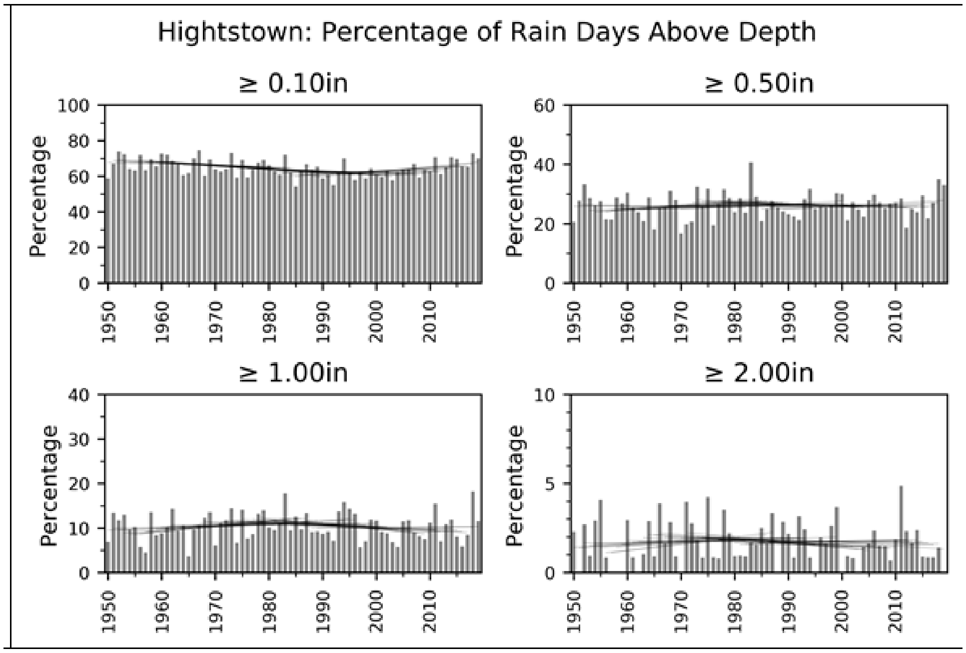


Figure 50. *Percentage of precipitation days above various threshold depths at New Brunswick (top) and Hightstown (bottom). Dotted lines show the 30-year trend.*

Accumulated totals at the 0.50” level showed little seasonality at either station (figure 51). They appeared to fluctuate randomly at 2.00”. There was clear seasonality in accumulation rates at 10.00” and 20.00” levels. At 10.00”, precipitation accumulated most rapidly in the spring and late fall and slowest in the late summer, early fall, and winter. Both intervals showed quicker spring and early summer and slower late summer and early fall accumulations. Throughout a large majority of the year at 10.00” and 20.00”, the most recent two decades saw faster accumulations than the first five decades. The same overall patterns were found when comparing 1980-1999 with 2000-2019, though somewhat less pronounced than when looking at the full early 50-year interval (figure 52).

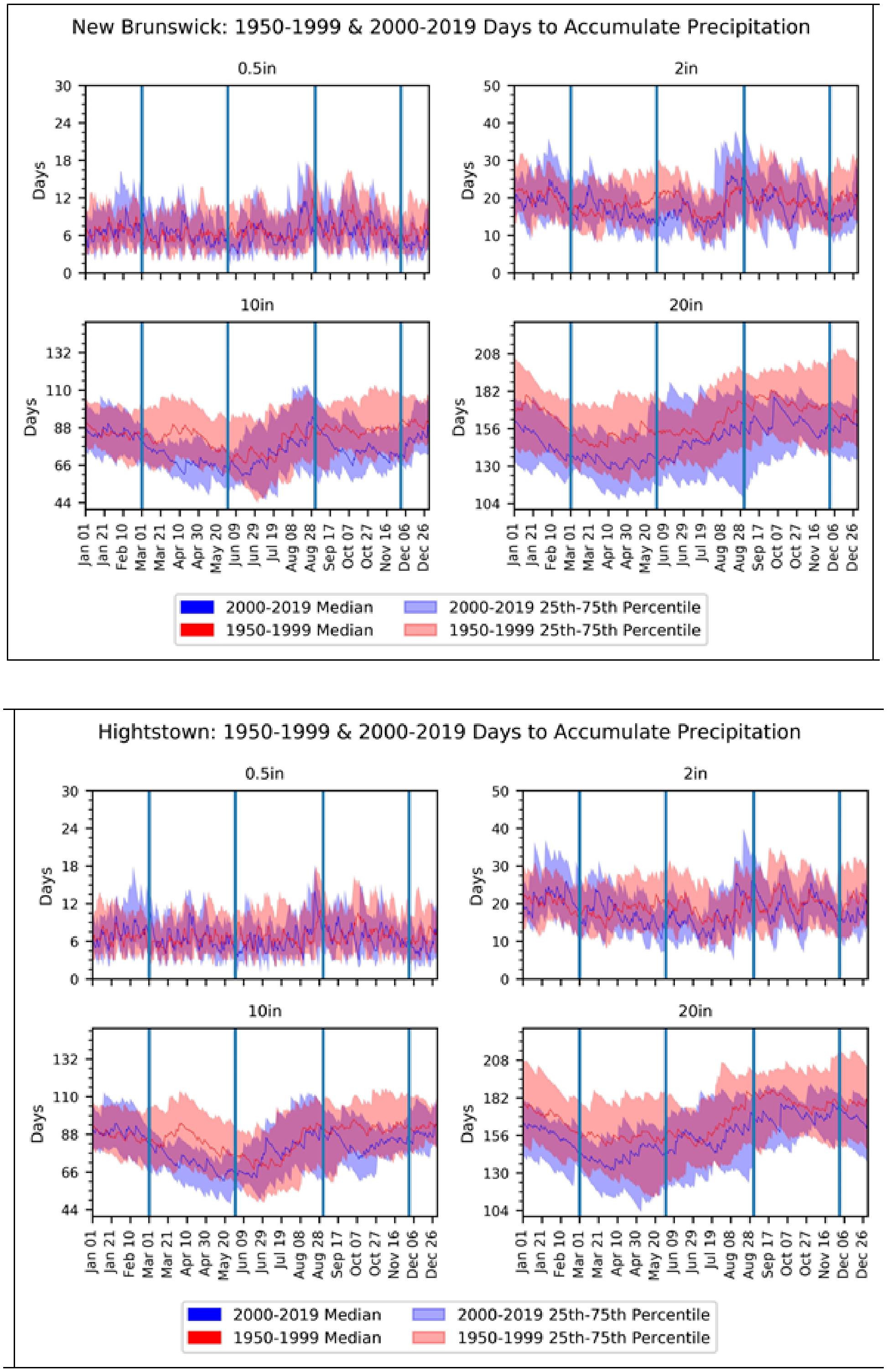
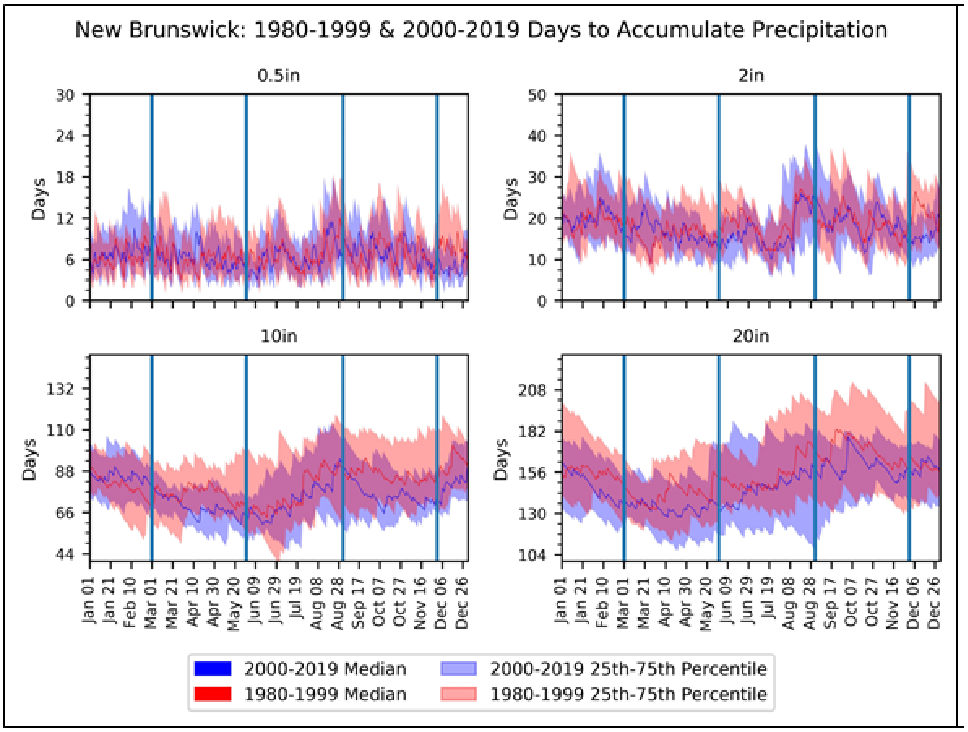


Figure 51. *The number of days it takes to accumulate multiple threshold values at New Brunswick (top) and Hightstown (bottom) for both 2000-2019 and 1950-1999 periods. See Figure 41 for further information.*



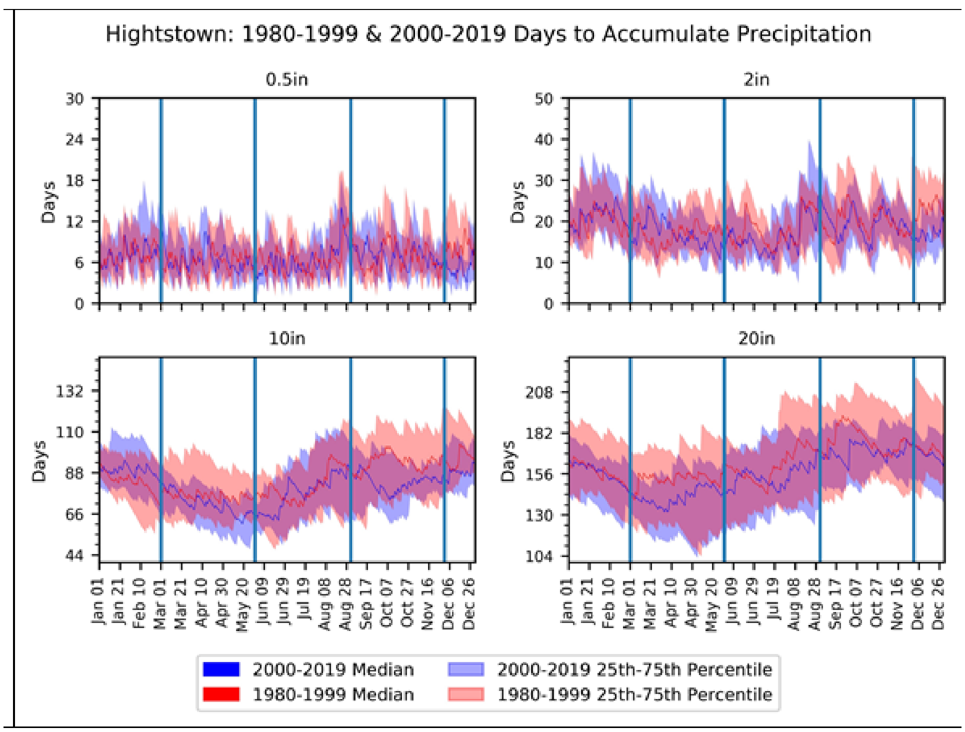


***Figure 52**. Same as figure 51 except for 2000-2019 and 1980-1999 periods.*

Coastal North

Long Branch is the lone station available in this region for a 70-year examination. Like stations to the north, an increase in precipitation was noted until the 1970s (figure 53). Totals declined somewhat in the 1980s and 1990s until rising again quite notably over the past 20 years. Days with 0.10” or more increased until the 1970s, then leveled off. 0.50” and greater days exhibited a rather continuous increase, much as seen in 1.00” or greater days, though they seem to have at least briefly declined in recent years (figure 54). Days exceeding 2.00” increased up until the 1990s and have since leveled off. Percentages of days for the various thresholds suggest a larger fraction of heavy precipitation days in the years centered around 2010 followed by a notable decline in this percentage (figure 55). This suggests more recent days of rain with small totals, with no commensurate decline in total precipitation.

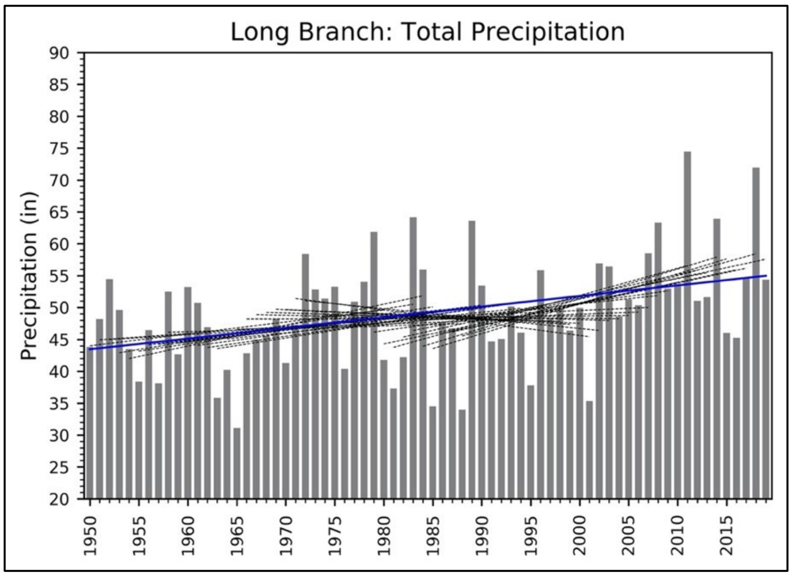


Figure 53. *Total annual precipitation between 1950-2019 at Long Branch. See Figure 38 for further information.*

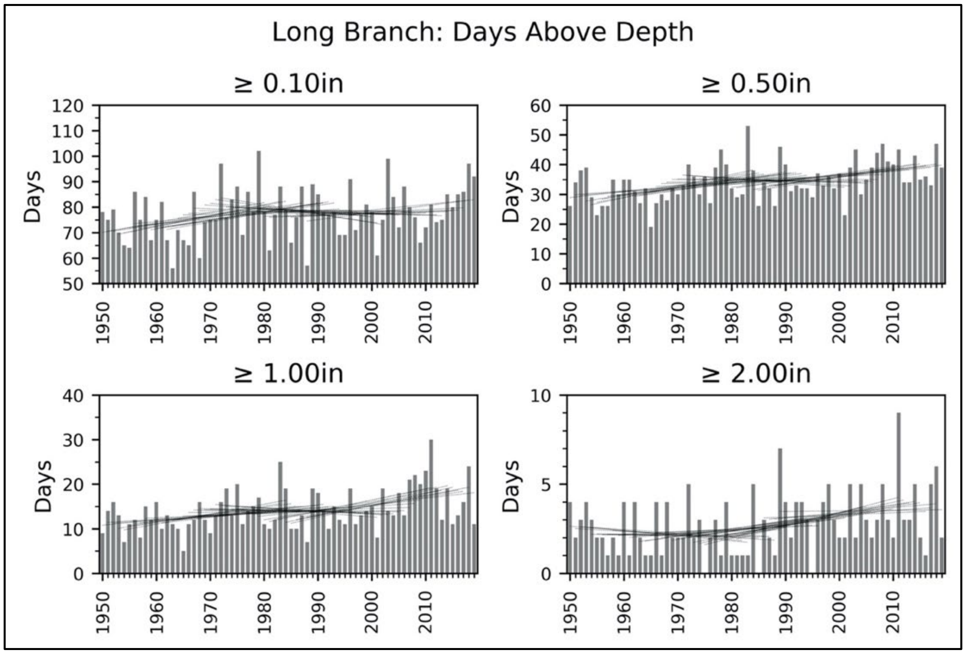


Figure 54. *The number of days per year with daily precipitation equal to or exceeding four thresholds (bars) at Long Branch. See figure 39 for more information.*

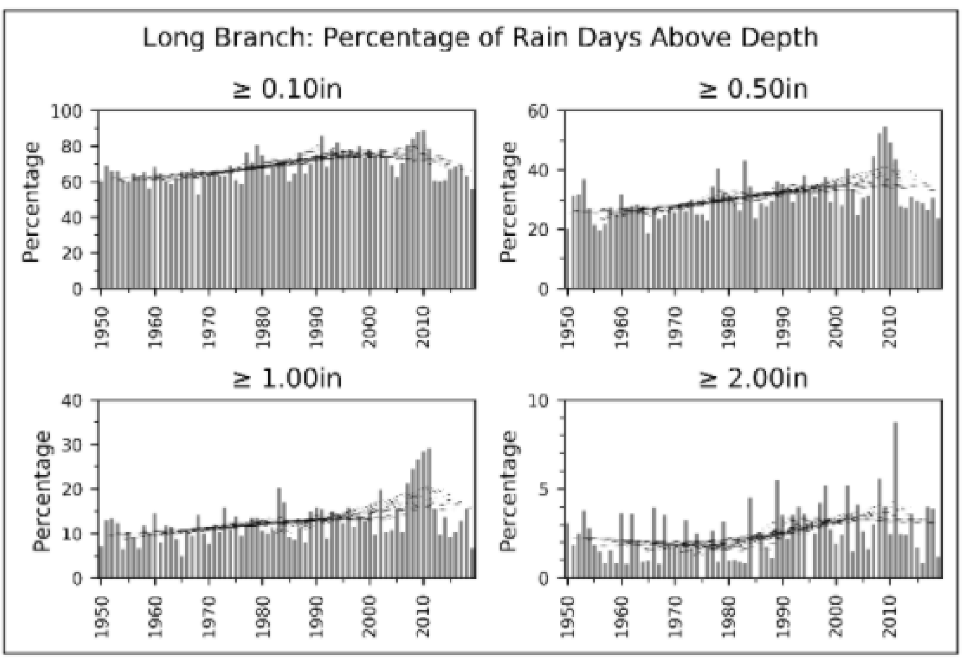


Figure 55. *Percentage of precipitation days above various threshold depths at Long Branch. Dotted lines show the 30-year trend.*

There was little difference between study intervals, nor any seasonality noted for days to accumulate 0.50” (figure 56). No seasonality was noted for 2.00” accumulations, with some tendency, except in winter, for a faster accumulation period in the past two decades compared to the previous five. A faster accumulation rate from 2000-2019 was clearly evident at 10.00” and 20.00” levels, especially for the latter where differences of 20 days were common. Neither level showed as much seasonality as seen to the north, although 20.00” times were faster in the spring and summer throughout the 70 years. The early period had a slow 10.00” rate while it was on the fast end in the past two decades, medians differing by as much as 30-40 days. The same overall patterns were found when comparing 1980-1999 with 2000-2019 than when looking at the full early 50-year interval (Figure 57).

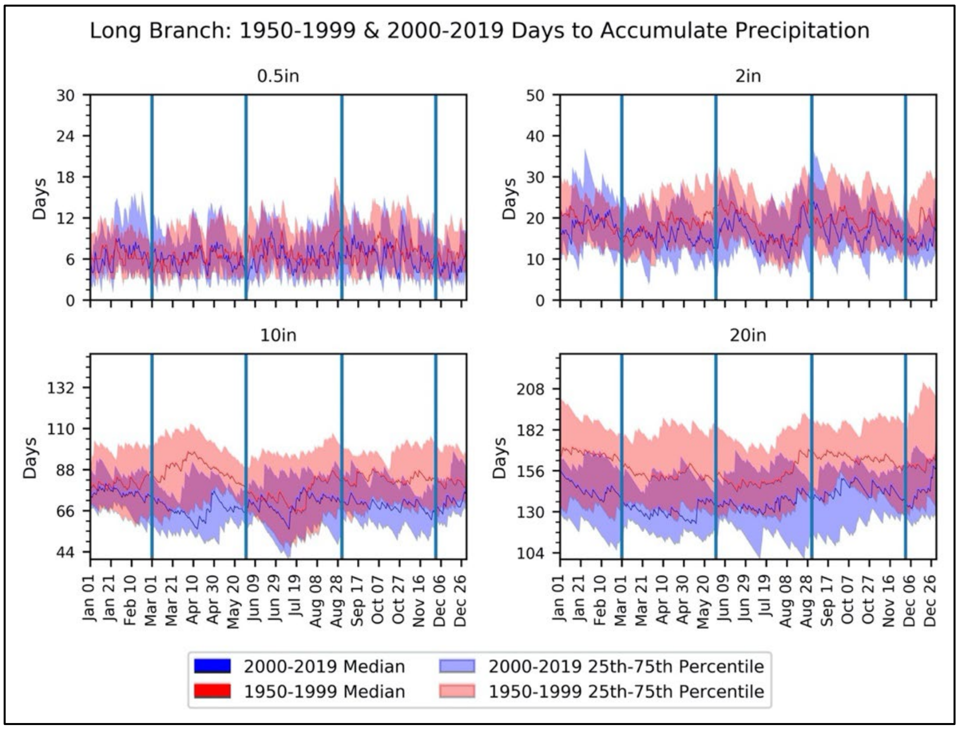


Figure 56. *The number of days it takes to accumulate multiple threshold values at Long Branch for both 2000-2019 and 1950-1999 periods. See Figure 41 for further information.*

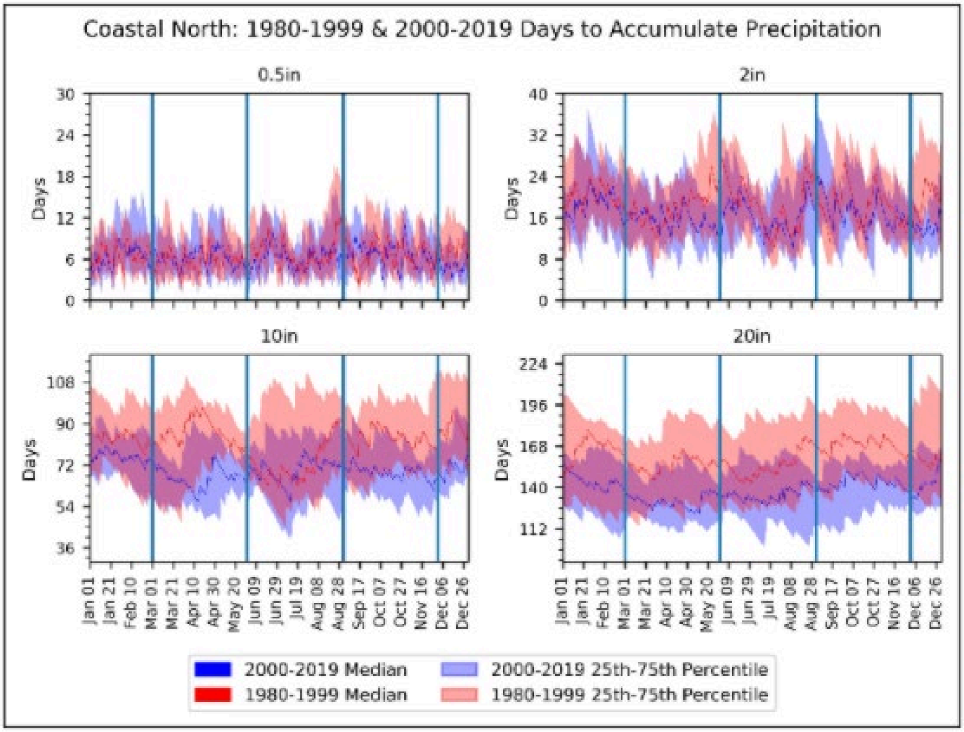


Figure 57. *Same as figure 56 except for 2000-2019 and 1980-1999 periods.*

Southwest

Annual precipitation rose at both Indian Mills and Moorestown into the 1970s (figure 58). After a brief leveling off, precipitation continued rising at the former location while generally leveling off at the latter. Both stations showed continuous upward trends in days with 0.10" or greater precipitation (figure 59). The same is evident for 0.50" days at Indian Mills while Moorestown days peaked in the 1970s and have leveled off since then. Days with 1.00" and 2.00" have also risen throughout the study period at Indian Mills. Again, Moorestown exhibited a 1970s peak while remaining a bit lower and rather stable since then. Differences between the two stations were also noted in percentages of precipitation days at the four levels (figure 60). Indian Mills showed a notable rise in the percentage of days exceeding 0.10" while Moorestown showed a subtle decline at that level during the full study period. Much the same was seen with both stations at the 0.50" level. Increases in percentages were seen during the course of the study period at the 1.00" and 2.00" levels at Indian Mills, while Moorestown showed short peaks in the early 1970s at both levels but at other times showed no trends.

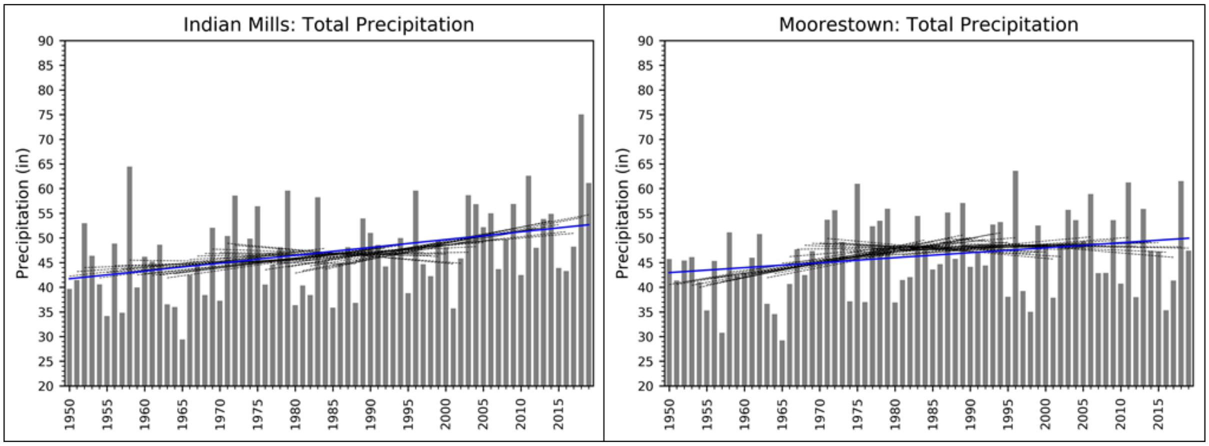
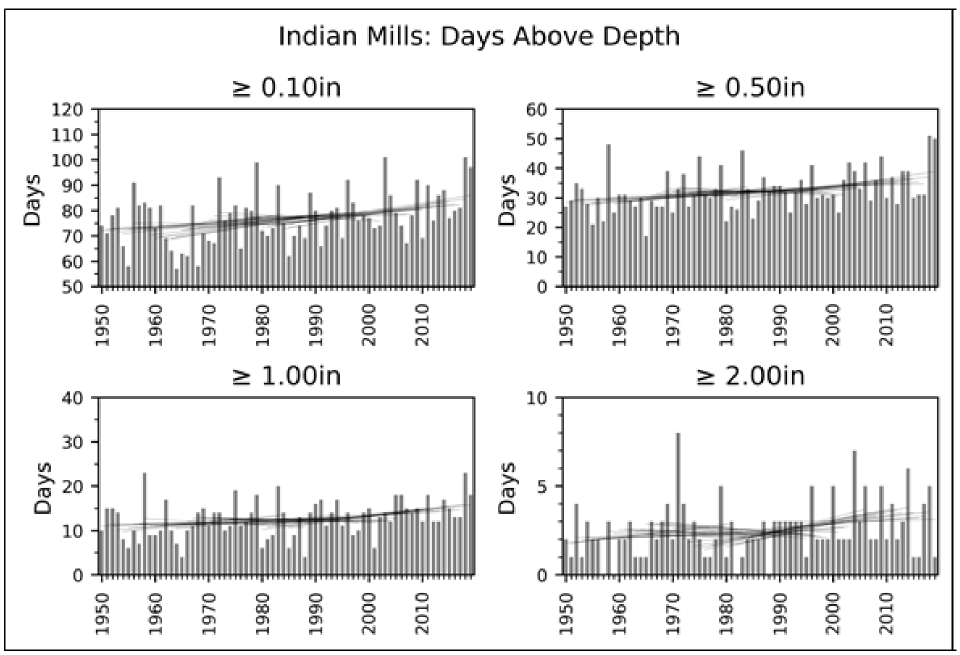


Figure 58. *Total annual precipitation between 1950-2019 at Indian Mills (left) and Moorestown (right). See figure 38 for further information.*



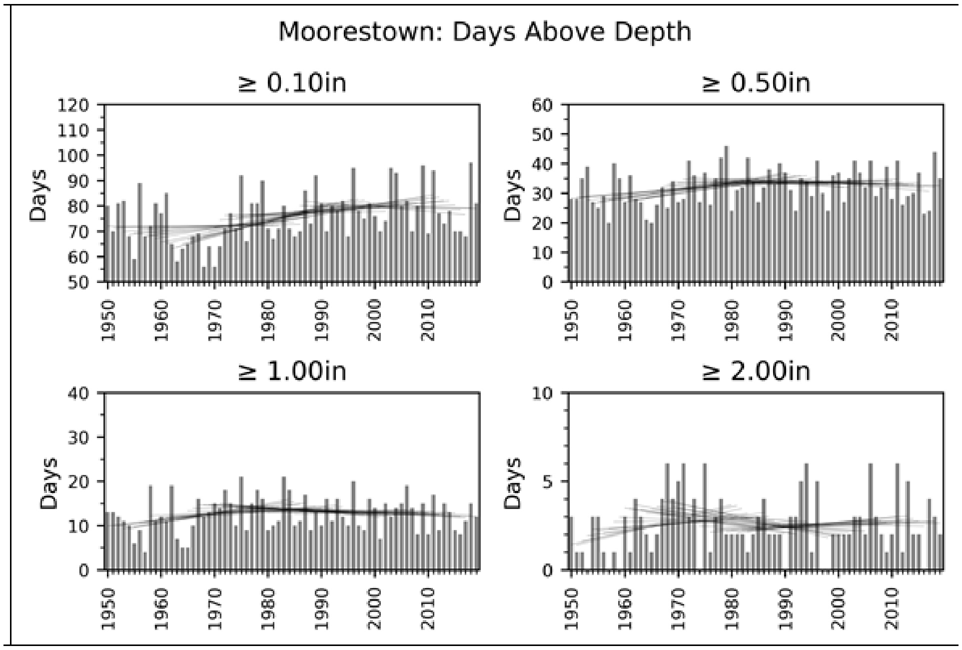
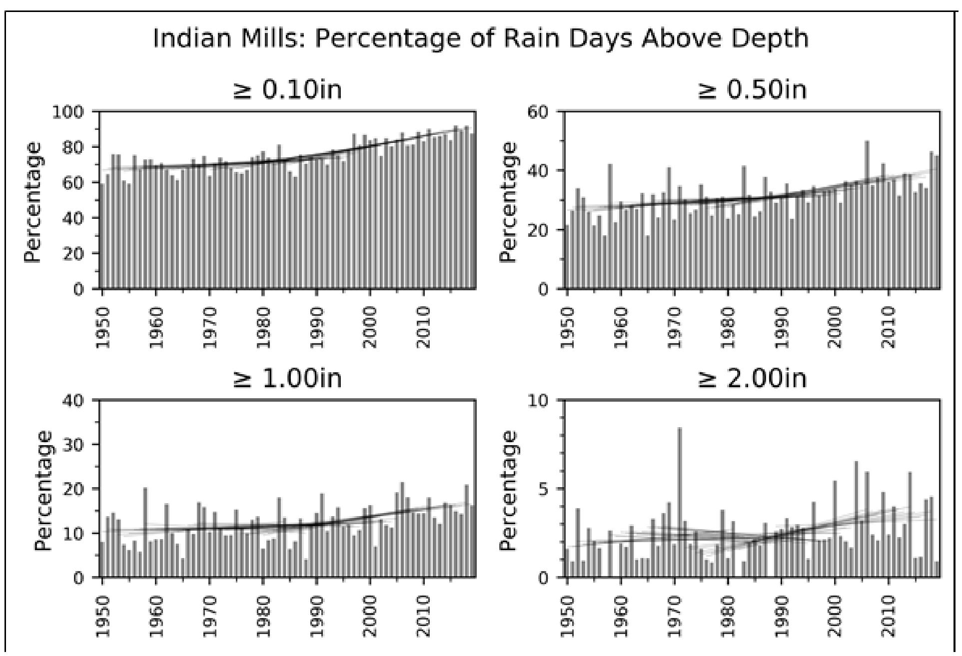


***Figure 59**. The number of days per year with daily precipitation equal to or exceeding four thresholds (bars) at Indian Mills (top) and Moorestown (bottom). See figure 39 for more information.*



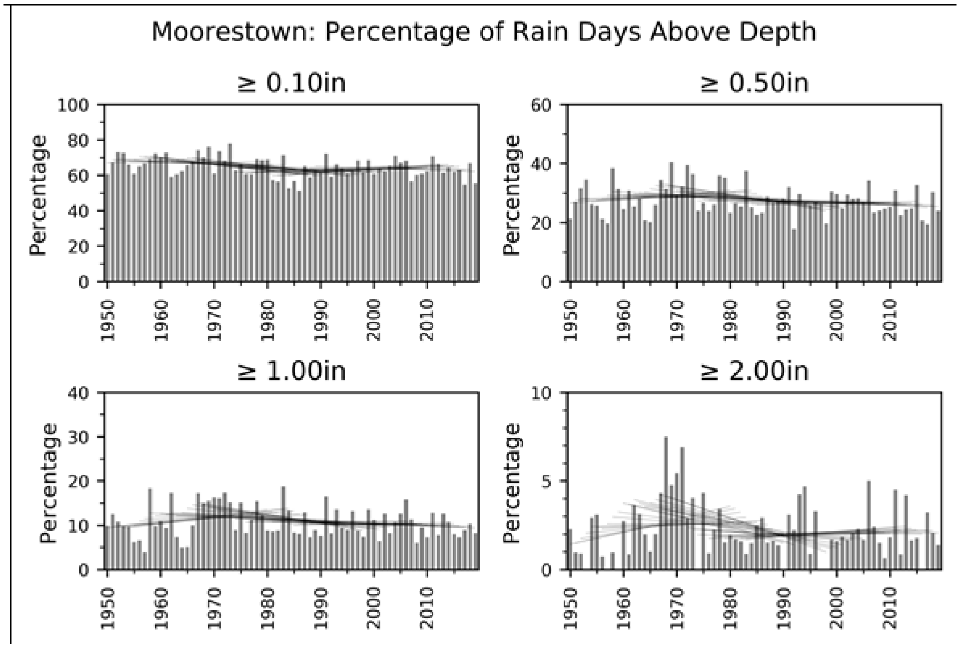
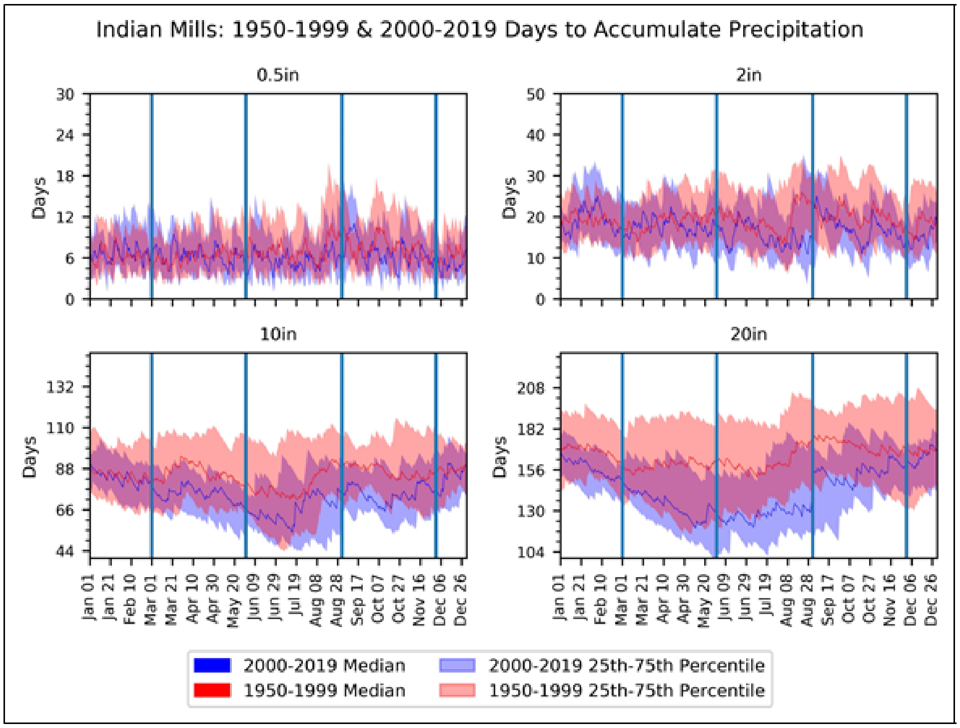


***Figure 60**. Percentage of precipitation days above various threshold depths at Indian Mills (top) and Moorestown (bottom). Dotted lines show the 30-year trend.*

With the exception of slower accumulation rates in late summer and fall at both stations, there was limited seasonality nor differences between 1950-1999 and 2000-2019 at the 0.50" and 2.00" levels (figure 61). The 10.00" and 20.00" accumulations occurred faster at both locations in the spring to mid-summer. The rate of accumulation was considerably faster in the 2000-2019 period except the two periods were close in winter. The largest difference between the two periods was in Indian Mills at the 20" level. The relationships between 1950-1999 and 2000-2019 and 1980-1999 and 2000-2019 were very close to the same (Figure 62).



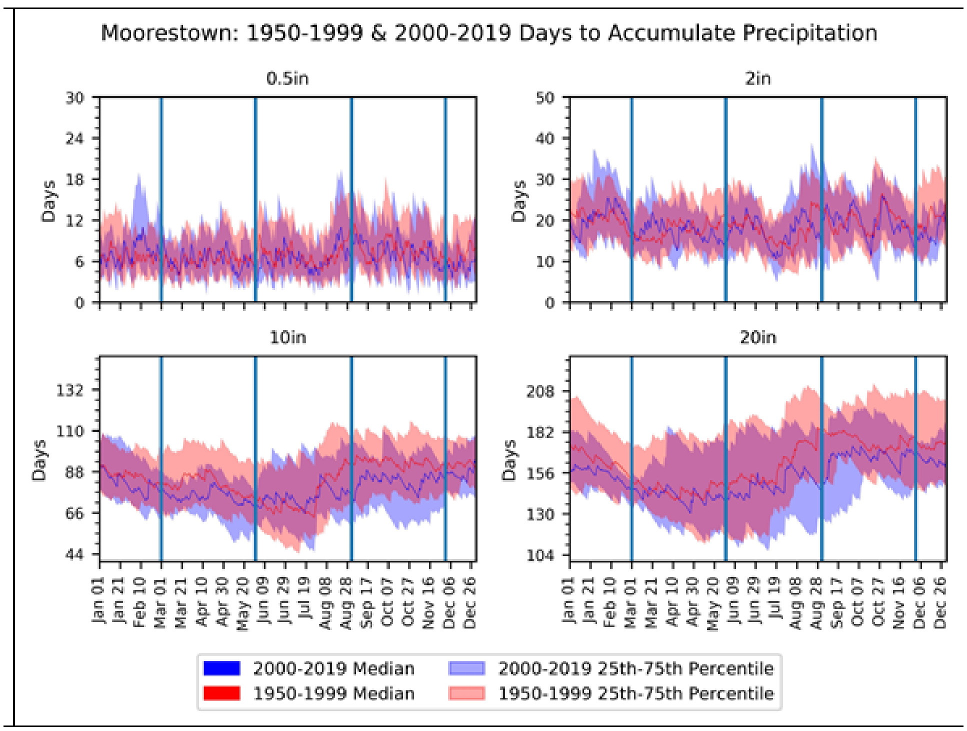
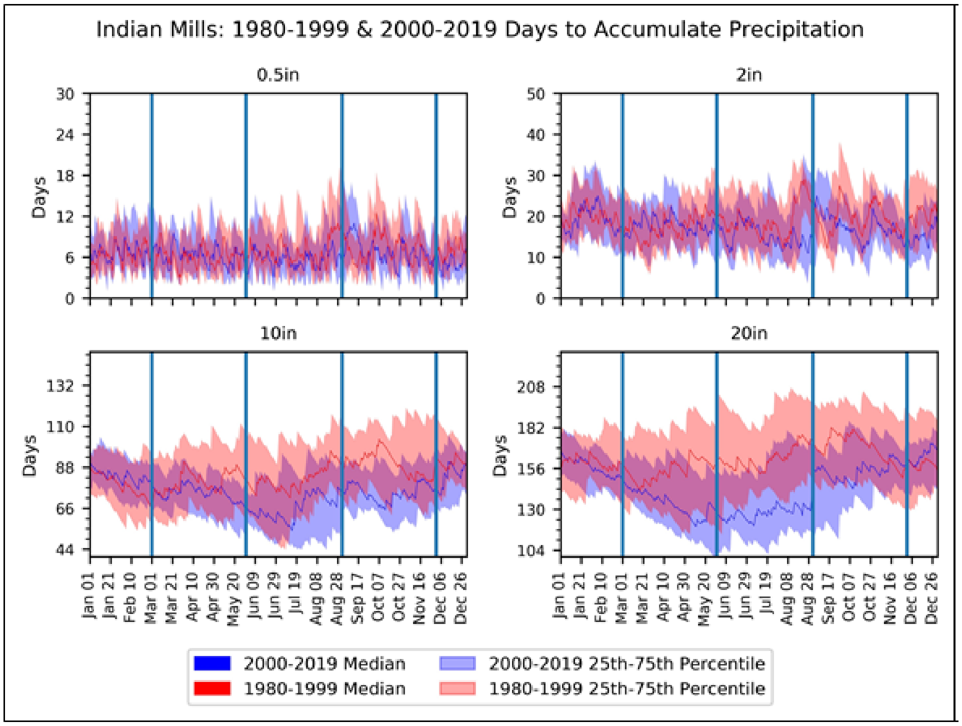


Figure 61. *The number of days it takes to accumulate multiple threshold values at Indian Mills (top) and Moorestown (bottom) for both 2000-2019 and 1950-1999 periods. See Figure 41 for further information.*



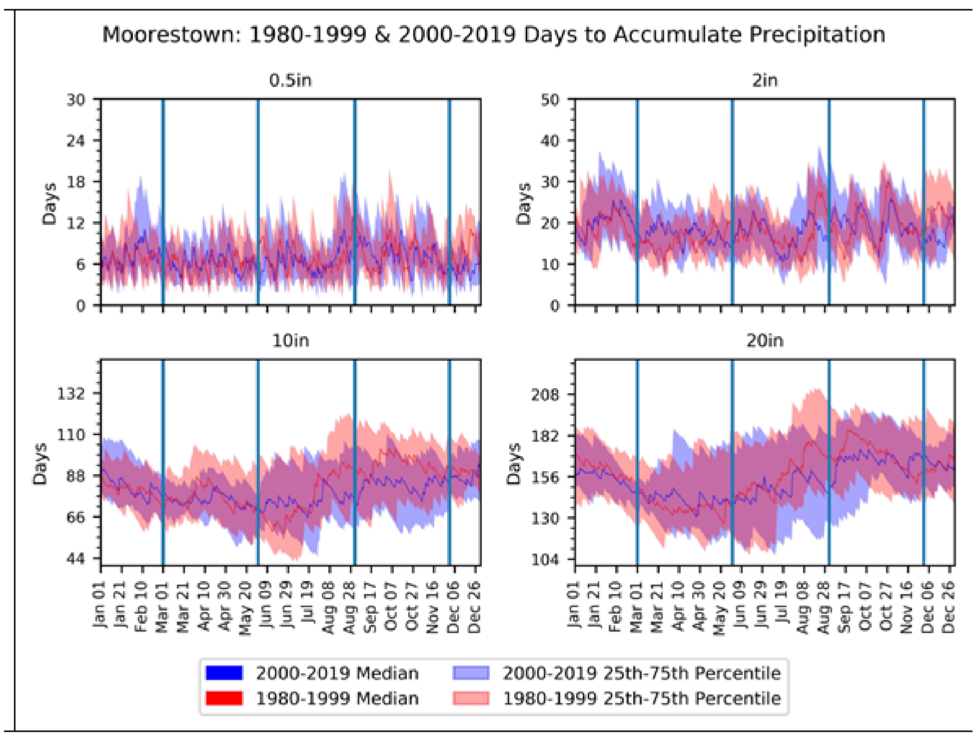


Figure 62. *Same as figure 61 except for 2000-2019 and 1980-1999 periods.*

Coastal South

Both Atlantic City Marina and Cape May saw a decline in annual precipitation until the 1980s and upward trends since then (figure 63). This pattern was considerably more pronounced at the

Marina. Overall, each location became wetter during the full period, about 5.00” more over the period at the Marina and several inches at Cape May. The number of days with 0.10” or more changed little at the Marina over the full study period but was up a little at Cape May (figure 64). There was a bit of a 2000-2019 rise in days of 0.50” or greater at Atlantic City Marina but the overall period showed no trend at Cape May. The same held for each station at the 1.00” and 2.00” levels. The percentage of precipitation days above 0.10” and 0.50” was similar at both stations and showed no period of record trends (figure 65). The same holds for Cape May at 1.00” and 2.00”, while the latest two decades exhibited a rise in percent days at the Marina.

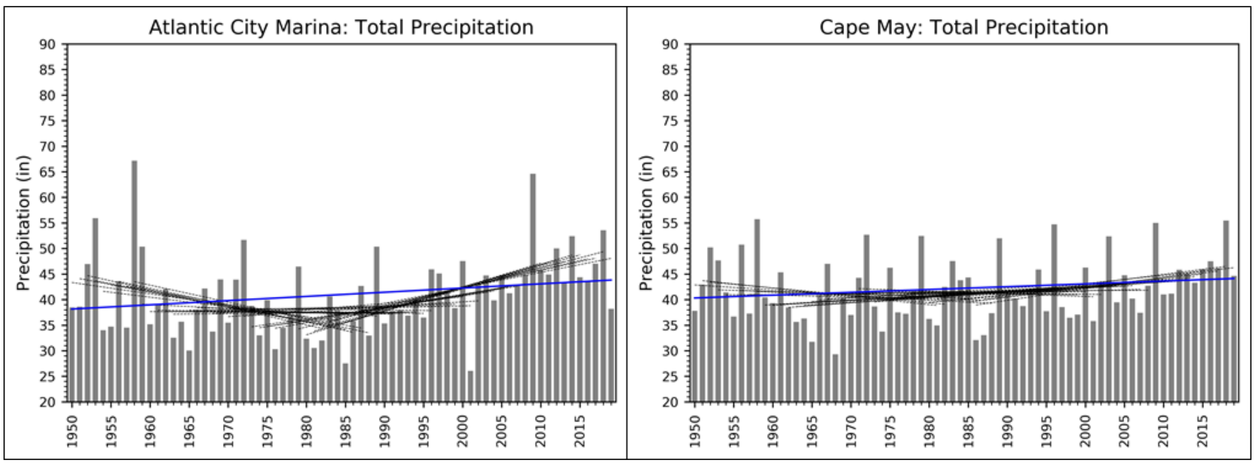
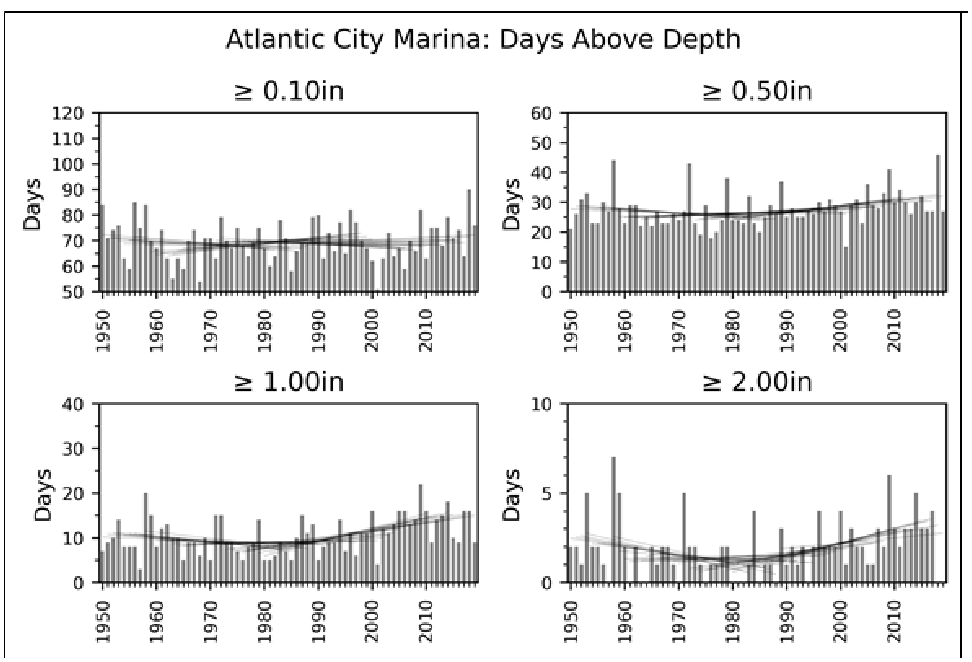


Figure 63. Total annual precipitation between 1950-2019 at Atlantic City Marina (left) and *Cape May (right). See figure 38 for further information.*



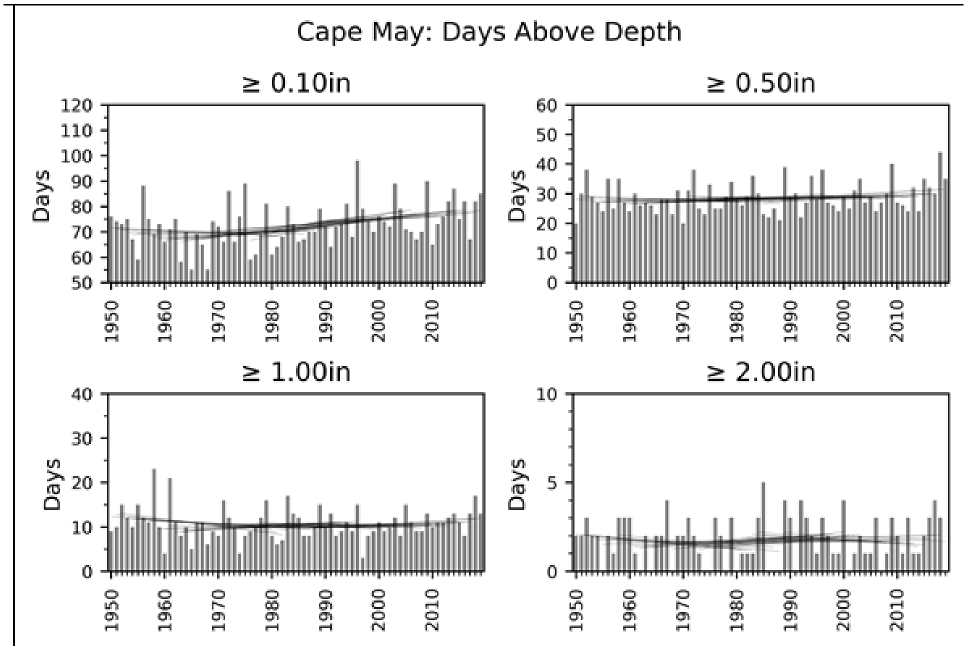
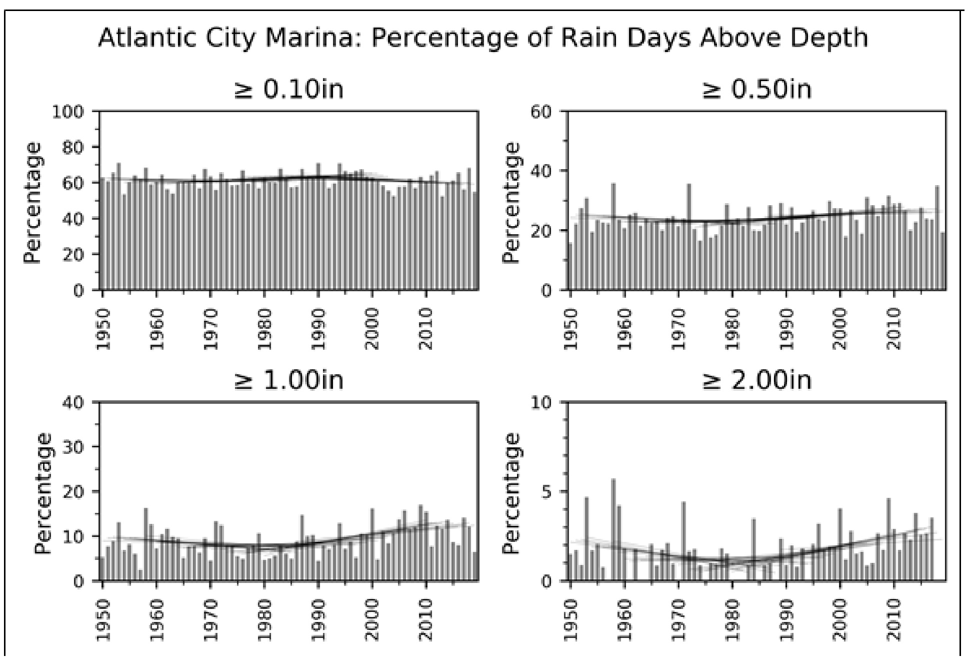


Figure 64*. The number of days per year with daily precipitation equal to or exceeding four thresholds (bars) at Atlantic City Marina (top) and Cape May (bottom). See Figure 39 for more information.*



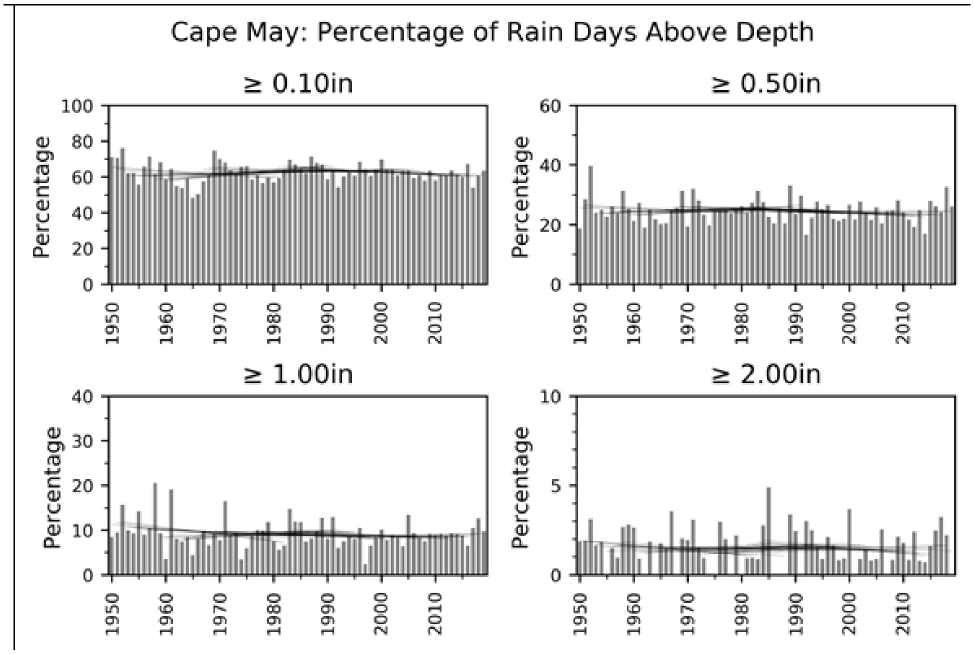
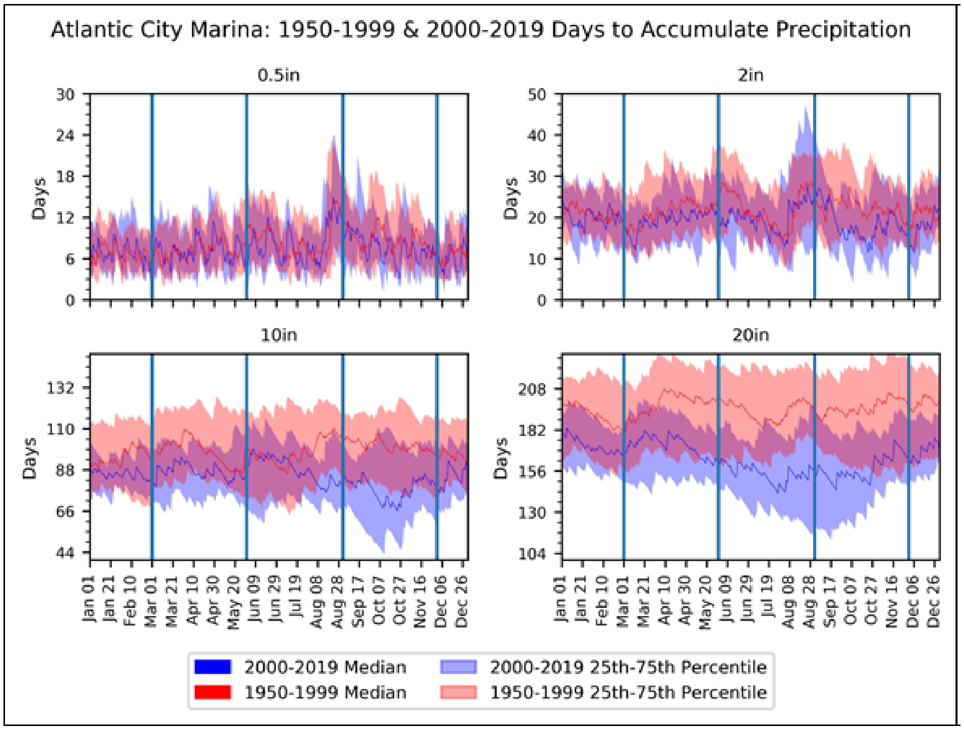


***Figure 65**. Percentage of precipitation days above various threshold depths at Atlantic City Marina (top) and Cape May (bottom). Dotted lines show the 30-year trend.*

Accumulation rates at 0.50" and 2.00" show little difference between the two stations (figure 66). There is some tendency for rates to slow at both levels and stations in the late summer and early fall. This includes one particular sharp peak denoting a decline in accumulation right at the end of summer at both levels at the Marina and at 0.50" in Cape May. This is seen in both the 1950-1999 and 2000-2019 periods. This peak is not seen at 10.00" or 20.00", both of which show a faster accumulation rate at both stations in recent decades, particularly at the Marina. The Marina difference is most pronounced at 20.00". The fall and winter at Cape May show slower accumulation rates, especially at 20.00". All of these tendencies and trends are noted between 1980-1999 and 2019-2020 periods, including the sharp late summer rise at the lower accumulation totals (Figure 67).



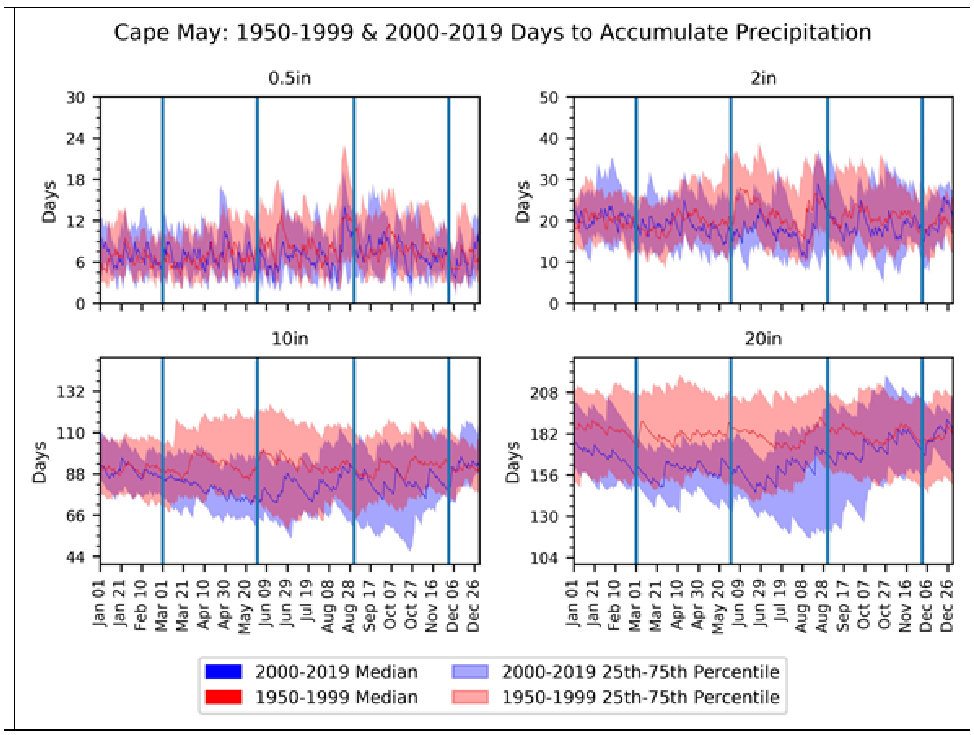


Figure 66. *The number of days it takes to accumulate multiple threshold values at Atlantic City Marina (top) and Cape May (bottom) for both 2000-2019 and 1950-1999 periods. See Figure 41 for further information.*

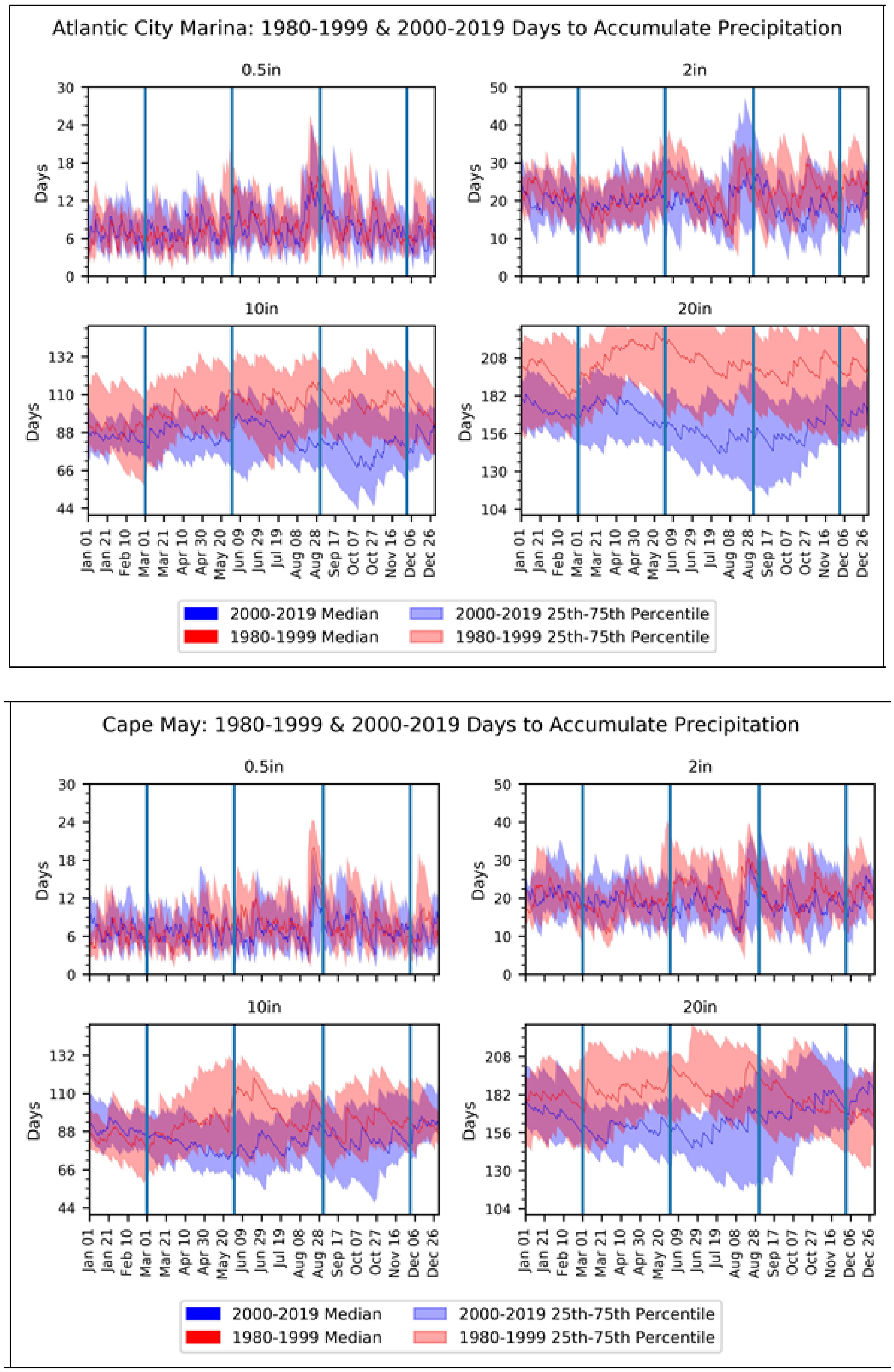


Figure 67*. Same as Figure 66 except for 2000-2019 and 1980-1999 periods.*

Lorenz curve comparisons

The last analyses performed on precipitation data for the recent 70-year and 40-year periods looks to Lorenz curves to illustrate how different portions of the annual precipitation distribution vary in their contributions to annual precipitation totals over time, for each region. This was performed for Tier 1 stations in each region by comparisons of intra-annual precipitation distribution through 25th-75th percentiles of annual Lorenz curves.

For instance, looking first at Sussex, it is seen in figure 68 that there is little difference in the contribution of light, medium or heavy precipitation totals to annual precipitation between 1950-1999 and 2000-2019 or between 1980-1999 and 2000-2019. There is just a subtle indication that the most recent decades delivered more precipitation in medium events (65-80% of ranked precipitation events) than in the 1980-1999 period (blue slightly to the left of pink).

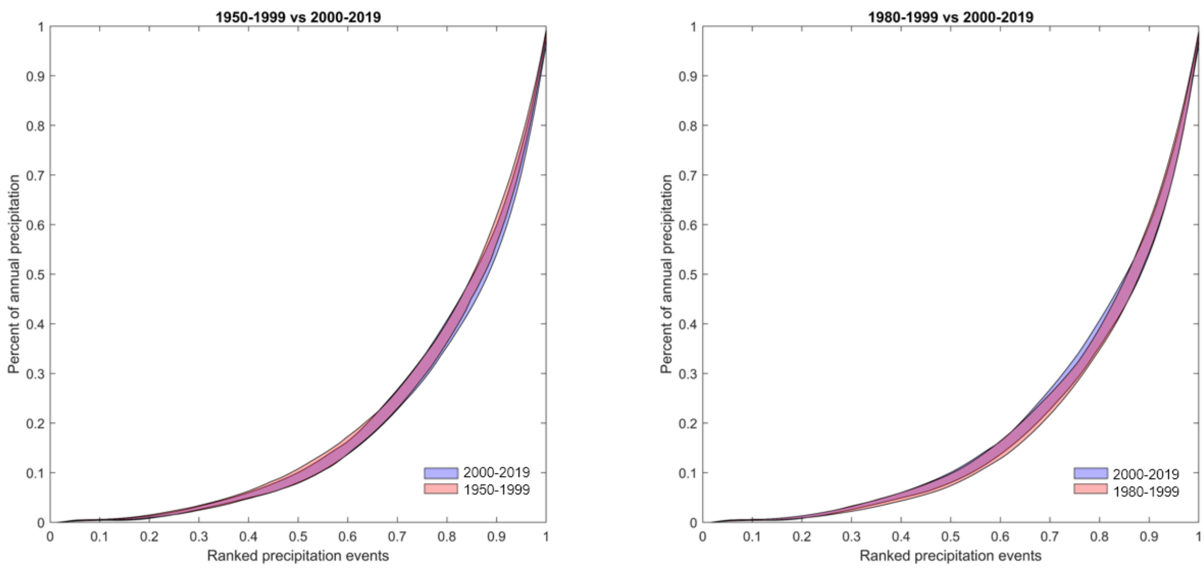


***Figure 68**. The 25th-75th percentile of annual Lorenz curves for Sussex for 2000-2019 are compared against those from 1950-1999 (left) and 1980-1999 (right).*

At Charlotteburg, the 25th-75th percentiles of annual Lorenz curves from 2000-2019 align with that of 1950-1999 (figure 69). However, the curves for 2000-2019 are higher than those for much of the precipitation distribution for 1980-1999 (blue to the left of pink). This indicates that the medium and large precipitation events comprising the upper 60-90% of precipitation events in 2000-2019 contribute more to annual precipitation totals than they did in 1980-1999.

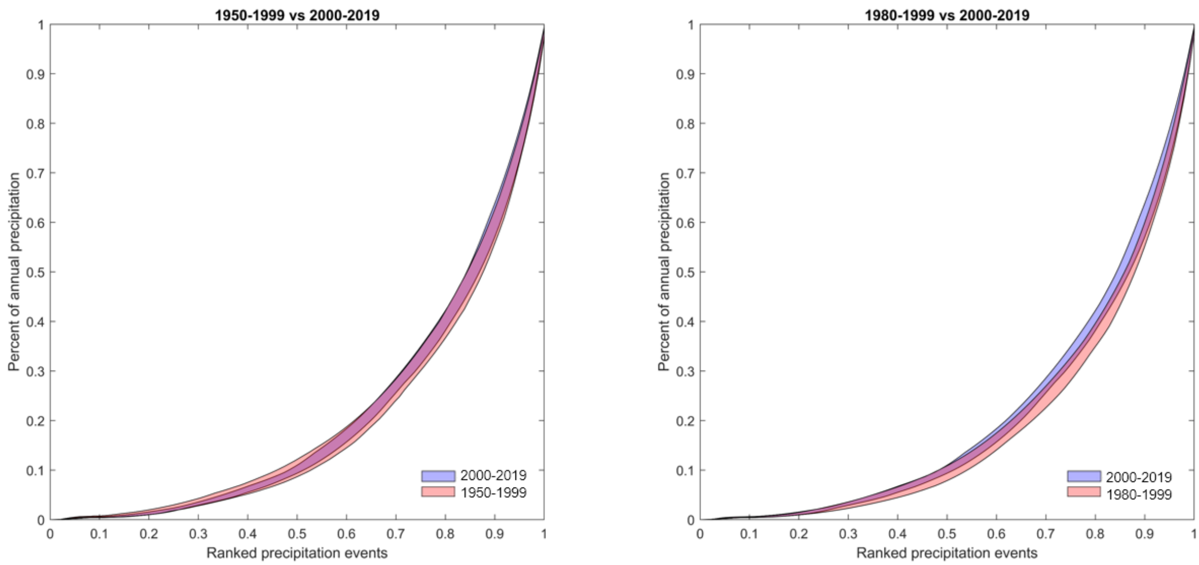


Figure 69. *The 25th-75th percentile of annual Lorenz curves for Charlotteburg for 2000-2019 are compared against those from 1950-1999 (left) and 1980-1999 (right).*

As at the northern stations, for New Brunswick, the 25th-75th percentiles of annual Lorenz curves from 2000-2019 align with those of 1950-1999 (figure 70). The moderate and heavy precipitation events (upper 50-85% of daily precipitation events) from 2000-2019 contribute more to annual precipitation than in 1980-1999.

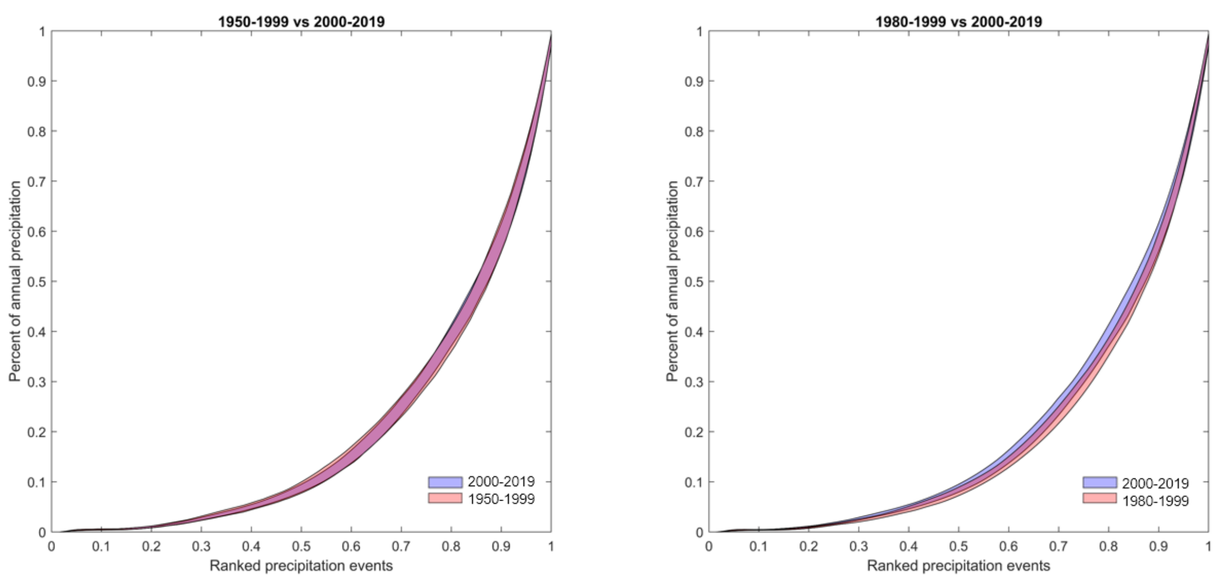


Figure 70. *The 25th-75th percentile of annual Lorenz curves for New Brunswick for 2000-2019 are compared against those from 1950-1999 (left) and 1980-1999 (right).*

At Long Branch, the 25^{th}-75^{th} percentiles of annual Lorenz curves from 2000-2019 span a wider range than those of 1950-1999 and 1980-1999 (figure 70). While this range centers over the 1950-1999 curves, they are slightly lower than the 1980-1999 curve, indicating that less annual precipitation is delivered by small events in 2000-2019 than in 1980-1999. This could also indicate that there were a greater number of small events and moderate events in 2000-2019 than 1980-1999.

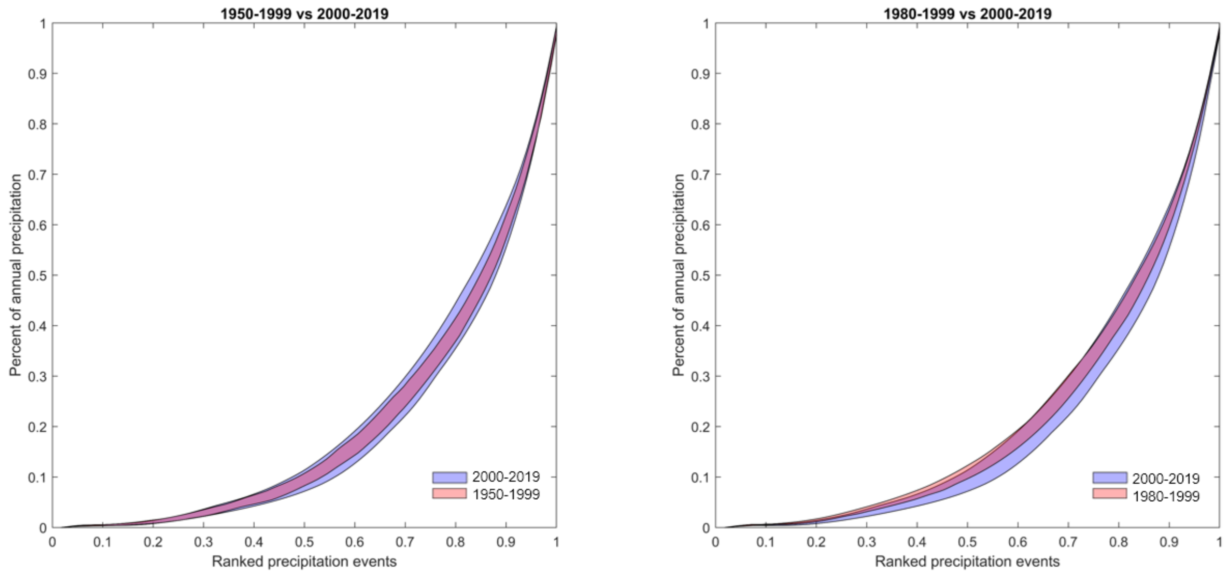


Figure 71. *The 25^{th}-75^{th} percentile of annual Lorenz curves for Long Branch for 2000-2019 are compared against those from 1950-1999 (left) and 1980-1999 (right).*

For Indian Mills, the 25^{th}-75^{th} percentiles of annual Lorenz curves from 2000-2019 do not overlap with those from 1950-1999 (Figure 71). The placement of the 2000-2019 Lorenz curves above those from 1950-1999 indicates that the heaviest precipitation events contribute less to annual precipitation totals in the latter time period than they did in the earlier period, and that the small and medium precipitation events (the bottom 10-60%) in 2000-2019 contribute substantially more to annual precipitation totals than they did in 1950-1999. This pattern also appears in comparisons of 2000-2019 to 1980-1999 Lorenz curves, though to a lesser extent (figure 72). The largest of precipitation events contribute more to annual precipitation totals in 1980-1999 than they do in 2000-2019, and small precipitation events (bottom 20%-45%) contribute substantially more to annual precipitation totals in 2000-2019 than they did in 1980-1999.

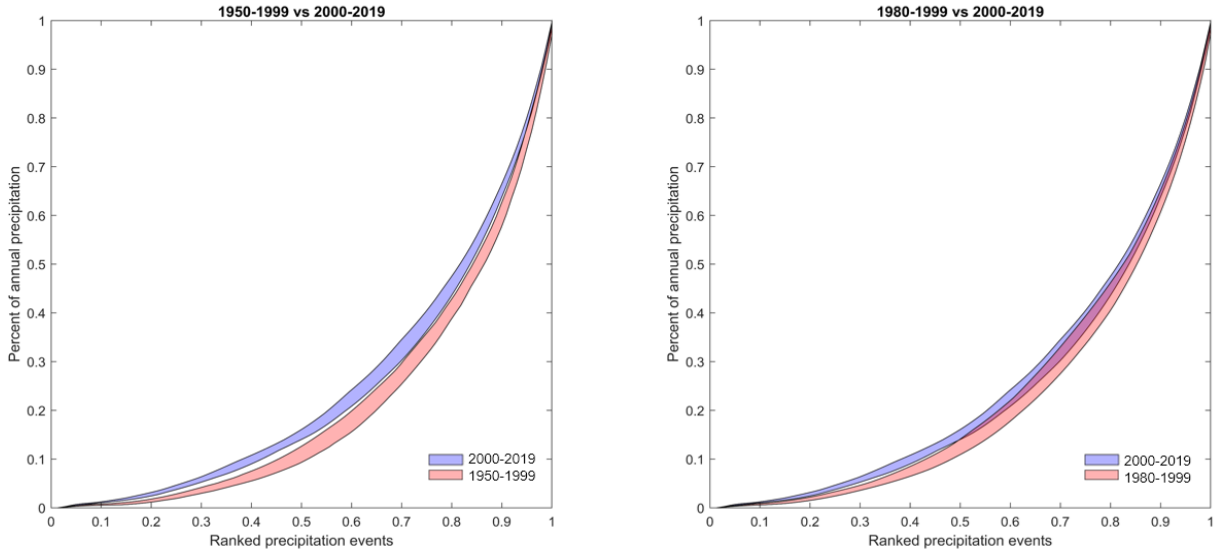


Figure 72. *The 25th-75th percentile of annual Lorenz curves for Indian Mills for 2000-2019 are compared against those from 1950-1999 (left) and 1980-1999 (right).*

Quite the opposite to Indian Mills is seen at Atlantic City Marina, where again the 25th-75th percentiles of annual Lorenz curves from 2000-2019, for the most part, do not overlap with those from 1950-1999 or those from 1980-1999 (Figure 73). However, here in both comparisons, the Lorenz curves from 2000-2019 are lower than the earlier time periods. This placement indicates that the majority of the precipitation distribution contributes less to annual precipitation totals in the latter time period than in the earlier time periods, and that precipitation from the heaviest of precipitation events contributes more to annual precipitation in the latter time period compared to the earlier periods.

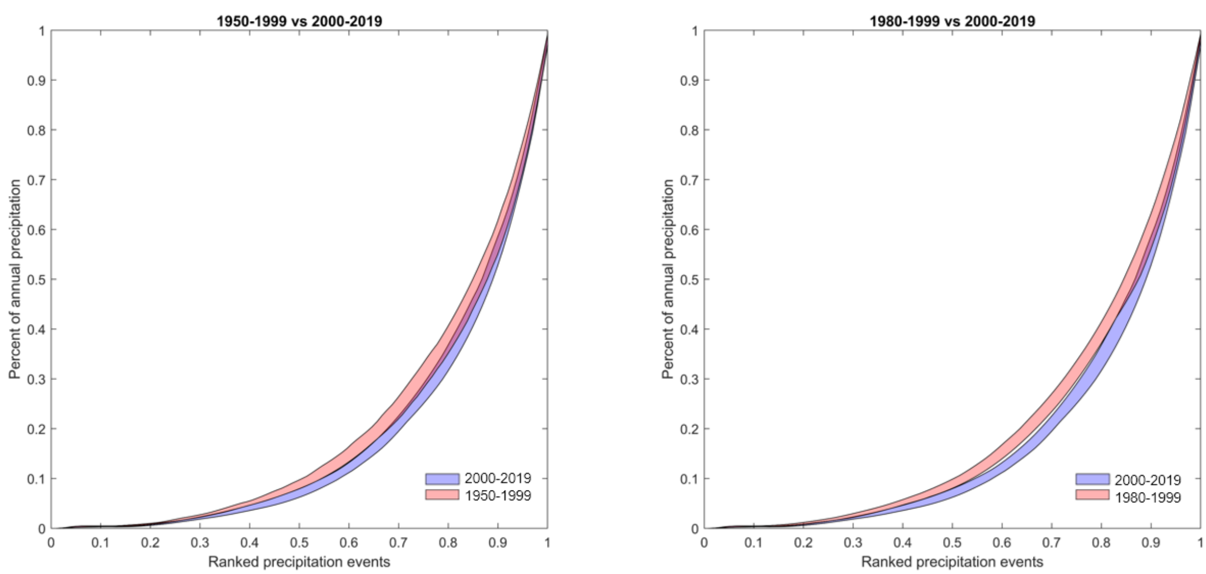


Figure 73. *The 25th-75th percentile of annual Lorenz curves for Atlantic City Marina for 2000-2019 are compared against those from 1950-1999 (left) and 1980-1999 (right).*

To sum up this section, it is quite apparent that the evaluation of the distribution of precipitation in terms of the magnitude of events contributing to annual totals varies from station to station (region to region) independently of each other. This highlights the spatiotemporal complexity of precipitation patterns in the state over the past 70 years. In some areas, heavier events are playing a more important role in the past 20 years while in others little difference through time is seen or even the opposite may be found.

5) Comparison of climate normals: 1981-2010 vs 1991-2020

Climate normals are recent 30-year averages of weather observations. They are the basis for judging how daily, monthly, and annual weather conditions compare to what is normal for a specific location during recent decades. Adhering to World Meteorological Office standards, normals are updated every ten years at the ’00 year (e.g., 1991-2020). Official 1991-2020 normals for the United States have recently been generated at NCEI. Included are annual, seasonal, monthly, and daily normals of temperature, precipitation, and other climatological variables for New Jersey NWS Cooperative stations, counties, climate divisions, and the state as a whole. Here, a comparison of statewide precipitation normals between 1981-2010 and 1991-2020 normal periods is provided.

The statewide normals are based on the nClimDiv monthly division dataset, which is maintained by NCEI. nClimDiv is a gridded product derived from area-weighted averages of 5 km x 5 km grid-point estimates taken from monthly weather station data (Vose et al. 2018). Station data are gridded via climatologically aided interpolation to minimize biases from topographic and network variability. Statewide gridded temperature and precipitation values are then averaged over the full normal period (e.g., each January statewide value over thirty years) to obtain the statewide monthly values.

Differences between 1981-2010 and 1991-2020 normals are a result of swapping out 1981-1990 observations and replacing them with 2011-2020 observations. The intervening 20-year interval of 1991-2010 represents two thirds of each 30-year normal period. Thus, the results and comparisons in this study are essentially comparisons between the first and last decades of the overall 40-year 1981-2020 interval.

New Jersey annual precipitation for the 1991-2020 normal period is 47.56 inches while the annual precipitation for the 1981-2010 normal is 46.36 inches (Table 10). The monthly differences between the two normal periods ranges from 0.06” to 0.47”. The monthly normals for the two periods are plotted alongside each other in Figure 74, while Figure 75 shows the monthly differences between the two. Nine months show increasing precipitation, led by August and December, while April shows the largest decrease in precipitation, closely followed by November and May.

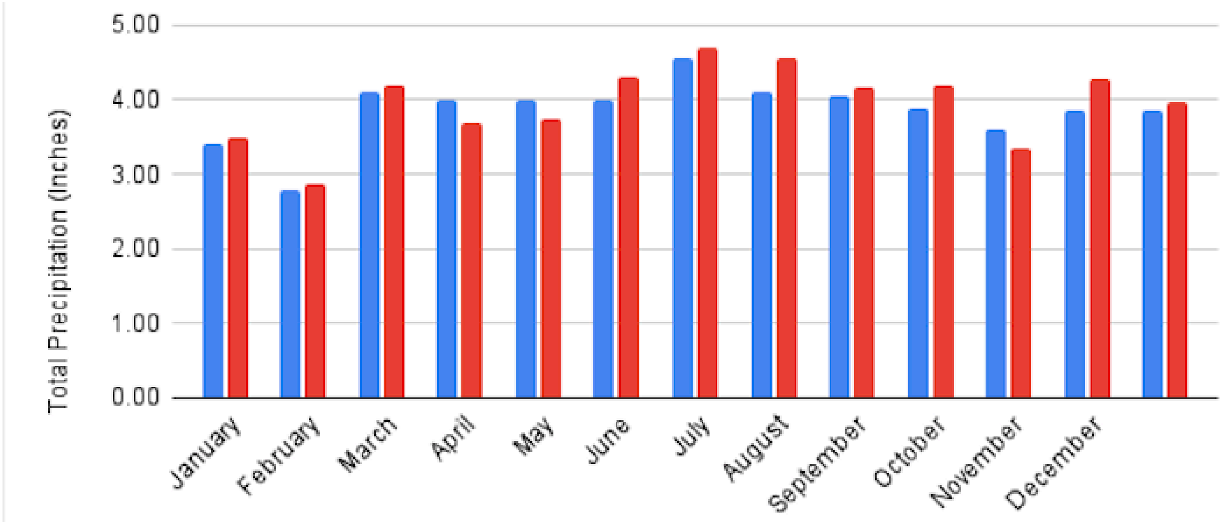


Figure 74. *New Jersey statewide monthly total precipitation normals for the 1981-2010 (blue bars) and 1991-2020 (red bars) periods.*

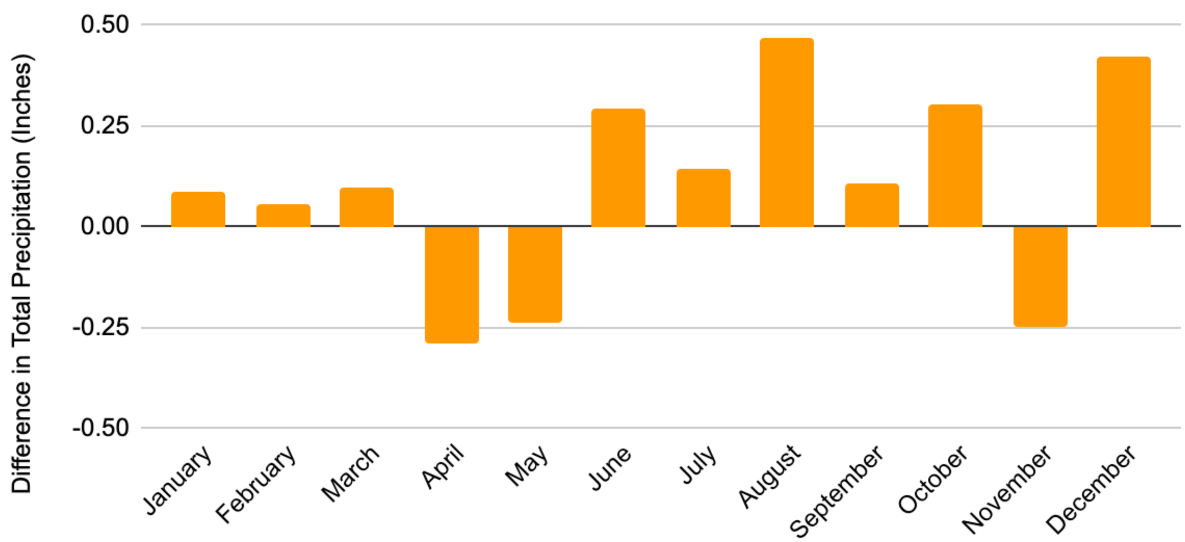


Figure 75. *New Jersey monthly differences in precipitation normals between the 1981-2010 and 1991-2020 periods. Positive values indicate the more recent 30-year interval is wetter.*

***Table 10**. New Jersey statewide 30-year precipitation normals for 1981-2010 and 1991-2020 as generated by NCEI (values in inches).*

Norm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1981-2010	3.40	2.80	4.11	3.99	3.99	4.01	4.57	4.10	4.05	3.89	3.61	3.85	46.37
1991-2020	3.49	2.86	4.22	3.70	3.75	4.30	4.71	4.57	4.16	4.19	3.36	4.27	47.56

NCEI divides New Jersey into three climate divisions. Tables 11-13 show the monthly and annual normals for the 1981-2010 and 1991-2020 intervals for each of the three. The northern division includes all counties north and inclusive of Hunterdon, Somerset, and Union counties and covers 37% of the state. The annual difference between the two 30-year intervals in the north shows the most recent interval being only 0.11” wetter. Six months show increases of as much as 0.45” (August). Six months show decreases of as much as 0.39” (November), although three were only 0.01” to 0.06” drier.

***Table 11.** New Jersey northern climate division 30-year precipitation normals for 1981-2010 and 1991-2020* (values in inches).

Norm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1981-2010	3.41	2.82	3.96	4.20	4.34	4.45	4.75	4.11	4.47	4.31	3.86	3.95	48.63
1991-2020	3.50	2.79	4.01	3.90	4.02	4.61	4.72	4.56	4.46	4.45	3.47	4.25	48.74

The southern climate division is south and inclusive of Mercer, Middlesex, and Monmouth counties except within about 10 miles of the Atlantic coast. It covers 56% of the state. The new normal period is 1.85” wetter than the former one, with nine months wetter and three drier. Each summer month (June-August) is 0.35”-0.49” wetter, with October (+0.40”) and December (+0.49”) also considerably wetter. April is 0.38” drier for the latest normal, with May (-0.20”) and November (-0.16”) also drier.

***Table 12.** New Jersey southern climate division 30-year precipitation normals for 1981-2010 and 1991-2020* (values in inches).

Norm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1981-2010	3.39	2.78	4.19	3.86	3.80	3.77	4.49	4.08	3.82	3.63	3.45	3.79	45.05
1991-2020	3.47	2.89	4.32	3.58	3.60	4.14	4.74	4.57	3.99	4.03	3.29	4.28	46.90

The coastal division includes all land within about 10 miles of the Atlantic coast and covers 7% of the state. Conditions were considerably wetter in the 2011-2020 decade than from 1981-1990, as the new annual normal increased 2.38". Like the southern division, nine months are wetter in the most recent normals and three are drier. The increase is as large as 0.60" in December, while the 0.28" decrease in April is the largest decline.

Table 13. *New Jersey coastal climate division30-year precipitation normals for 1981-2010 and 1991-2020* (values in inches).

Norm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1981-2010	3.44	2.89	4.31	3.83	3.56	3.45	4.16	4.16	3.57	3.60	3.46	3.76	44.19
1991-2020	3.51	3.07	4.42	3.55	3.51	3.85	4.38	4.60	3.89	4.09	3.34	4.36	46.57

Summing up the comparison of the two normals intervals, New Jersey has gotten wetter statewide. The coast leads the way, followed rather closely by the south. Meanwhile, the north barely got wetter. Nine months became wetter in the south and at the coast, particularly in summer and December, while April, May, and November have become drier statewide. In the north, February, July, and September also became slightly drier.

Concluding remarks

This has been a comprehensive examination of New Jersey's precipitation regime from geographic and temporal perspectives. Traditional and some rather unique approaches have been taken while delving into this subject. Individual station data and products employing amalgamations of station observations have been applied. Along the way, statewide and regional (based on NJDEP drought regions) analyses were taken.

The executive summary section provides a listing of key study findings that identify an overall increasingly wetter state over the 12-decade study period, especially in southern and coastal areas in recent decades and in the late summer. Late falls have trended drier. Recently, there is also a general leaning toward a greater contribution to annual precipitation totals from moderate and large daily events, especially along the southern coast and in the northwest. Also, of note in the past two decades is a more rapid pace of accumulating multi-month totals (10.00" and 20.00") in the warm half of the year than seen during the last half of the 20th century.

We trust this report has achieved its goal of providing a better understanding of New Jersey precipitation and will contribute to better-informed decisions being made with regard to planning and responses to flooding, including flash and riverine events. We also trust that it has provided valuable insights into critical drought monitoring and associated water management. Finally, we think this report has provided a valuable baseline for future use in evaluating observed and projected precipitation patterns.

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Appendix A: Metadata for stations and threading

Regional breakdown of stations used in this study, including 1) region; 2) Tier 1 stations (top six rows of station), Tier 2 stations (bottom five rows); 3) date range for each station; 4) six columns of "threaded" stations used to generate temporally complete records for the Tier 1 and 2 stations. The percentage of available data for each station is bolded in parentheses below each station for the date range for the tiered stations. For example, Newark-Liberty had complete daily data for the 1950-2019 period, while Long Branch-Oakhurst only was 84% complete for that station from 1900-2019 and required daily data from six other stations to complete the daily record. Rounding to the whole number results in a 103% total for Coastal North.

Region	Station	Date-Range	Threaded Station #1	Threaded Station #2	Threaded Station #3	Threaded Station #4	Threaded Station #5	Threaded Station #6
Coastal South	Atlantic City Marina **(99%)**	1900-2019	Atlantic City **(1%)**					
Northwest	Sussex 3 WNW **(88%)**	1900-2019	Newton **(10%)**	Sussex Airport **(<1%)**	High Point **(<1%)**	Layton **(<1%)**	Canistear Reservoir **(<1%)**	
Central	New Brunswick 3 SE **(53%)**	1900-2019	New Brunswick Experimental **(43%)**	New Brunswick (1) **(3%)**	Plainfield **(<1%)**			
Northeast	Charlotteburg Reservoir **(53%)**	1900-2019	Oak Ridge Reservoir **(41%)**	Dover **(4%)**	Wanaque **(2%)**	Boonton **(<1%)**	Greenwood Lake **(<1%)**	
Coastal North	Long Branch-Oakhurst **(84%)**	1900-2019	Sandy Hook **(4%)**	Fort Hancock **(3%)**	Toms River **(5%)**	Sea Girt **(4%)**	Freehold-Marlboro **(1%)**	New Brunswick **(2%)**
Southwest	Indian Mills 2 W **(98%)**	1900-2019	Pemberton **(<1%)**	Hammonton **(<1%)**	Clayton **(<1%)**	Vineland **(<1%)**	Moorestown **(<1%)**	
Southwest	Moorestown **(87%)**	1950-2019	Philadelphia Airport **(13%)**					
Coastal South	Cape May **(99%)**	1950-2019	Belleplain State Forest **(1%)**					
Central	Hightstown **(99%)**	1950-2019	Princeton Water Works **(<1%)**	Trenton-Mercer **(<1%)**				
Northwest	Flemington **(98%)**	1950-2019	Wertsville **(2%)**	Lambertville **(<1%)**				
Northeast	Newark Liberty **(100%)**	1950-2019						

Appendix B: Significance tables

1) Significance values for 1900-2019 trends for some key variables examined for Tier 1 stations. Note the shading and italics denoting various levels of significance.

Trend analyses (P-values: **Significant at 0.1**, ***Significant at 0.05,*** Not Significant*)								
	Test	Time period	New Brunswick	Charlotteburg	Sussex	Indian Mills	Atlantic City Marina	Long Branch
Annual precipitation totals	Kendall-Tau, P-Value	1900-2019	0.12, ***0.045***	0.11, **0.083**	0.16, ***0.008***	0.06*, 0.355*	0.08*, 0.192*	0.13, ***0.030***
Days with Precipitation	Kendall-Tau, P-Value	1900-2019	**0.033,** **0.598**	**0.036,** **0.563**	*0.129,* ***0.039***	*-0.122,* ***0.050***	***-0.135,*** ***0.031***	0.066, 0.289*
Percentage of precipitation from <1" events	Kendall-Tau, P-Value	1900-2019	-0.07*, 0.246*	-0.11, **0.0757**	-0.04*, 0.542*	-0.17, ***0.007***	-0.15, ***0.015***	-0.08*, 0.223*
Percentage of precipitation from 1-2" events	Kendall-Tau, P-Value	1900-2019	0.06*, 0.304*	0.00*, 0.991*	-0.09*, 0.147*	0.06*, 0.324*	**0.11, 0.0876**	0.05*, 0.408*
Percentage of precipitation from >2" events	Kendall-Tau, P-Value	1900-2019	-0.01*, 0.872*	0.08*, 0.187*	0.12, **0.0539**	0.10*, 0.324*	0.09*, 0.163*	0.06*, 0.343*
Gini coefficient	Kendall-Tau, P-Value	1900-2019	-0.02*, 0.715*	0.00*, 0.987*	-0.16, ***0.0109***	0.17, ***0.0056***	0.17, ***0.0057***	-0.02*, 0.805*

2) Significance values for 1950-2019 trends for two key variables examined for Tier 1 and 2 stations. Those significant at the 0.05 are underlined. Total precipitation is the same as annual precipitation totals stated in the above table.

	Test	Year-Range	Cape May	Atlantic City	Flemington	Sussex	Hightstown	New Brunswick	Newark	Charlotteburg	Moorestown	Indian Mills
Total Precipitation	Kendall-Tau, P-Value	1950-2019	0.14, **0.08**	0.23, **0.01**	0.18, **0.03**	0.14, **0.08**	0.17, **0.04**	0.20, **0.02**	0.19, **0.02**	0.10, 0.21	0.17, **0.03**	0.24, **0.00**
Days with Precipitation	Kendall-Tau, P-Value	1950-2019	0.20, **0.01**	0.02, 0.82	0.05, 0.52	0.08, 0.32	0.18, **0.03**	0.13, 0.11	0.01, 0.90	0.02, 0.77	0.21, **0.01**	0.22, **0.01**

Appendix C: Enlarged sections of Table 8

Sussex

Year	Slope	Kendall's Tau-b	P-value	Std Error
1989-2019	0.14	0.02	0.87	0.21
1988-2018	0.19	0.05	0.71	0.21
1987-2017	0.1	0.01	0.97	0.20
1986-2016	0.1	-0.01	0.97	0.20
1985-2015	0.21	0.06	0.64	0.19
1984-2014	0.26	0.11	0.42	0.19
1983-2013	0.26	0.1	0.44	0.19
1982-2012	0.31	0.14	0.28	0.19
1981-2011	0.39	0.2	0.13	0.19
1980-2010	0.28	0.19	0.14	0.16
1979-2009	0.25	0.16	0.22	0.17
1978-2008	0.3	0.2	0.13	0.17
1977-2007	0.28	0.17	0.18	0.17
1976-2006	0.27	0.16	0.21	0.17
1975-2005	0.11	0.05	0.71	0.17
1974-2004	0.03	-0.02	0.89	0.17
1973-2003	-0.12	-0.12	0.34	0.17
1972-2002	-0.32	-0.24	0.06	0.16
1971-2001	-0.33	-0.25	0.05	0.16
1970-2000	-0.2	-0.16	0.21	0.16
1969-1999	-0.19	-0.17	0.18	0.16
1968-1998	-0.11	-0.11	0.42	0.16
1967-1997	-0.07	-0.08	0.54	0.16
1966-1996	0.05	0.03	0.84	0.17
1965-1995	0.01	0.03	0.84	0.16
1964-1994	0.18	0.14	0.26	0.17
1963-1993	0.21	0.16	0.21	0.17
1962-1992	0.29	0.22	0.09	0.17
1961-1991	0.27	0.2	0.13	0.17
1960-1990	0.29	0.2	0.11	0.17
1959-1989	0.25	0.16	0.21	0.17
1958-1988	0.23	0.13	0.31	0.17
1957-1987	0.31	0.2	0.11	0.16
1956-1986	0.34	0.24	0.06	0.16
1955-1985	0.29	0.19	0.14	0.16
1954-1984	0.32	0.2	0.11	0.16
1953-1983	0.29	0.16	0.22	0.16
1952-1982	0.15	0.06	0.64	0.17
1951-1981	0.15	0.06	0.64	0.17
1950-1980	0.16	0.07	0.59	0.17
1949-1979	0.27	0.16	0.22	0.16
1948-1978	0.19	0.09	0.48	0.16
1947-1977	0.15	0.07	0.59	0.17
1946-1976	0.2	0.11	0.42	0.17
1945-1975	0.12	0.05	0.74	0.18
1944-1974	0.04	0.01	0.97	0.17
1943-1973	0.06	0.01	0.95	0.17
1942-1972	-0.16	-0.11	0.4	0.18
1941-1971	-0.22	-0.14	0.29	0.16
1940-1970	-0.3	-0.21	0.1	0.16
1939-1969	-0.26	-0.18	0.16	0.16
1938-1968	-0.38	-0.25	0.05	0.16
1937-1967	-0.39	-0.27	0.03	0.16
1936-1966	-0.41	-0.29	0.02	0.16
1935-1965	-0.34	-0.24	0.06	0.16
1934-1964	-0.3	-0.21	0.1	0.16
1933-1963	-0.2	-0.15	0.24	0.16
1932-1962	-0.16	-0.14	0.29	0.16
1931-1961	-0.04	-0.03	0.81	0.16
1930-1960	0.04	0.03	0.81	0.16
1929-1959	0.02	0.0	1.0	0.16
1928-1958	0.01	-0.01	0.95	0.16
1927-1957	-0.03	-0.05	0.74	0.16
1926-1956	0.05	0.02	0.87	0.16
1925-1955	0.08	0.05	0.71	0.16
1924-1954	0.12	0.06	0.64	0.16
1923-1953	0.21	0.13	0.31	0.16
1922-1952	0.26	0.17	0.19	0.16
1921-1951	0.24	0.15	0.24	0.16
1920-1950	0.17	0.09	0.5	0.17
1919-1949	0.12	0.04	0.79	0.17
1918-1948	0.21	0.09	0.48	0.17
1917-1947	0.28	0.15	0.25	0.17
1916-1946	0.24	0.11	0.38	0.17
1915-1945	0.31	0.17	0.18	0.16
1914-1944	0.25	0.15	0.24	0.15
1913-1943	0.28	0.16	0.22	0.15
1912-1942	0.33	0.21	0.1	0.14
1911-1941	0.2	0.13	0.33	0.13
1910-1940	0.29	0.24	0.06	0.13
1909-1939	0.27	0.22	0.09	0.13
1908-1938	0.35	0.3	0.02	0.12
1907-1937	0.21	0.2	0.11	0.11
1906-1936	0.16	0.14	0.26	0.11
1905-1935	0.18	0.14	0.26	0.11
1904-1934	0.15	0.11	0.4	0.12
1903-1933	0.0	-0.01	0.97	0.13
1902-1932	-0.13	-0.1	0.46	0.15
1901-1931	-0.25	-0.2	0.13	0.14
1900-1930	-0.18	-0.14	0.29	0.15

Charlotteburg

Year	Slope	Kendall's Tau-b	P-value	Std Error
1989-2019	0.15	-0.02	0.87	0.24
1988-2018	0.1	-0.04	0.79	0.23
1987-2017	-0.1	-0.14	0.26	0.22
1986-2016	-0.09	-0.14	0.26	0.22
1985-2015	-0.03	-0.12	0.36	0.21
1984-2014	0.02	-0.09	0.5	0.21
1983-2013	-0.03	-0.1	0.46	0.22
1982-2012	0.06	-0.05	0.74	0.21
1981-2011	0.19	0.06	0.64	0.21
1980-2010	0.03	0.03	0.84	0.18
1979-2009	-0.04	-0.02	0.89	0.18
1978-2008	0.02	0.02	0.87	0.18
1977-2007	-0.01	-0.02	0.92	0.18
1976-2006	-0.01	-0.04	0.79	0.18
1975-2005	-0.09	-0.11	0.4	0.18
1974-2004	-0.13	-0.17	0.2	0.18
1973-2003	-0.2	-0.24	0.06	0.18
1972-2002	-0.44	-0.36	0.0	0.16
1971-2001	-0.41	-0.35	0.01	0.16
1970-2000	-0.28	-0.28	0.03	0.15
1969-1999	-0.28	-0.3	0.02	0.15
1968-1998	-0.23	-0.24	0.06	0.16
1967-1997	-0.18	-0.2	0.11	0.16
1966-1996	-0.09	-0.11	0.38	0.16
1965-1995	-0.04	-0.11	0.42	0.17
1964-1994	0.09	0.0	1.0	0.18
1963-1993	0.21	0.09	0.5	0.18
1962-1992	0.29	0.17	0.2	0.18
1961-1991	0.32	0.21	0.1	0.18
1960-1990	0.39	0.26	0.04	0.17
1959-1989	0.37	0.25	0.05	0.17
1958-1988	0.37	0.23	0.07	0.17
1957-1987	0.51	0.33	0.01	0.16
1956-1986	0.49	0.32	0.01	0.16
1955-1985	0.52	0.34	0.01	0.16
1954-1984	0.55	0.37	0.0	0.16
1953-1983	0.54	0.35	0.01	0.16
1952-1982	0.4	0.26	0.04	0.16
1951-1981	0.38	0.25	0.05	0.16
1950-1980	0.46	0.33	0.01	0.15
1949-1979	0.52	0.4	0.0	0.15
1948-1978	0.4	0.3	0.02	0.15
1947-1977	0.4	0.32	0.01	0.15
1946-1976	0.42	0.32	0.01	0.15
1945-1975	0.37	0.27	0.03	0.15
1944-1974	0.25	0.17	0.19	0.15
1943-1973	0.26	0.18	0.16	0.15
1942-1972	0.16	0.08	0.54	0.15
1941-1971	0.07	0.07	0.61	0.13
1940-1970	-0.01	-0.01	0.97	0.13
1939-1969	-0.0	0.01	0.95	0.13
1938-1968	-0.1	-0.08	0.52	0.12
1937-1967	-0.12	-0.11	0.42	0.12
1936-1966	-0.18	-0.16	0.21	0.12
1935-1965	-0.18	-0.16	0.21	0.12
1934-1964	-0.08	-0.09	0.48	0.11
1933-1963	-0.06	-0.07	0.59	0.11
1932-1962	0.01	-0.0	1.0	0.10
1931-1961	0.09	0.1	0.46	0.10
1930-1960	0.13	0.13	0.31	0.11
1929-1959	0.08	0.08	0.54	0.11
1928-1958	0.08	0.09	0.5	0.11
1927-1957	-0.0	-0.02	0.89	0.11
1926-1956	0.04	0.02	0.92	0.10
1925-1955	0.07	0.06	0.66	0.10
1924-1954	0.07	0.08	0.57	0.10
1923-1953	0.14	0.16	0.22	0.11
1922-1952	0.13	0.16	0.22	0.11
1921-1951	0.1	0.13	0.31	0.11
1920-1950	0.0	0.03	0.84	0.11
1919-1949	-0.02	-0.0	1.0	0.12
1918-1948	0.05	0.07	0.61	0.12
1917-1947	0.02	0.05	0.74	0.11
1916-1946	0.03	0.07	0.61	0.12
1915-1945	0.03	0.06	0.64	0.12
1914-1944	0.02	0.05	0.74	0.11
1913-1943	-0.02	0.01	0.97	0.11
1912-1942	-0.02	0.02	0.92	0.11
1911-1941	-0.16	-0.1	0.44	0.12
1910-1940	-0.13	-0.07	0.61	0.12
1909-1939	-0.17	-0.14	0.29	0.12
1908-1938	-0.16	-0.13	0.31	0.12
1907-1937	-0.23	-0.22	0.08	0.11
1906-1936	-0.23	-0.21	0.1	0.11
1905-1935	-0.23	-0.22	0.08	0.11
1904-1934	-0.27	-0.25	0.05	0.12
1903-1933	-0.29	-0.28	0.03	0.12
1902-1932	-0.36	-0.35	0.0	0.12
1901-1931	-0.39	-0.39	0.0	0.11
1900-1930	-0.32	-0.32	0.01	0.12

New Brunswick

Year	Slope	Kendall's Tau-b	P-value	Std Error
1989-2019	0.1	0.08	0.52	0.16
1988-2018	0.07	0.04	0.76	0.15
1987-2017	-0.03	-0.03	0.81	0.14
1986-2016	-0.0	-0.01	0.95	0.14
1985-2015	0.09	0.08	0.52	0.14
1984-2014	0.13	0.11	0.42	0.14
1983-2013	0.04	0.03	0.84	0.14
1982-2012	0.12	0.11	0.42	0.15
1981-2011	0.23	0.22	0.09	0.14
1980-2010	0.19	0.21	0.1	0.13
1979-2009	0.14	0.18	0.15	0.14
1978-2008	0.14	0.18	0.16	0.14
1977-2007	0.09	0.12	0.36	0.14
1976-2006	0.12	0.14	0.28	0.15
1975-2005	-0.01	0.05	0.74	0.16
1974-2004	-0.0	0.04	0.76	0.16
1973-2003	-0.06	-0.02	0.89	0.16
1972-2002	-0.19	-0.11	0.38	0.16
1971-2001	-0.22	-0.16	0.22	0.16
1970-2000	-0.11	-0.06	0.66	0.16
1969-1999	-0.06	-0.02	0.89	0.16
1968-1998	-0.03	-0.01	0.95	0.16
1967-1997	-0.01	-0.0	1.0	0.16
1966-1996	0.01	0.01	0.95	0.16
1965-1995	0.06	0.02	0.89	0.17
1964-1994	0.18	0.13	0.31	0.17
1963-1993	0.26	0.19	0.14	0.17
1962-1992	0.3	0.22	0.09	0.17
1961-1991	0.32	0.23	0.07	0.17
1960-1990	0.32	0.23	0.08	0.17
1959-1989	0.32	0.22	0.09	0.17
1958-1988	0.22	0.13	0.31	0.17
1957-1987	0.27	0.17	0.18	0.17
1956-1986	0.26	0.15	0.24	0.17
1955-1985	0.32	0.19	0.14	0.17
1954-1984	0.35	0.21	0.1	0.16
1953-1983	0.31	0.16	0.21	0.16
1952-1982	0.18	0.07	0.61	0.16
1951-1981	0.19	0.07	0.59	0.16
1950-1980	0.25	0.14	0.26	0.16
1949-1979	0.33	0.23	0.07	0.15
1948-1978	0.21	0.13	0.33	0.15
1947-1977	0.21	0.12	0.34	0.15
1946-1976	0.21	0.12	0.36	0.15
1945-1975	0.22	0.12	0.34	0.15
1944-1974	0.05	0.02	0.92	0.13
1943-1973	0.11	0.08	0.54	0.14
1942-1972	-0.01	-0.02	0.87	0.13
1941-1971	-0.04	-0.04	0.79	0.12
1940-1970	-0.11	-0.12	0.36	0.12
1939-1969	-0.06	-0.05	0.69	0.12
1938-1968	-0.1	-0.09	0.48	0.12
1937-1967	-0.12	-0.11	0.42	0.12
1936-1966	-0.17	-0.16	0.21	0.12
1935-1965	-0.18	-0.16	0.21	0.12
1934-1964	-0.07	-0.09	0.48	0.11
1933-1963	-0.06	-0.07	0.59	0.10
1932-1962	0.01	-0.0	1.0	0.10
1931-1961	0.09	0.1	0.46	0.10
1930-1960	0.13	0.14	0.29	0.11
1929-1959	0.08	0.08	0.52	0.11
1928-1958	0.08	0.09	0.48	0.11
1927-1957	-0.0	-0.02	0.92	0.11
1926-1956	0.04	0.02	0.89	0.10
1925-1955	0.08	0.07	0.59	0.11
1924-1954	0.08	0.09	0.5	0.10
1923-1953	0.15	0.17	0.19	0.11
1922-1952	0.14	0.17	0.19	0.11
1921-1951	0.1	0.14	0.26	0.11
1920-1950	0.01	0.04	0.76	0.12
1919-1949	-0.03	0.01	0.97	0.12
1918-1948	0.04	0.08	0.57	0.12
1917-1947	0.01	0.05	0.69	0.12
1916-1946	0.02	0.08	0.57	0.12
1915-1945	0.02	0.07	0.61	0.12
1914-1944	0.01	0.05	0.69	0.12
1913-1943	-0.03	0.01	0.95	0.11
1912-1942	-0.02	0.02	0.89	0.11
1911-1941	-0.16	-0.1	0.46	0.12
1910-1940	-0.13	-0.06	0.66	0.12
1909-1939	-0.17	-0.13	0.33	0.12
1908-1938	-0.14	-0.09	0.5	0.12
1907-1937	-0.2	-0.17	0.18	0.12
1906-1936	-0.18	-0.16	0.21	0.12
1905-1935	-0.17	-0.15	0.25	0.12
1904-1934	-0.21	-0.18	0.16	0.12
1903-1933	-0.24	-0.21	0.1	0.12
1902-1932	-0.32	-0.29	0.02	0.12
1901-1931	-0.35	-0.32	0.01	0.12
1900-1930	-0.3	-0.28	0.03	0.12

Long Branch

Year	Slope	Kendall's Tau-b	P-value	Std Error
1989-2019	0.33	0.27	0.03	0.16
1988-2018	0.43	0.31	0.01	0.17
1987-2017	0.33	0.28	0.03	0.16
1986-2016	0.33	0.27	0.03	0.16
1985-2015	0.47	0.37	0.0	0.16
1984-2014	0.47	0.38	0.0	0.16
1983-2013	0.3	0.26	0.04	0.17
1982-2012	0.35	0.29	0.02	0.17
1981-2011	0.43	0.33	0.01	0.17
1980-2010	0.32	0.31	0.01	0.16
1979-2009	0.22	0.23	0.07	0.17
1978-2008	0.16	0.18	0.15	0.17
1977-2007	0.07	0.11	0.4	0.17
1976-2006	0.06	0.1	0.44	0.17
1975-2005	0.01	0.06	0.66	0.17
1974-2004	-0.02	0.02	0.92	0.17
1973-2003	-0.05	-0.01	0.97	0.17
1972-2002	-0.16	-0.11	0.42	0.17
1971-2001	-0.2	-0.14	0.26	0.16
1970-2000	-0.07	-0.05	0.74	0.16
1969-1999	-0.08	-0.05	0.69	0.16
1968-1998	-0.05	-0.02	0.92	0.16
1967-1997	-0.03	0.0	1.0	0.16
1966-1996	0.0	0.02	0.87	0.16
1965-1995	0.05	0.05	0.74	0.17
1964-1994	0.16	0.14	0.28	0.17
1963-1993	0.24	0.2	0.13	0.17
1962-1992	0.22	0.17	0.18	0.17
1961-1991	0.21	0.17	0.2	0.17
1960-1990	0.19	0.15	0.24	0.17
1959-1989	0.18	0.14	0.29	0.17
1958-1988	0.04	0.05	0.74	0.17
1957-1987	0.18	0.15	0.24	0.16
1956-1986	0.18	0.16	0.21	0.16
1955-1985	0.23	0.2	0.13	0.16
1954-1984	0.33	0.27	0.03	0.15
1953-1983	0.25	0.2	0.12	0.15
1952-1982	0.09	0.08	0.54	0.14
1951-1981	0.11	0.1	0.46	0.14
1950-1980	0.19	0.17	0.19	0.14
1949-1979	0.27	0.25	0.05	0.13
1948-1978	0.11	0.13	0.33	0.13
1947-1977	0.04	0.06	0.66	0.13
1946-1976	0.07	0.08	0.52	0.14
1945-1975	0.06	0.07	0.61	0.14
1944-1974	-0.05	-0.04	0.76	0.14
1943-1973	-0.05	-0.04	0.79	0.14
1942-1972	-0.13	-0.11	0.38	0.14
1941-1971	-0.16	-0.13	0.33	0.13
1940-1970	-0.18	-0.15	0.24	0.13
1939-1969	-0.15	-0.13	0.33	0.13
1938-1968	-0.28	-0.21	0.1	0.14
1937-1967	-0.29	-0.23	0.08	0.14
1936-1966	-0.3	-0.23	0.07	0.14
1935-1965	-0.25	-0.18	0.15	0.14
1934-1964	-0.13	-0.09	0.48	0.14
1933-1963	-0.09	-0.06	0.66	0.14
1932-1962	-0.02	0.02	0.89	0.13
1931-1961	0.05	0.09	0.5	0.14
1930-1960	0.09	0.11	0.38	0.14
1929-1959	0.05	0.08	0.54	0.14
1928-1958	0.07	0.1	0.44	0.14
1927-1957	0.0	0.02	0.87	0.14
1926-1956	0.06	0.08	0.54	0.13
1925-1955	0.1	0.11	0.38	0.13
1924-1954	0.19	0.2	0.11	0.13
1923-1953	0.22	0.24	0.06	0.13
1922-1952	0.26	0.27	0.03	0.13
1921-1951	0.27	0.29	0.02	0.13
1920-1950	0.18	0.2	0.11	0.14
1919-1949	0.08	0.15	0.24	0.16
1918-1948	0.1	0.16	0.22	0.16
1917-1947	-0.04	0.05	0.69	0.16
1916-1946	0.0	0.07	0.61	0.16
1915-1945	0.05	0.1	0.46	0.16
1914-1944	0.02	0.07	0.59	0.16
1913-1943	-0.15	-0.04	0.79	0.16
1912-1942	-0.16	-0.05	0.71	0.16
1911-1941	-0.24	-0.13	0.31	0.16
1910-1940	-0.14	-0.05	0.74	0.16
1909-1939	-0.12	-0.03	0.81	0.16
1908-1938	-0.06	0.02	0.92	0.17
1907-1937	-0.23	-0.1	0.44	0.15
1906-1936	-0.27	-0.15	0.24	0.15
1905-1935	-0.24	-0.14	0.29	0.16
1904-1934	-0.2	-0.11	0.4	0.16
1903-1933	-0.22	-0.13	0.31	0.16
1902-1932	-0.26	-0.17	0.18	0.16
1901-1931	-0.34	-0.23	0.07	0.16
1900-1930	-0.27	-0.18	0.15	0.16

Indian Mills

Year	Slope	Kendall's Tau-b	P-value	Std Error
1989-2019	0.28	0.13	0.31	0.15
1988-2018	0.29	0.14	0.29	0.16
1987-2017	0.14	0.08	0.54	0.13
1986-2016	0.17	0.1	0.44	0.13
1985-2015	0.28	0.2	0.11	0.13
1984-2014	0.33	0.26	0.04	0.13
1983-2013	0.23	0.17	0.19	0.14
1982-2012	0.26	0.19	0.14	0.14
1981-2011	0.31	0.24	0.06	0.14
1980-2010	0.28	0.23	0.07	0.14
1979-2009	0.23	0.2	0.13	0.15
1978-2008	0.17	0.15	0.25	0.14
1977-2007	0.17	0.15	0.25	0.14
1976-2006	0.24	0.21	0.1	0.14
1975-2005	0.13	0.13	0.33	0.15
1974-2004	0.08	0.07	0.61	0.15
1973-2003	0.03	0.03	0.84	0.14
1972-2002	-0.12	-0.08	0.52	0.14
1971-2001	-0.14	-0.12	0.36	0.14
1970-2000	-0.01	-0.0	1.0	0.14
1969-1999	-0.05	-0.05	0.69	0.14
1968-1998	-0.01	-0.03	0.84	0.15
1967-1997	0.03	0.01	0.95	0.15
1966-1996	0.07	0.05	0.69	0.15
1965-1995	0.09	0.06	0.66	0.15
1964-1994	0.19	0.15	0.25	0.15
1963-1993	0.22	0.17	0.2	0.15
1962-1992	0.18	0.13	0.33	0.15
1961-1991	0.19	0.14	0.29	0.15
1960-1990	0.16	0.1	0.44	0.15
1959-1989	0.15	0.09	0.5	0.15
1958-1988	-0.02	-0.02	0.87	0.17
1957-1987	0.09	0.08	0.54	0.17
1956-1986	0.05	0.02	0.87	0.17
1955-1985	0.12	0.08	0.52	0.17
1954-1984	0.2	0.15	0.25	0.17
1953-1983	0.19	0.12	0.36	0.17
1952-1982	0.05	0.02	0.89	0.17
1951-1981	0.11	0.07	0.61	0.17
1950-1980	0.17	0.12	0.34	0.16
1949-1979	0.25	0.19	0.14	0.16
1948-1978	0.1	0.08	0.57	0.16
1947-1977	0.09	0.06	0.64	0.16
1946-1976	0.12	0.09	0.48	0.16
1945-1975	0.12	0.08	0.52	0.16
1944-1974	0.05	0.03	0.84	0.16
1943-1973	0.06	0.04	0.79	0.16
1942-1972	0.06	0.02	0.89	0.16
1941-1971	0.01	-0.01	0.97	0.15
1940-1970	-0.09	-0.1	0.44	0.15
1939-1969	-0.09	-0.11	0.42	0.15
1938-1968	-0.21	-0.21	0.1	0.15
1937-1967	-0.23	-0.22	0.08	0.15
1936-1966	-0.24	-0.24	0.06	0.15
1935-1965	-0.26	-0.26	0.04	0.15
1934-1964	-0.2	-0.23	0.07	0.14
1933-1963	-0.22	-0.24	0.06	0.14
1932-1962	-0.2	-0.23	0.07	0.14
1931-1961	-0.17	-0.2	0.13	0.14
1930-1960	-0.1	-0.14	0.28	0.15
1929-1959	-0.11	-0.14	0.26	0.15
1928-1958	-0.11	-0.14	0.28	0.15
1927-1957	-0.24	-0.22	0.08	0.13
1926-1956	-0.2	-0.18	0.15	0.12
1925-1955	-0.21	-0.18	0.15	0.12
1924-1954	-0.18	-0.17	0.19	0.12
1923-1953	-0.15	-0.13	0.33	0.12
1922-1952	-0.11	-0.09	0.48	0.12
1921-1951	-0.09	-0.08	0.54	0.12
1920-1950	-0.09	-0.08	0.54	0.13
1919-1949	-0.08	-0.08	0.54	0.12
1918-1948	-0.01	-0.0	1.0	0.13
1917-1947	-0.09	-0.08	0.52	0.12
1916-1946	-0.03	-0.02	0.87	0.12
1915-1945	-0.01	0.01	0.95	0.12
1914-1944	0.02	0.05	0.71	0.12
1913-1943	0.04	0.09	0.5	0.12
1912-1942	0.08	0.13	0.33	0.11
1911-1941	0.03	0.09	0.48	0.12
1910-1940	0.13	0.2	0.13	0.12
1909-1939	0.15	0.2	0.11	0.12
1908-1938	0.13	0.2	0.13	0.12
1907-1937	0.02	0.08	0.54	0.13
1906-1936	-0.04	-0.01	0.97	0.13
1905-1935	-0.03	0.02	0.92	0.13
1904-1934	0.01	0.06	0.64	0.13
1903-1933	-0.02	0.02	0.87	0.13
1902-1932	-0.15	-0.09	0.5	0.13
1901-1931	-0.22	-0.18	0.16	0.12
1900-1930	-0.12	-0.07	0.61	0.13

Atlantic City Marina

Year	Slope	Kendall's Tau-b	P-value	Std Error
1989-2019	0.3	0.34	0.01	0.13
1988-2018	0.4	0.44	0.0	0.12
1987-2017	0.34	0.39	0.0	0.12
1986-2016	0.36	0.4	0.0	0.12
1985-2015	0.44	0.45	0.0	0.12
1984-2014	0.45	0.47	0.0	0.12
1983-2013	0.39	0.42	0.0	0.12
1982-2012	0.44	0.45	0.0	0.12
1981-2011	0.45	0.45	0.0	0.12
1980-2010	0.47	0.46	0.0	0.12
1979-2009	0.39	0.36	0.0	0.13
1978-2008	0.26	0.32	0.01	0.11
1977-2007	0.25	0.32	0.01	0.11
1976-2006	0.27	0.35	0.01	0.11
1975-2005	0.25	0.31	0.01	0.11
1974-2004	0.24	0.3	0.02	0.11
1973-2003	0.22	0.28	0.03	0.11
1972-2002	0.1	0.17	0.19	0.13
1971-2001	0.03	0.09	0.48	0.13
1970-2000	0.13	0.18	0.15	0.12
1969-1999	0.04	0.08	0.52	0.12
1968-1998	0.07	0.11	0.4	0.12
1967-1997	0.02	0.05	0.71	0.12
1966-1996	-0.02	-0.01	0.95	0.12
1965-1995	-0.02	-0.0	1.0	0.12
1964-1994	-0.0	0.02	0.89	0.12
1963-1993	0.01	0.03	0.84	0.12
1962-1992	-0.01	-0.01	0.95	0.12
1961-1991	-0.03	-0.05	0.74	0.12
1960-1990	-0.01	-0.03	0.81	0.12
1959-1989	-0.08	-0.08	0.54	0.13
1958-1988	-0.33	-0.2	0.12	0.15
1957-1987	-0.27	-0.14	0.26	0.15
1956-1986	-0.33	-0.22	0.08	0.15
1955-1985	-0.29	-0.2	0.12	0.15
1954-1984	-0.19	-0.11	0.42	0.15
1953-1983	-0.29	-0.17	0.19	0.16
1952-1982	-0.34	-0.24	0.06	0.16
1951-1981	-0.29	-0.19	0.14	0.16
1950-1980	-0.22	-0.14	0.29	0.16
1949-1979	-0.18	-0.1	0.46	0.16
1948-1978	-0.35	-0.2	0.12	0.17
1947-1977	-0.28	-0.14	0.28	0.17
1946-1976	-0.19	-0.05	0.71	0.18
1945-1975	-0.16	-0.03	0.84	0.18
1944-1974	-0.2	-0.08	0.54	0.18
1943-1973	-0.12	-0.01	0.95	0.18
1942-1972	-0.13	-0.04	0.76	0.18
1941-1971	-0.14	-0.04	0.79	0.18
1940-1970	-0.16	-0.08	0.57	0.18
1939-1969	-0.15	-0.09	0.48	0.18
1938-1968	-0.22	-0.17	0.2	0.18
1937-1967	-0.17	-0.14	0.28	0.18
1936-1966	-0.21	-0.19	0.14	0.18
1935-1965	-0.26	-0.23	0.08	0.18
1934-1964	-0.16	-0.15	0.24	0.18
1933-1963	-0.17	-0.17	0.19	0.18
1932-1962	-0.12	-0.13	0.31	0.17
1931-1961	-0.03	-0.06	0.64	0.18
1930-1960	0.08	0.02	0.89	0.19
1929-1959	0.17	0.08	0.54	0.18
1928-1958	0.12	0.03	0.84	0.18
1927-1957	-0.02	-0.03	0.84	0.16
1926-1956	0.03	0.02	0.89	0.16
1925-1955	0.07	0.05	0.74	0.16
1924-1954	0.15	0.11	0.4	0.16
1923-1953	0.22	0.17	0.19	0.15
1922-1952	0.15	0.13	0.33	0.15
1921-1951	0.16	0.13	0.33	0.15
1920-1950	0.16	0.12	0.34	0.15
1919-1949	0.13	0.09	0.48	0.15
1918-1948	0.21	0.16	0.22	0.15
1917-1947	0.09	0.1	0.46	0.14
1916-1946	0.18	0.18	0.15	0.13
1915-1945	0.27	0.27	0.03	0.12
1914-1944	0.25	0.25	0.05	0.12
1913-1943	0.22	0.23	0.07	0.12
1912-1942	0.22	0.23	0.07	0.12
1911-1941	0.17	0.17	0.18	0.13
1910-1940	0.26	0.27	0.03	0.12
1909-1939	0.28	0.28	0.03	0.12
1908-1938	0.26	0.26	0.04	0.12
1907-1937	0.16	0.15	0.24	0.12
1906-1936	0.09	0.08	0.54	0.13
1905-1935	0.06	0.04	0.76	0.13
1904-1934	0.03	0.04	0.76	0.12
1903-1933	-0.11	-0.04	0.79	0.14
1902-1932	-0.24	-0.16	0.22	0.13
1901-1931	-0.26	-0.18	0.16	0.13
1900-1930	-0.13	-0.06	0.64	0.14