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Maryland Climate Bulletin Annual 2024

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DEPARTMENT OF ATMOSPHERIC & OCEANIC SCIENCE
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Maryland State Climatologist Office

Summary

Statewide averages show that 2024 was warmer and drier than normal (i.e., 1991-2020 averages) again. Regionally, annual mean temperatures were between 50 and 60°F, annual maximum temperatures were in the 60 to 70°F range, and annual minimum temperatures were between 40 and 51°F. Annual-accumulated precipitation was between 34 and 50 inches.

Maryland Regional Features (Figures 1-4, C1, and D1)

- Mean temperature was warmer than normal everywhere in the state, especially over Garrett County (3.4°F), western Montgomery and Frederick counties (2.4−2.8°F), western Charles County (2.4−2.6°F), and parts of Carroll, Baltimore, Harford, northern Anne Arundel, and southern Saint Mary's and Calvert counties (2.4°F).

- Maximum temperature was also warmer than normal throughout the state, notably over Garrett County (3.0−4.0°F), southern Baltimore, southeastern Howard, and northern Anne Arundel counties (2.6°F), and Carroll, Howard, portions of Baltimore, northern Anne Arundel, western Montgomery, Frederick, Prince George's, Charles, southern Calvert and Saint Mary's, and western Dorchester counties (2.4°F).

- Minimum temperature was warmer than normal in the entire state, too, particularly over western Montgomery and Frederick counties (2.6−3.2°F), Garrett County (2.6−3.0°F), northern Carroll, Baltimore, Harford, and Cecil counties (2.4−2.6°F), Charles County (2.2−2.8°F), and parts of Prince George's, Calvert, Saint Mary's, Talbot, Queen Anne's and Kent counties (around 2.2°F).

- Precipitation was below normal everywhere in the state, especially over portions of Calvert, Charles, and Saint Mary's counties (9−10 inches deficit), Harford County, and counties in the Eastern Shore (7−9 inches deficit). These counties received 80−84% of their climatological annual precipitation. The rest of the state got between 86 and 98% of their climatological annual precipitation; the counties in the central and western Piedmont and Garrett County were the less dry, with 96 to 98% of their climatological annual precipitation.

Maryland Statewide & Climate Divisions (Figures 5-7, B1, and B2)

- The monthly evolution of statewide temperatures and accumulated precipitation in 2024 showed that in eleven of the twelve months, the state was warmer than normal, particularly in November (4.2°F), and that in ten of the twelve months, the state was drier than normal, especially in October (3.66 inches deficit). Mean temperature anomalies from January to March and September to November followed the increasing anomalies in maximum temperatures in these months. Above-normal precipitation occurred only in January and March, with the latter making a spring with above-normal precipitation possible despite below-normal precipitation in April and May; June was the driest month in summer, and increasing precipitation deficits from July to October contributed to a fall with below-normal precipitation.

- All eight climate divisions were warmer and drier than normal in 2024. Climate Division 8, Allegheny Plateau, was the warmest (3.0°F), while Climate Division 3, Lower Southern, was the driest (9.34 inches deficit).

- Statewide temperature and precipitation anomalies have remained warmer and drier than normal since 2022. The low annual statewide temperature and precipitation anomalies in 2022 (0.3°F, −1.13 in) increased in 2023 (1.9°F, −7.15 in), but the temperature anomalies increased slightly more, and the precipitation anomalies decreased in 2024 (2.1°F, −5.87 in). The temperature anomalies in 2023 and 2024 surpassed the standard deviation for the 1895-2024 period (1.4°F), but only the precipitation anomalies in 2023 surpassed the precipitation standard deviation (5.96 in).

Statewide Extremes in 2024 (Figures 8–11)

- The number of statewide hot days (daily maximum temperatures greater than 86°F) was larger than normal by 2 days (50 vs. 48), although the number of heat waves was smaller by 2 waves (7 vs. 9) in 2024. The first heat wave started 21 days later than normal (June 14 vs. May 24), but the last wave started 7 days earlier (August 27 vs. September 3). The mean duration of the heat waves was longer than normal by 1 day (6 vs. 5 days), but the duration of the longest wave was normal (11 days).

- The number of statewide warm days (daily maximum temperatures greater than 80°F) was larger than normal by 13 days (114 vs. 101), but the number of warm-day spells was smaller by 2 days (9 vs. 11) in 2024. The first warm-day spell started 1 day earlier than normal (April 29 vs. April 30) as the last spell did (September 20 vs. September 21). The mean duration of the warm-day spells was longer than normal by 3 days (12 vs. 9 days), as the duration of the longest spell (49 vs. 33 days).

- The number of statewide warm nights (daily minimum temperatures greater than 68°F) was larger than normal by 13 nights (40 vs. 27), but the number of warm-night spells was normal (6) in 2024. The first warm-night spell started 1 day earlier than normal (June 22 vs. June 23), but the last spell started 30 days later (September 27 vs. August 28). The mean duration of the warm-night spells was longer than normal by 2 days (6 vs.4 days), while the duration of the longest spell was longer by 6 days (14 vs. 8 days).

- The number of statewide freezing days (daily minimum temperatures equal to or less than 32°F) was smaller than normal by 22 days (68 vs. 90) in 2024. Similarly, the number of statewide moderate freezing days (daily minimum temperatures equal to or less than 28°F) was smaller than normal by 14 days (45 vs. 59), as was the case for severe freezing days (21 vs. 35; daily minimum temperatures equal to or less than 24°F). The number of

freezing spells and their duration were also fewer than normal, except for the mean duration of the severe freezing spells, which was larger by one spell than its climatology.

- The statewide growing season lasted 16 more days (233 vs. 217) than normal in 2024. It started 6 days earlier than normal (March 26 vs. April 1) and ended 10 days later (November 13 vs. November 3).

- The statewide vegetation period lasted 21 fewer days (272 vs. 293) than normal in 2024. It started 16 days later than normal (March 3 vs. February 16) and ended 6 days earlier (November 29 vs. December 5) than normal.

- The number of statewide dry spells (consecutive days with daily total precipitation less than 0.04 inches) within the vegetation period was fewer than normal by 12 spells (26 vs. 38) and 10 fewer than normal within the calendar year (38 vs. 48) in 2024. The mean duration of the dry spells in the vegetation period was longer than normal by 1 day (6 vs. 5 days), while the duration of the longest spell was longer by 18 days (34 vs. 16 days); similarly, the mean duration of the dry spells in the calendar year was longer than normal by 1 day (6 vs. 5 days) while the duration of the longest spell was longer by 17 days (34 vs. 17 days). In other words, the longest dry spell, which started on October 8, lasted twice as long as normal.

- The number of statewide days with extreme precipitation (total daily precipitation equal to or greater than the 95th percentile: 0.64 inches) was 2 days fewer (17 vs. 19) than normal in 2024.

- Statewide cumulative growing degree days and modified growing degree days were above normal in 2024. Growing degree days accumulated faster than normal at the start of the vegetation period (March 3) and plateaued at the end of it (November 29).

Historical Context (Figure 12, Tables A1 and A2)

- The statewide annual mean temperatures were very close to set new records in 2024. The mean temperature (57.5°F) tied for the warmest year on record set in 2012; the minimum temperature (47.4°F) this year was the second warmest after the record of 47.5°F set in 2020, and the maximum temperature (67.6°F) was the third warmest after the record of 67.7°F of 2023. However, Garret and Montgomery counties reached the warmest year on record in the mean, maximum, and minimum temperatures. Mean and minimum temperatures this year reached values within the four warmest years in 20 counties, while the maximum temperature did in 19 counties.

- Statewide annual accumulated precipitation (39.36 inches) in 2024 was the thirty-fifth driest, far from the record of 23.28 inches set in 1930. Caroline County had the fourteenth driest year, while Charles, Dorchester, and Wicomico counties had the fifteenth.

Annual Trends: 1895-2024 & 1951-2024 (Figures 13, 14, 15)

- Statewide annual temperature, cooling degree days, heating degree days, and accumulated precipitation showed significant trends in the period 1895-2024. A warming trend (2.2°F/century), an increasing trend in cooling degree days (240.2°FDD/century), a decreasing trend in heating degree days (−6026.8°FDD/century), and a wetting trend in precipitation (2.97 in/century).

- Regionally, annual mean temperatures showed significant warming trends everywhere in the state for the 1895-2024 period. Notably, the largest trend is in Baltimore City (3.0°F/century). Trends above 2.4°F/century are also evident along the Piedmont counties of Montgomery, Howard, Carroll, and Baltimore counties and over Anne Arundel, Prince George's, and the counties of the Eastern Shore.

- Regionally, annual accumulated precipitation had significant wetting trends over large regions in the state in the same 1895-2024 period. In particular, over parts of Baltimore City, Baltimore, and Howard counties (5.5−6.0 in/century), over Montgomery, Howard, Anne Arundel, Prince George's, Carroll, Baltimore, Harford, and Cecil counties (above 4.0 in/century), and over portions of Garrett, Calvert, Saint Mary's counties and Somerset and Worcester counties (3.5−4.0 in/century).

- The statewide duration of the growing season, the duration of the vegetation period, and the number of dry spells within the vegetation period displayed significant increasing trends in the period 1951-2024 of 4.4 days/decade, 5.7 days/decade, and 0.8 spells/decade respectively. On the other hand, the number of dry spells within the calendar year and the number of days of extreme precipitation showed no significant trends.

Contents

1. Introduction

The Maryland Climate Bulletin is issued by the Maryland State Climatologist Office (MDSCO), which resides in the Department of Atmospheric and Oceanic Science at the University of Maryland, College Park. This is the bulletin's annual version.

Maryland's geography is challenging, with the Allegheny and Blue Ridge mountains to the west, Piedmont Plateau in the center, the Chesapeake Bay, and the Atlantic Coastal Plain to the east. The range of physiographic features and the eastern placement of the state within the expansive North American continent contribute to a comparatively wide range of climatic conditions.

The bulletin seeks to document and characterize annual surface climate conditions statewide, as well as climate division and county-wise, placing them in the context of regional and continental climate variability and change to help Marylanders interpret and understand recent climate conditions.

The annual surface climate conditions for 2024 are presented via maps of key variables, such as average surface air temperature, maximum surface air temperature, minimum surface air temperature, total precipitation, and their departure from normal (Section 3). The monthly evolution of statewide temperature and precipitation anomalies are presented via bar graphs, and the annual statewide and climate division averages are contrasted via scatter plots (Section 4). Extreme heat, cold, precipitation, and agricultural indicators such as the growing season, vegetation period, and degree days are presented from the analysis of daily statewide-averaged temperatures and precipitation (Section 5). The annual statewide averages are placed in the context of the historical record via box and whisker plots in Section 6. Century-plus trends in statewide air temperature, cooling and heating degree-days, precipitation, and state maps of air temperature and precipitation are presented in Section 7; half-century trends for the duration of the growing season, vegetation period, dry spells and the number of days with extreme precipitation (from daily statewide temperatures and precipitation) are also included in the section. Ancillary statewide, climate division and county-level information is provided via tables and bar graphs in Appendices A-B; climatology and variability maps are in Appendices C-D.

2. Data & Methods

Surface air temperatures, total precipitation, and degree-days data in this report are from the following sources:

- NOAA Monthly U.S. Climate *Gridded* Dataset at 5-km horizontal resolution (NClimGrid – Vose et al. 2014). It is available in a preliminary status at https://www.ncei.noaa.gov/data/nclimgrid-monthly/access/
  Data was downloaded on 1/11/2025.

- NOAA Monthly U.S. Climate *Divisional* Dataset (NClimDiv – Vose et al. 2014). It is available in a preliminary status (v1.0.0-20250107) at:
  https://www.ncei.noaa.gov/pub/data/cirs/climdiv/
  Data was downloaded on 1/11/2025.

- NOAA area averages of daily temperatures and precipitation dataset (nClimGrid−Daily −Durre et al. 2022). It is available in a preliminary status (v1.0.0) at:
  https://www.ncei.noaa.gov/pub/data/daily-grids/v1-0-0/
  Data was downloaded on 1/10/2025.

Some definitions:

About the annual values: Annual temperatures are obtained as the mean of the monthly temperatures from January to December, while annual accumulated precipitation and degree days are obtained as the sum of their values in the twelve months (which in turn are obtained as the sum of their daily values).

About climate and climatology. Weather and climate are closely related, but they are not the same. Weather represents the state of the atmosphere (temperature, precipitation, etc.) at any given time. On the other hand, climate refers to the time average of the weather elements when the average is over long periods. If the average period is long enough, we can start to characterize the climate of a particular region.

It is customary to follow the World Meteorological Organization (WMO) recommendation and use 30 years for the average. The 30-year averaged weather data is traditionally known as Climate Normal (Kunkel and Court, 1990), which is updated every ten years (WMO, 2017). Establishing a climate normal or climatology is important as it allows one to compare a specific day, month, season, year or even another normal period with the current normal. Such comparisons characterize anomalous weather and climate conditions, climate variability and change, and help define extreme weather and climate events (Arguez et al., 2012). The current climate normal, or just the climatology, is defined for 1991–2020.

About the anomalies: Anomalies for a given month, season, or year (e.g., 2024) are the departures of the monthly, seasonal, or annual value from the corresponding 30-year average during the 1991-2020 period; the 30-year average (or mean) is the climate normal, or just the climatology. When the observed value exceeds its climatological value, it is referred to as above normal (e.g., warmer than normal or wetter than normal) or a positive anomaly. In contrast, when this value is smaller than its climatological value, it is referred to as below normal (e.g., colder than normal or drier than normal) or negative anomaly.

About variability. The annual standard deviation of a climate variable measures its dispersion relative to its annual mean and assesses its year-to-year, or interannual, variability. Anomalies

are sometimes compared against that variability to identify extremes in the climate record. When the anomalies are divided by the standard deviation, they are named standardized anomalies.

About hot days, warm days, and warm nights. Humans, animals, and plants are sensitive to extreme heat. Crops without irrigation and populations without air conditioning, especially pregnant women, children, the elderly, and the sick, are very vulnerable to heat waves and warm spells. Extreme heat, detrimental to crops without irrigation and population lacking air conditioning, is tracked by the count of hot days, warm days, and nights and their consecutive occurrence (e.g., Tschurr et al., 2020; Barriopedro et al., 2023). Here, a hot day is defined as one when the maximum temperature is greater than 86°F, a warm day is when the maximum temperature is greater than 80°F while a warm night is when the minimum temperature is greater than 68°F (Tschurr et al., 2020). When these conditions persist for two or more days, they are called heat waves for the hot days and warm spells for the warm days and nights. These threshold values correspond to the 89th and 75th percentiles of statewide daily maximum temperature and the 95th percentile of statewide daily minimum temperature for the period 1951-2000.

About freezing days. Freezing temperatures affect people's health, comfort, and livelihood by impacting crops, livestock, infrastructure, water and energy resources, etc. Here, freezing temperatures are tracked by the count of days when daily minimum temperatures are equal to or below 32°F, 28°F, and 24°F (originally used to categorize agricultural impacts USDA, 2024) and their consecutive occurrence. These threshold values correspond to the 28th, 19th, and 12th percentiles of statewide daily minimum temperature for the period 1951−2000. Under these thresholds, a freeze is defined when minimum temperatures are equal to or below 32°F, a moderate freeze is defined when the minimum temperatures are equal to or below 28°F, and a severe freeze is defined when the minimum temperatures are equal to or below 24°F. When these conditions persist for two or more days, they define freezing day spells.

About degree days. Degree days are the difference between the *daily mean temperature* (high temperature plus low temperature divided by two) and a predefined base temperature; because energy demand is cumulative, degree-day totals are usually calculated on a daily, monthly, seasonal, and annual basis.

- *Heating and cooling degree days*. These are used to get a general idea of how much energy is required to warm or cool buildings. The base temperature used for this purpose is 65°F, which is considered tolerable for human comfort (CPC, 2023).

- *Growing Degree Days*. These are used to estimate the growth and development of plants and insects during the growing season under the idea that development will only occur if the temperature exceeds some minimum development threshold temperature or, in other words, if enough warmth is accumulated. Because the actual development will differ for different plants and insects, and the presence of weeds and precipitation can influence the

development, a base temperature of 50°F is generally considered acceptable for all plants and insects (OSU 2024). However, this base temperature is best suited for the development of specific crops like corn, sweet corn, soybeans, tomatoes, and a few others.

- *Modified Growing degree days.* The modified growing degree days are obtained if base temperatures are established for the daily maximum and minimum temperatures before calculating the daily mean temperature. When the base temperature for the daily maximum temperature is set to 86°F, and the base temperature for the daily minimum temperature is set to 50°F, the growing degree days are specific to corn development as no appreciable growth is detected with temperatures lower than 50°F or greater than 86°F.

About the growing season. This is the period between the last frost of spring and the first frost of fall when the minimum air temperature is above the freezing point of 32°F (USEPA, 2023). Thus, the *growing season* focuses on the weather conditions that allow plants to grow actively (e.g., Körner et al., 2023).

About the vegetation period. This is defined as the period between the first day of the first occurrence of 6 consecutive days with daily mean temperatures equal to or above 41°F and the day before the first occurrence of 6 consecutive days with daily mean temperatures below 41°F after the first of July (Tschurr et al., 2020). Hence, the *vegetation period* captures weather conditions that allow plants to grow at a different pace, even if it is minimal; the vegetation period, in this way, can last the whole year, including the dormant period.

The growing season and the vegetation period can be used as climate change indicators to track how vegetation conditions change over time.

About the dry days. A dry day is defined as a day with precipitation below 0.04 inches. These conditions are named dry spells if they persist for two or more days. The number of dry spells and their length are particularly important during the vegetation period (Tschurr et al., 2020).

About e*xtreme precipitation.* This is defined as the annual number of days with a statewide averaged daily total precipitation equal to or greater than 0.64 inches. This threshold represents the 95th percentile of statewide averaged daily total precipitation for 1951-2000.

About NOAA's Climate Divisions. The term "climate division" refers to one of the eight divisions in the state that represent climatically homogeneous regions, as determined by NOAA: https://www.ncei.noaa.gov/access/monitoring/dyk/us-climate-divisions

The eight climate divisions in Maryland are:

- Climate Division 1: Southeastern Shore. It includes the counties of Somerset, Wicomico, and Worcester.

- Climate Division 2: Central Eastern Shore. It includes the counties of Caroline, Dorchester, and Talbot.
- Climate Division 3: Lower Southern. It includes the counties of Calvert, Charles, and St. Mary's.
- Climate Division 4: Upper Southern. It includes the counties of Anne Arundel and Prince George's.
- Climate Division 5: Northeastern Shore. It includes the counties of Kent and Queen Anne's.
- Climate Division 6: North Central. It includes the counties of Baltimore, Carroll, Cecil, Frederick, Harford, Howard, Montgomery, and the city of Baltimore.
- Climate Division 7: Appalachian Mountains. It includes the counties of Allegany and Washington.
- Climate Division 8: Allegheny Plateau. It includes Garrett County.

Note that these Climate Divisions do not correspond with the *Physiographic Provinces* in the state, as the former follow county lines. Climate Division 8 follows the *Appalachian Plateau Province*, Climate Division 7 follows the *Ridge and Valley Province*; however, Climate Division 6 includes the *Blue Ridge and the Piedmont Plateau provinces*, Climate Divisions 3, 4, and a portion of 6 include the *Upper Coastal Plain Province*, and Climate Divisions 1, 2, 5, and a portion of 6 include the *Lower Coastal Plain (or Atlantic Continental Shelf) Province*.

3. 2024 Annual Mean Maps

A. Mean Temperatures

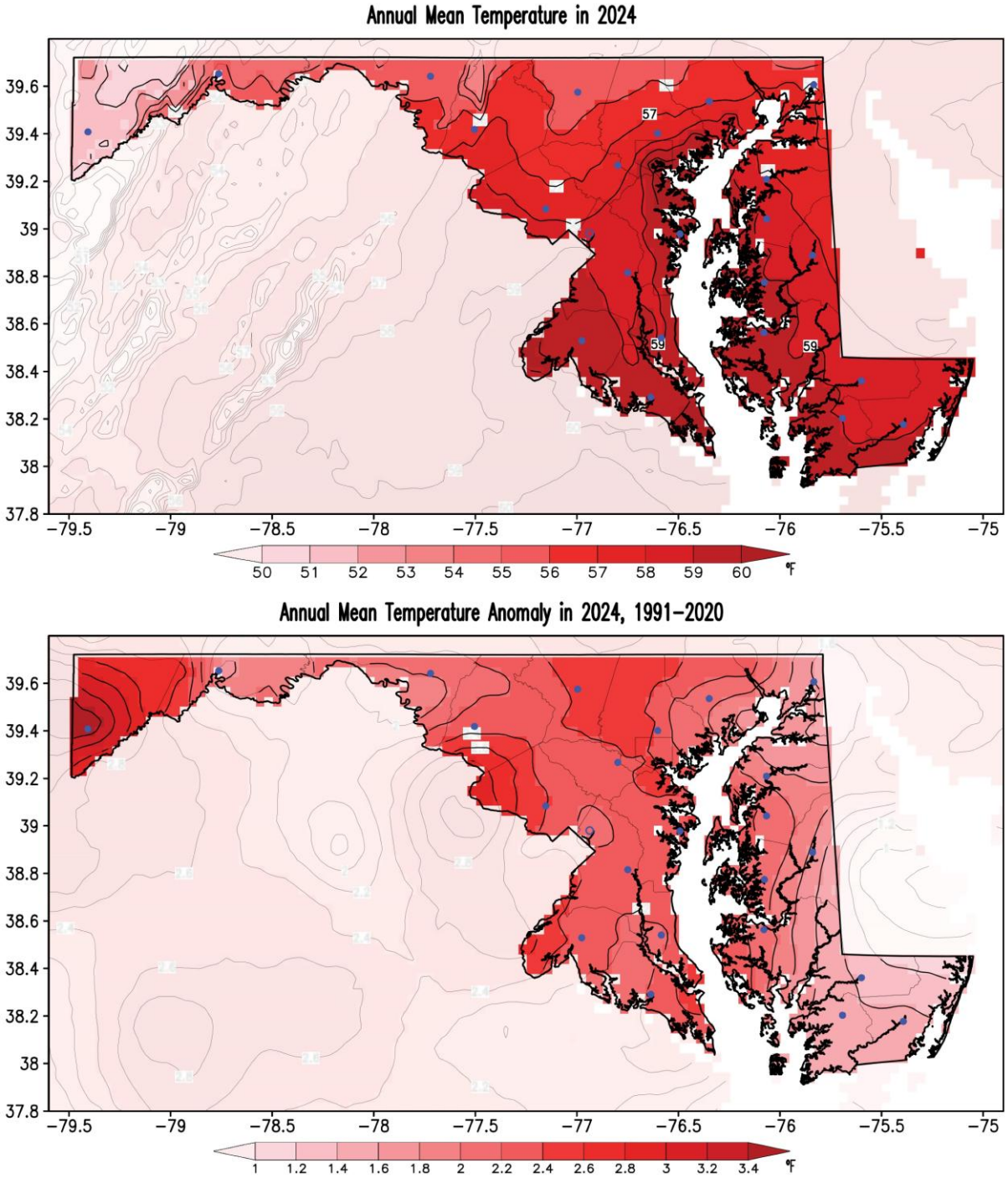

Figure 1. Annual mean of the mean surface air temperature (top panel) and its anomaly with respect to the 1991-2020 climatology (bottom panel) for 2024. Temperatures are in °F following the color bar. Red shading in the anomaly map marks warmer than normal conditions. Note shading outside the state has been washed out to facilitate focusing on Maryland. Filled blue circles mark the county seats.

B. Maximum Temperatures

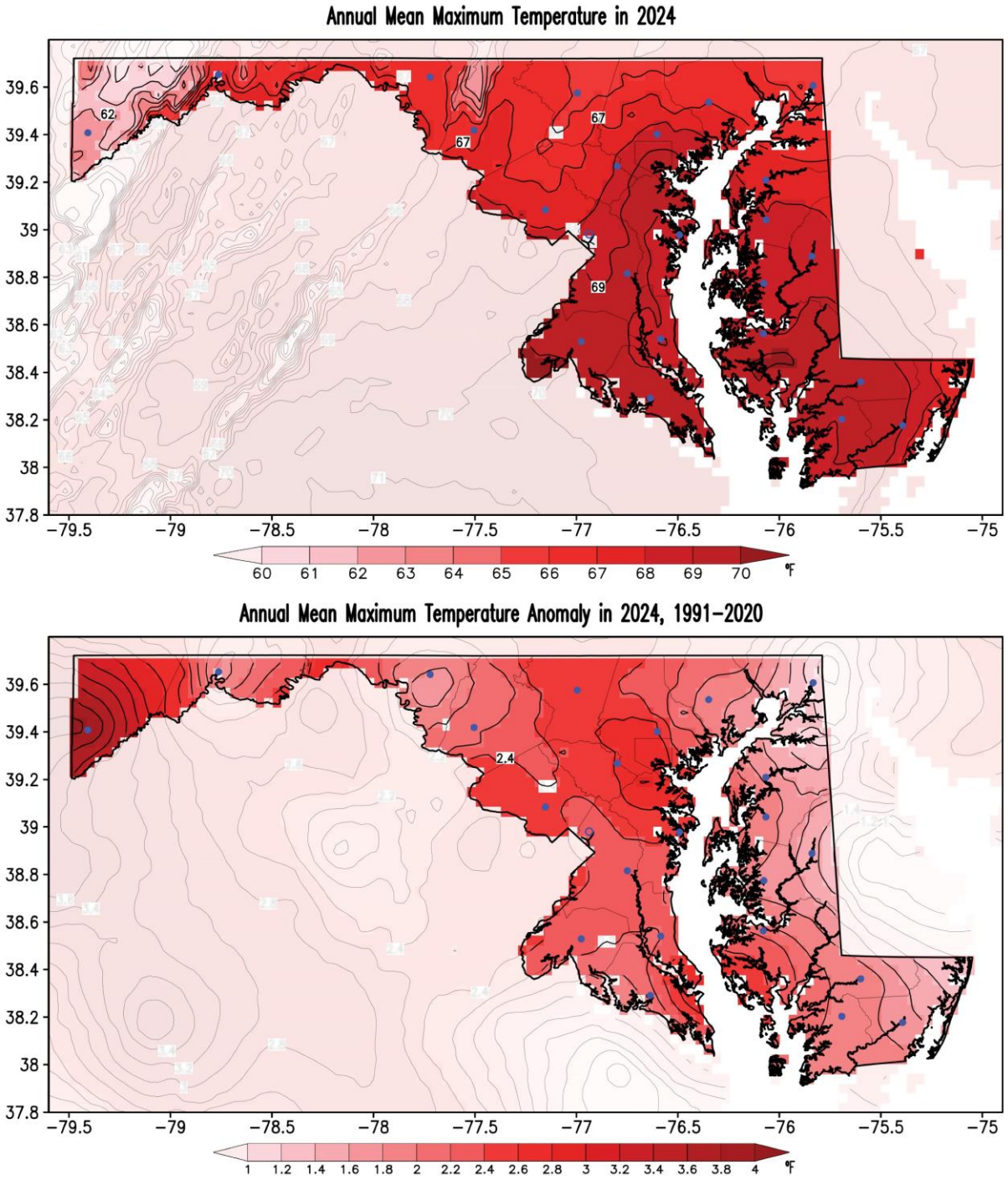

Figure 2. Annual mean of the maximum surface air temperature (top panel) and its anomaly with respect to the 1991-2020 climatology (bottom panel) for 2024. Temperatures are in °F following the color bar. Red shading in the anomaly map marks warmer than normal conditions. Note shading outside the state has been washed out to facilitate focusing on Maryland. Filled blue circles mark the county seats.

C. Minimum Temperatures

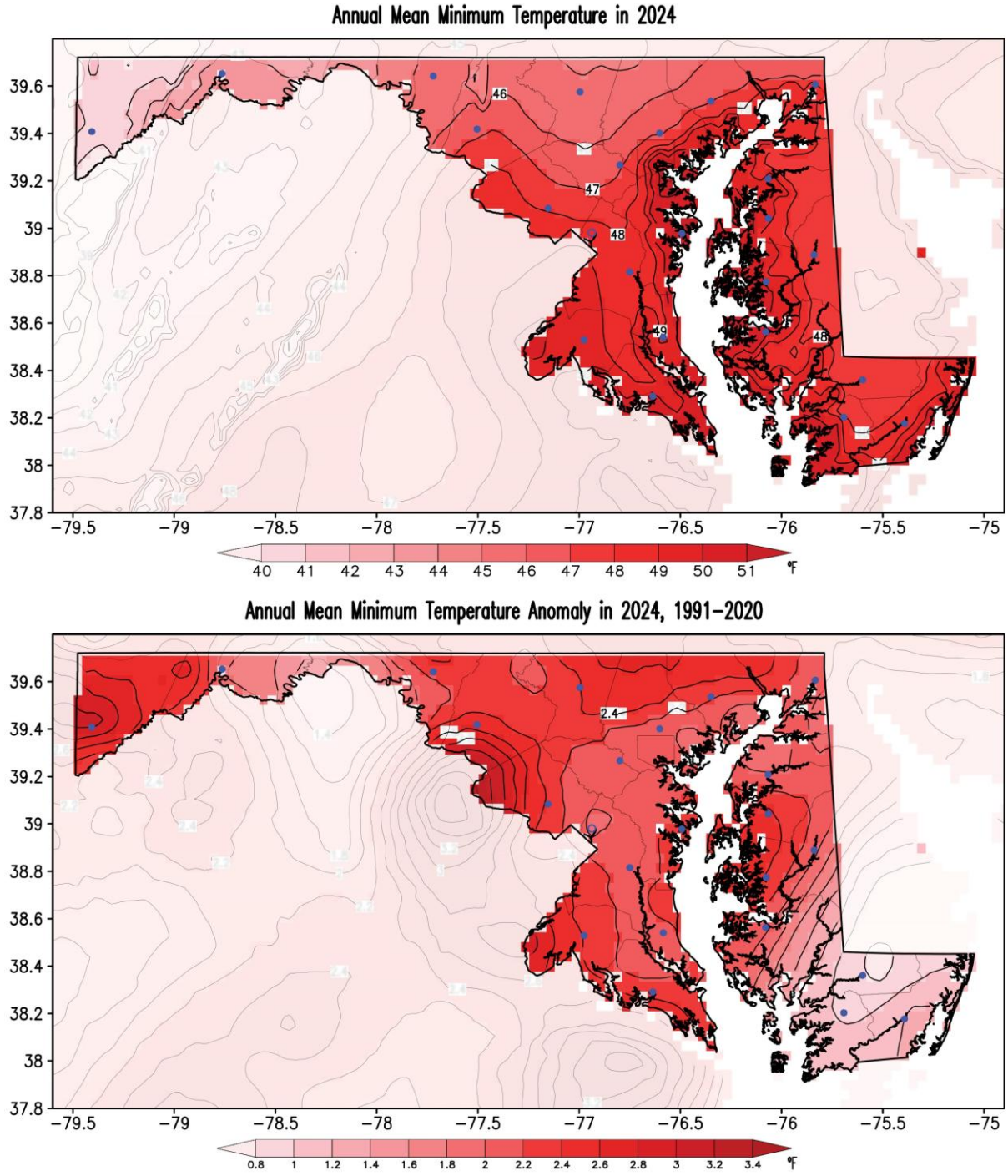

Figure 3. Annual mean of the minimum surface air temperature (top panel) and its anomaly with respect to the 1991-2020 climatology (bottom panel) for 2024. Temperatures are in °F following the color bar. Red shading in the anomaly map marks warmer than normal conditions. Note shading outside the state has been washed out to facilitate focusing on Maryland. Filled blue circles mark the county seats.

D. Precipitation

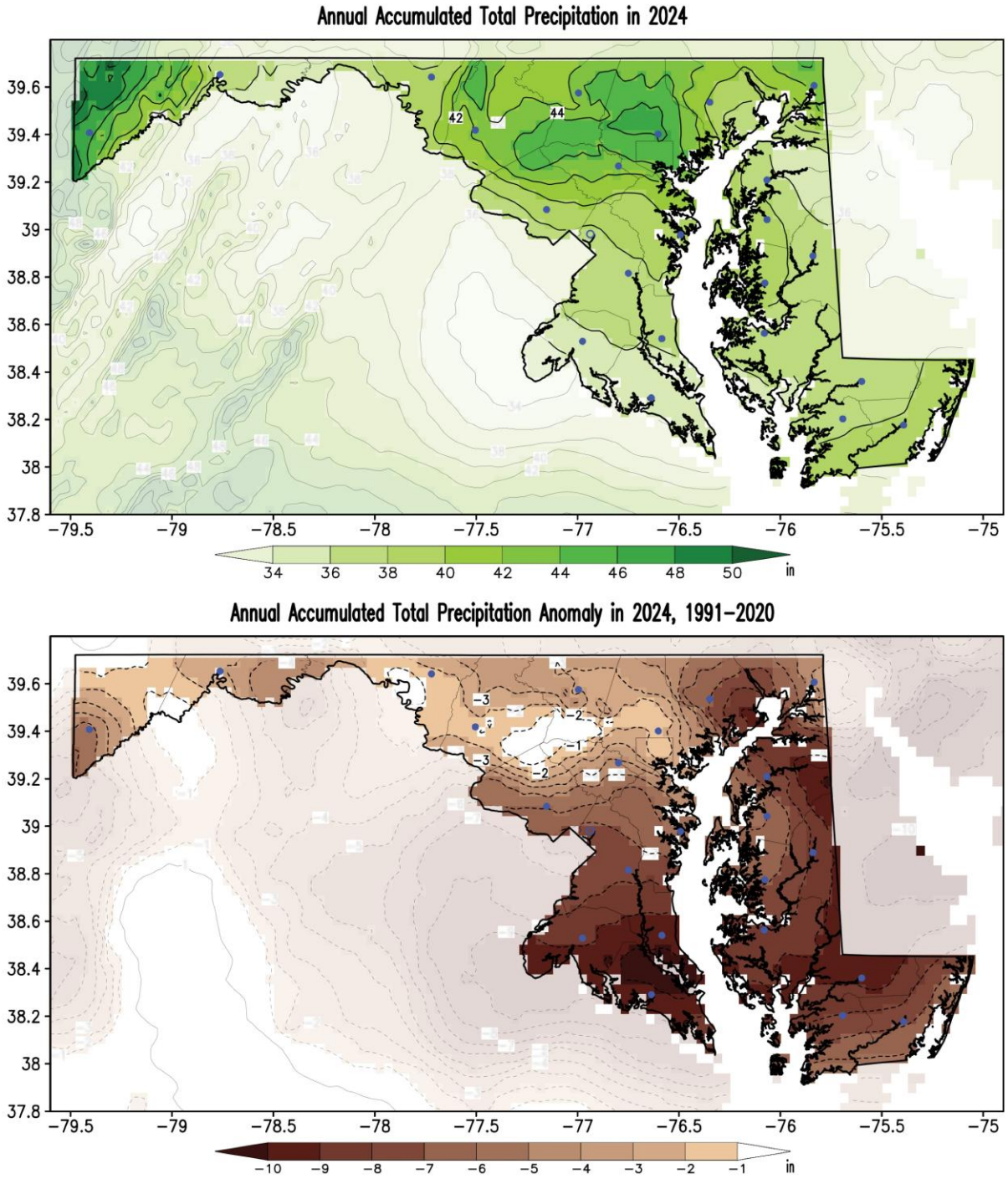

Figure 4. Annual accumulated total precipitation (top panel) and its anomaly with respect to the 1991-2020 climatology (bottom panel) for 2024. Precipitation is in inches following the color bar. Brown shading in the anomaly map marks drier than normal conditions. Note shading outside the state has been washed out to facilitate focusing on Maryland. Filled blue circles mark the county seats.

4. Statewide and Climate Divisions Averages in 2024

A. Statewide Monthly Evolution of Anomalies

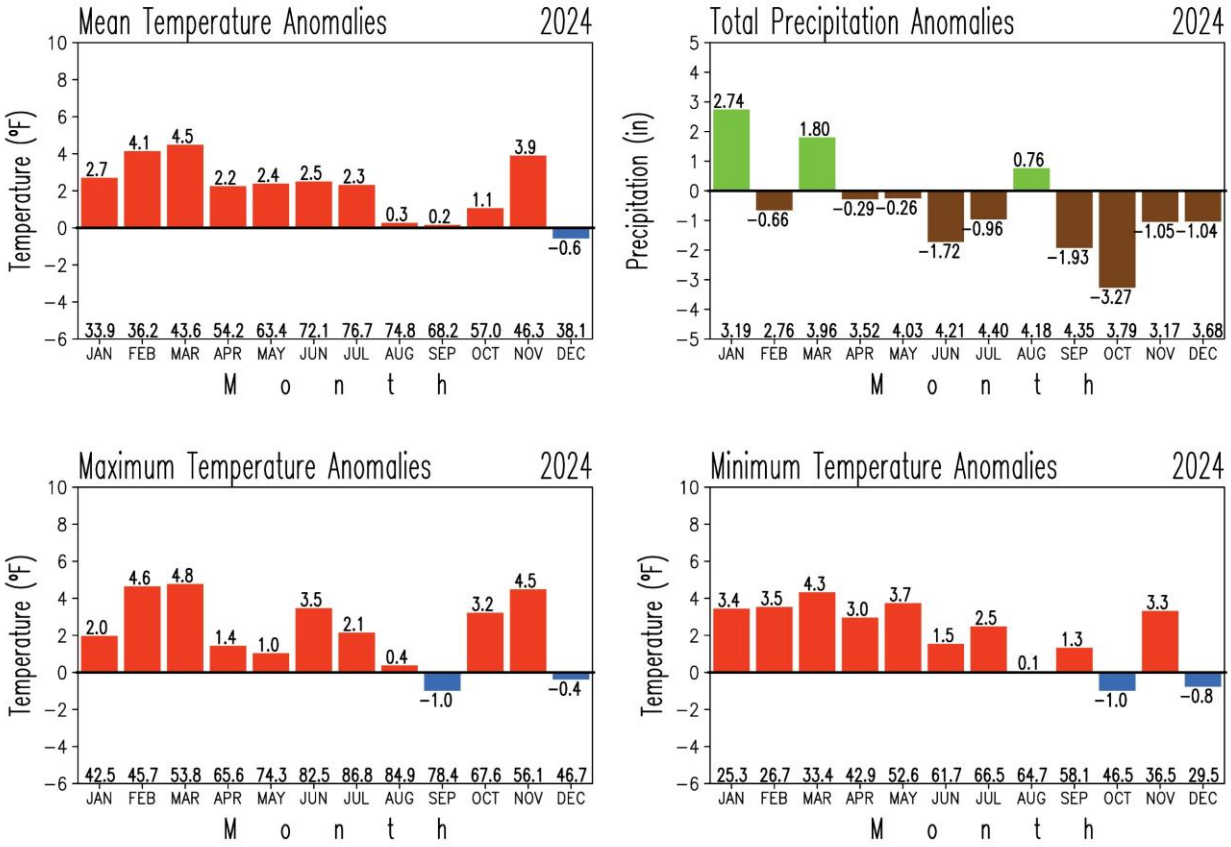

Figure 5. Maryland (statewide) monthly evolution of surface variables and their anomalies in 2024. Anomalies are with respect to the 1991-2020 climatology. Red/blue color represents positive/negative anomalies for mean surface air temperature (upper left), maximum surface air temperature (bottom left), and minimum surface air temperature (bottom right), while green/brown color indicates positive/negative anomalies in total precipitation (upper right). Temperatures are in °F, and precipitation is in inches. The numbers outside the bars indicate the magnitude of the anomaly, while the number at the bottom of each panel shows the monthly climatology. Eleven of the twelve months were warmer than normal in the mean temperature, notably in February, March, and November. On the other hand, nine months were drier than normal, notably in June, September, and October, and three months were wetter than normal: January, March, and August.

B. 2024 Scatter Plots

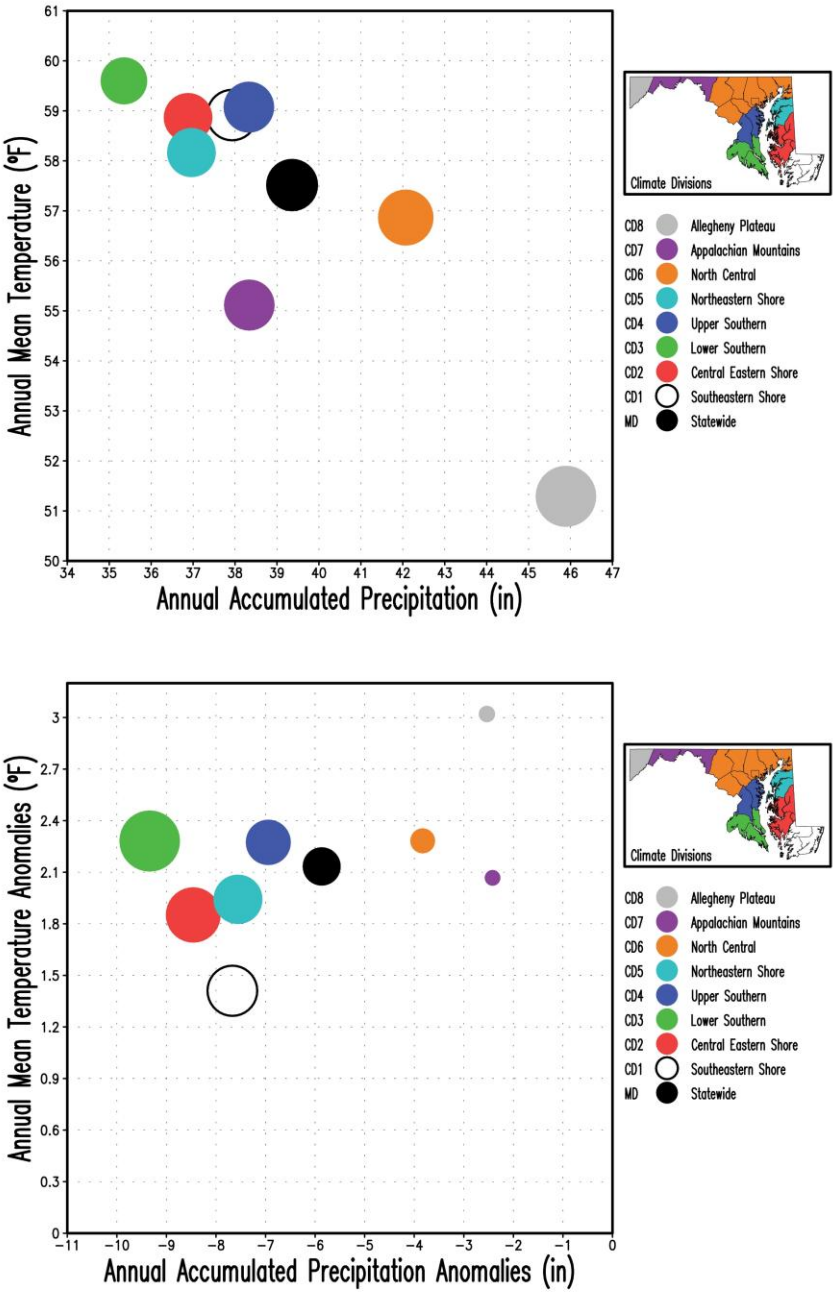

Figure 6. Scatter plots of Maryland (statewide) and Climate Divisions (CD#) annual mean surface air temperature vs. annual accumulated total precipitation for 2024. The upper panel shows the mean temperature and total precipitation, and the bottom panel displays their anomalies with respect to the 1991-2020 climatology. Temperatures are in °F, and precipitation is in inches. The size of the circles is proportional to the total precipitation scaled down by the maximum precipitation (45.89 inches in CD8, top panel) and by the maximum precipitation anomaly (|−9.34| inches in CD3, bottom panel) among the nine regions. Note that the color of the filled circles corresponds to the color in the Climate Divisions according to the inset map.

C. 2022−2024 Scatter Plots

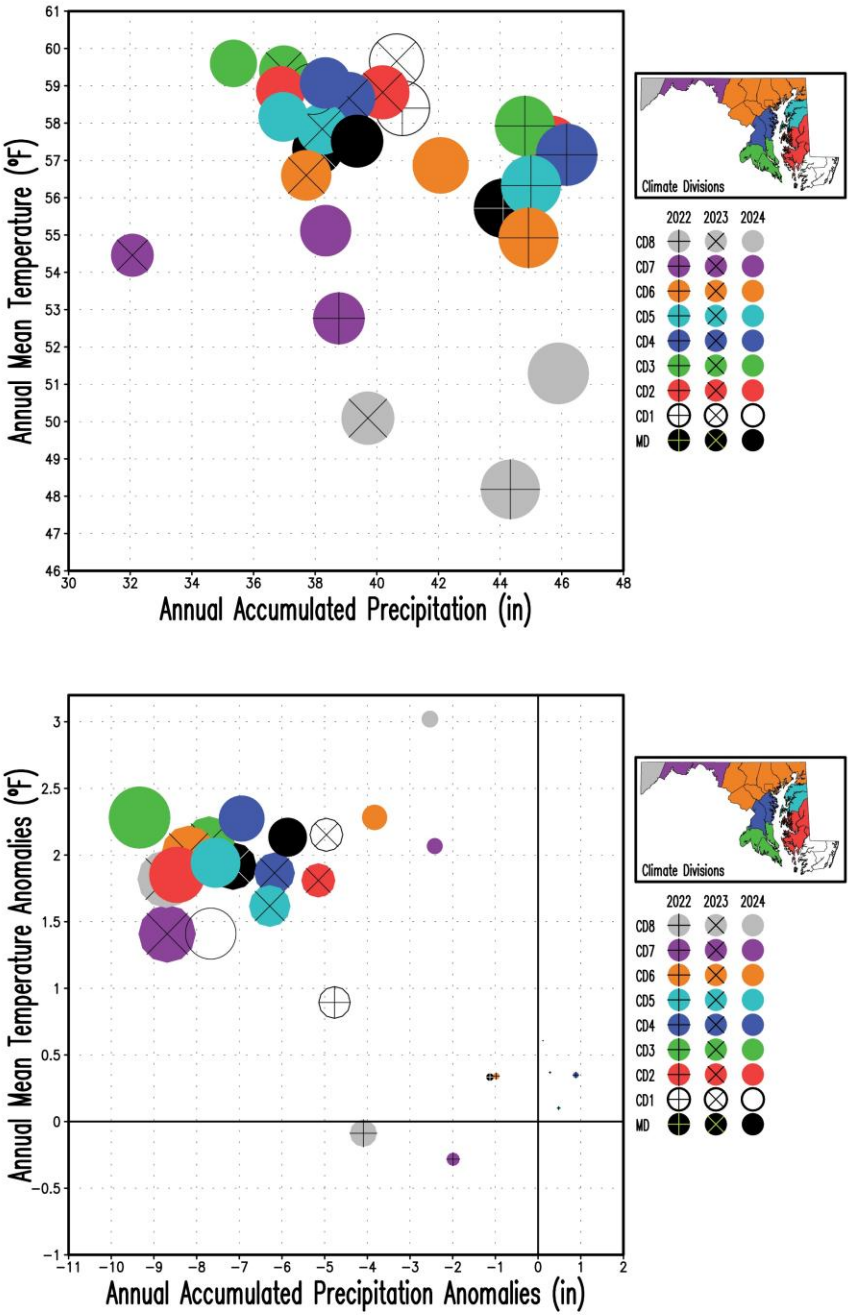

Figure 7. Scatter plots of Maryland (statewide) and Climate Divisions (CD#) annual mean surface air temperature vs. annual accumulated total precipitation for 2022, 2023, and 2024. The upper panel shows the mean temperature and total precipitation, and the bottom panel displays their anomalies with respect to the 1991-2020 climatology. Temperatures are in °F, and precipitation is in inches. The size of the circles is proportional to the total precipitation scaled down by the maximum precipitation (46.16 inches in CD4 in 2022, top panel) and by the maximum precipitation anomaly (|−9.34| inches in CD3 in 2024, bottom panel) among the nine regions and three years. The year 2024 is displayed with filled circles only, while years 2023 and 2022 are displayed with superposed multiplication and addition signs, respectively.

5. Statewide Extremes & Daily Evolution in 2024

A. Hot Days, Warm Days, and Warm Nights

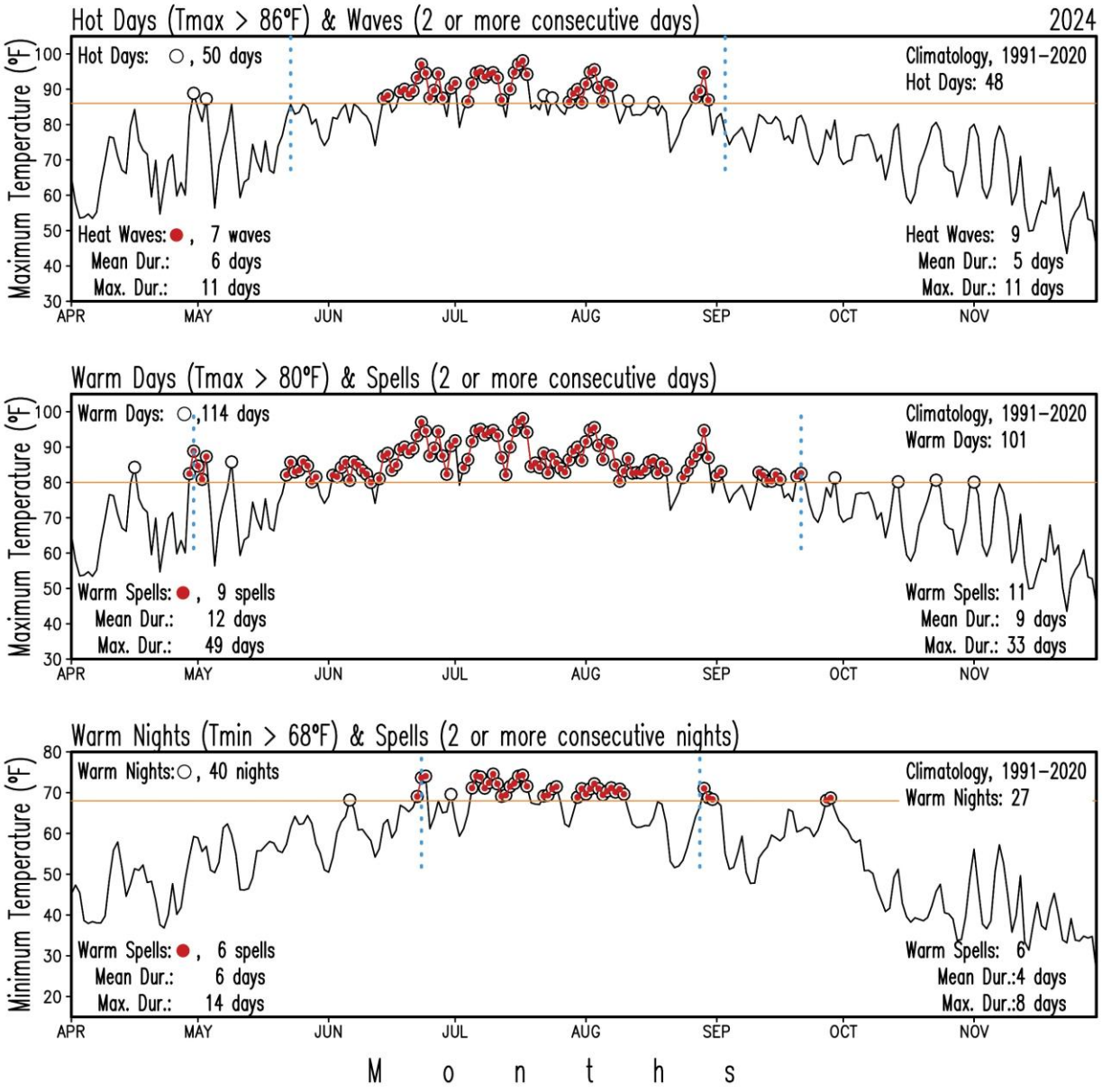

Figure 8. Maryland (statewide) number of hot days (upper panel), warm days (middle panel), and warm nights (bottom panel), and their consecutive occurrence for the period January 1 – December 31, 2024. The upper panel shows hot days in open circles and heat waves in red-filled circles from statewide daily maximum temperatures. The middle panel shows warm days in open circles and warm day spells in red-filled circles from statewide daily maximum temperatures. The lower panel shows warm nights in open circles and warm night spells in red-filled circles from statewide daily minimum temperatures. The continuous orange line in each panel marks the 86, 80, and 68°F threshold temperatures for each case. The vertical light blue dotted lines mark the 1991-2020 climatological start dates of the first and last waves and spells. Figures at the county and climate division level and summary tables can be found on the MDSCO website.

B. Freezing Days

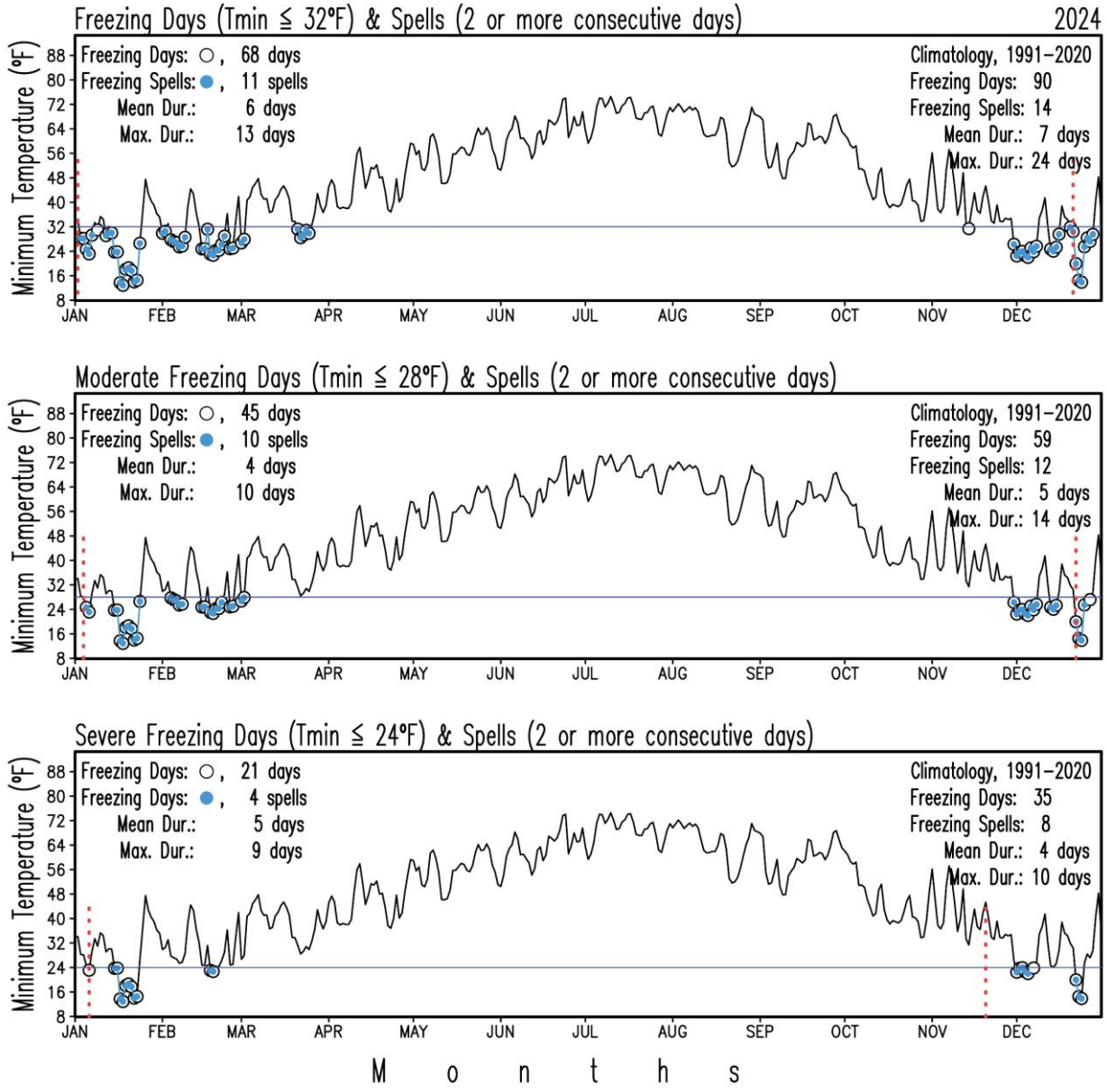

Figure 9. Maryland (statewide) number of freezing days (upper panel), moderate freezing days (middle panel), and severe freezing (bottom panel), and their consecutive occurrence for the period January 1 – December 31, 2024. The upper panel shows freezing days in open circles and freezing spells in blue-filled circles from statewide daily minimum temperatures. The middle panel shows moderate freezing days in open circles and moderate freezing spells in blue-filled circles from statewide daily minimum temperatures. The lower panel shows severe freezing days in open circles and severe freezing spells in blue-filled circles from statewide daily minimum temperatures. The continuous blue line in each panel marks the 32, 28, and 24°F threshold temperatures for each case. The vertical red dotted lines mark the 1991-2020 climatological start dates of the first and last spells in the year. Figures at the county and climate division level and summary tables can be found on the MDSCO website.

C. Growing Season, Vegetation Period, Dry Spells, and Extreme Precipitation

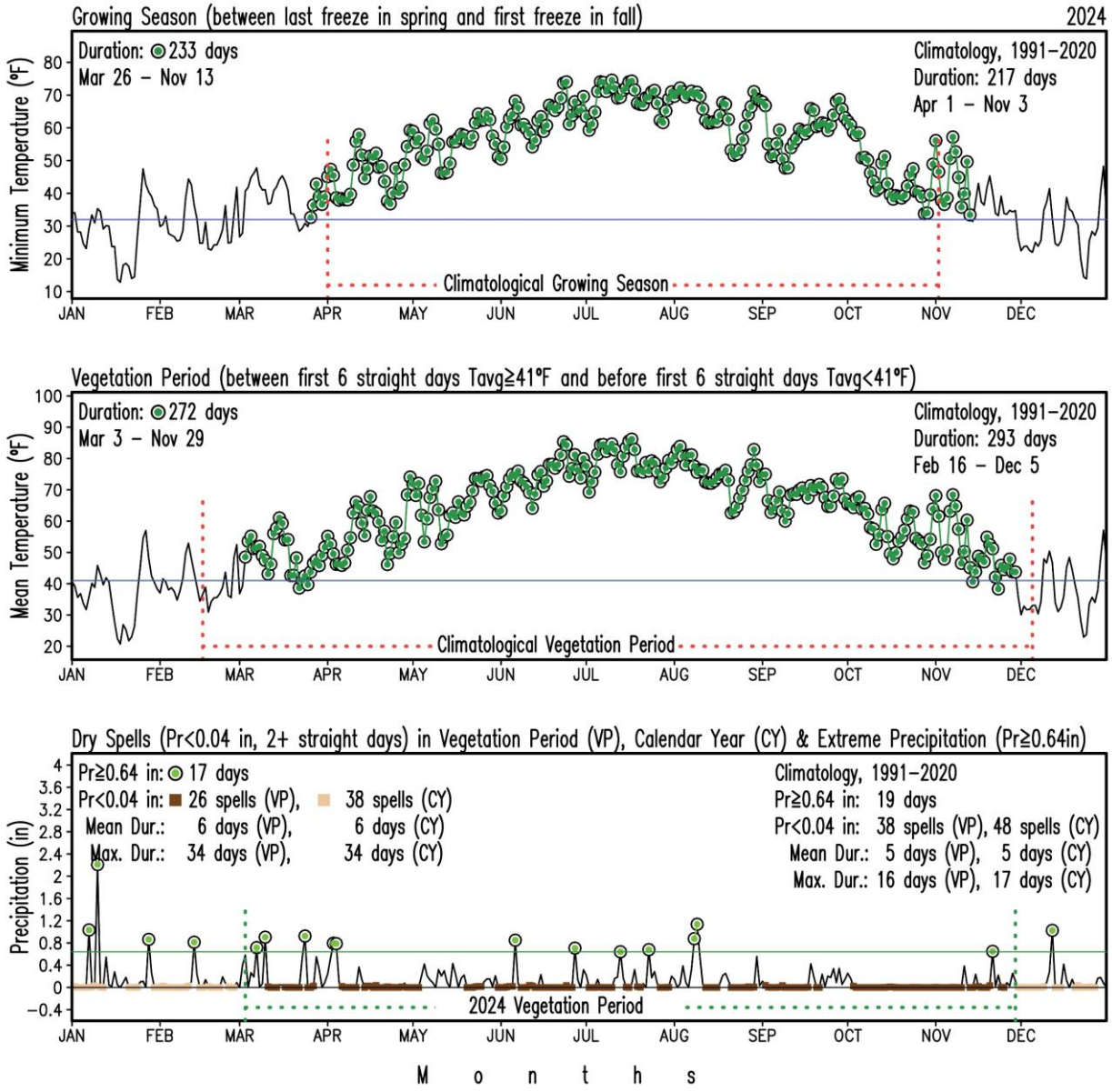

Figure 10. Maryland (statewide) growing season (upper panel), vegetation period (middle panel) and dry spells within the vegetation period, and extreme precipitation (lower panel) for the period January 1 - December 31, 2024. The upper panel shows the growing season from statewide daily minimum temperatures in green circles. The middle panel displays the vegetation period from statewide daily mean temperatures in green-filled circles. The lower panel shows dry spells (consecutive days with daily total precipitation less than 0.04 inches) within the vegetation period (VP) in brown-filled squares, additional dry spells within the calendar year (CY) in light brown squares, and extreme precipitation days (precipitation equal to or larger than 0.64 inches) in green-filled circles from statewide daily total precipitation. The dotted red lines in the upper panel mark the climatological start and end of the growing season, and those in the middle panel mark the climatological start and end of the vegetation period. The dotted green line in the bottom panel marks the start and end of the vegetation period in 2024 while the horizontal green line marks the threshold precipitation value of 0.64 in. Figures at the county and climate division level and summary tables can be found on the MDSCO website.

D. Growing Degree Days

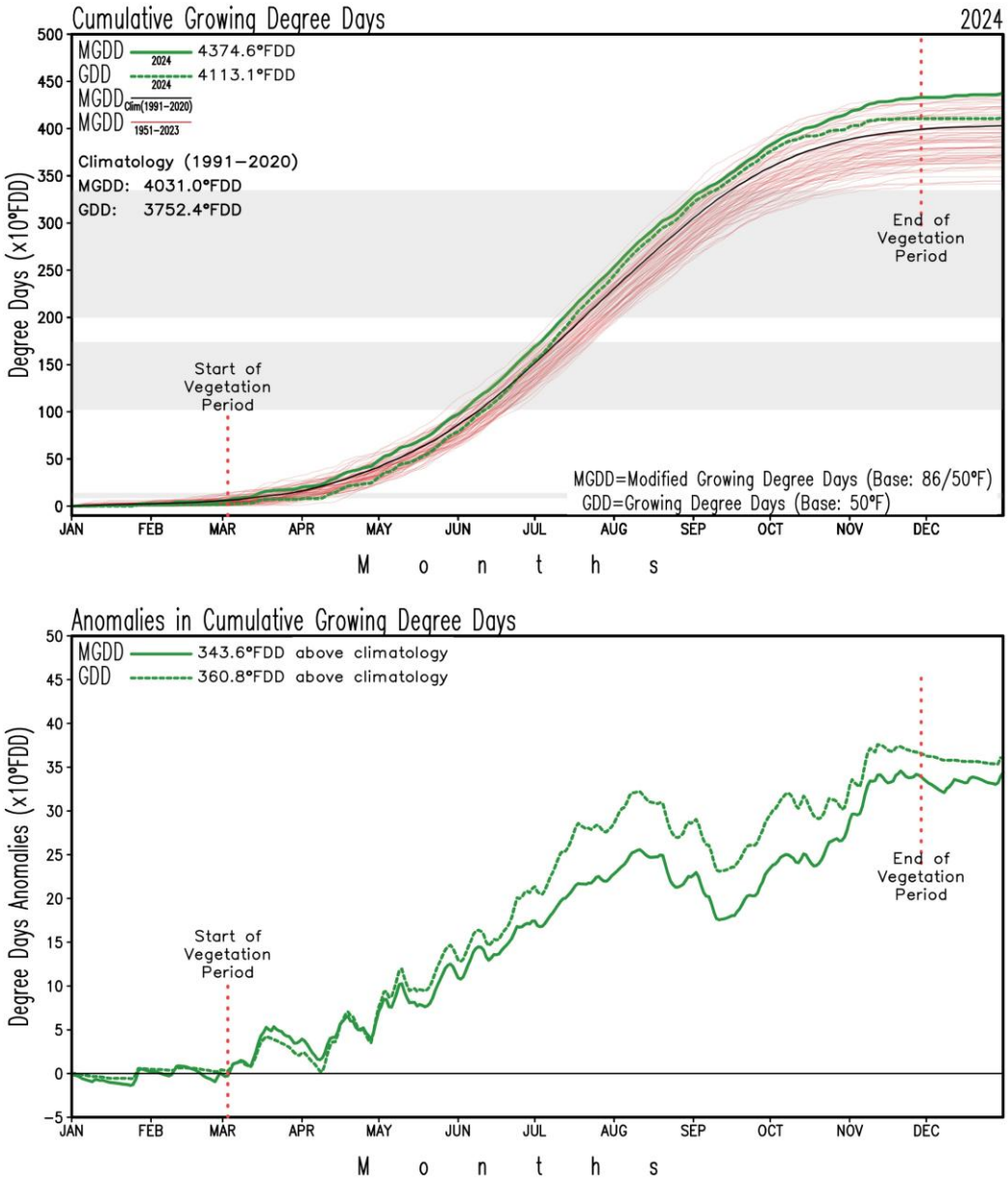

Figure 11. Maryland (statewide) cumulative growing degree days (upper panel) and its anomaly with respect to the 1991-2020 climatology (lower panel) for the period January 1 - December 31, 2024. The growing degree days are displayed with the dashed green line, while the modified growing degree days are shown with the continuous green line in the upper panel; the black line shows the 1991-2020 climatology of the cumulative modified growing degree days; the thin red lines display the cumulative modified growing degree days every year from 1951 to 2023. The gray shaded areas mark a range of values in corn development (IPAD, 2023): emergence (82-140), tassel-silk (1024-1740), and physiological maturity (2000-3350). Anomalies with respect to the 1991-2020 climatology in the cumulative modified growing degree days (bottom panel) are displayed with the continuous green line, while those for the cumulative growing degree days are shown with the dashed green line. The vertical dotted red lines mark the start and end of the vegetation period in 2024. The accumulated growing degree days and their anomalies at the end of the year are displayed at the top left in each panel. Figures at the county and climate division level and summary tables can be found on the MDSCO website.

6. 2024 Statewide Averages in the Historical Record

A. Box and Whisker Plots

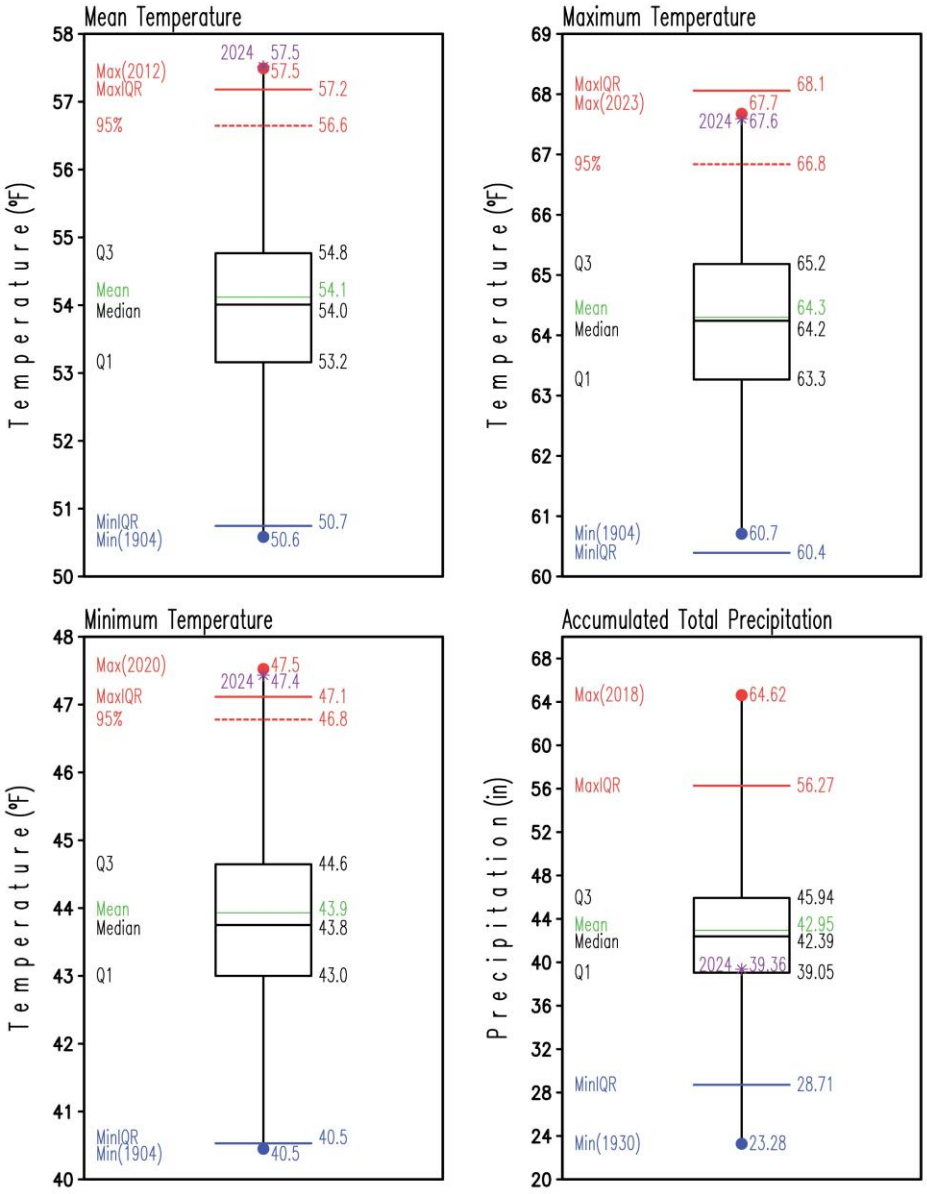

Figure 12. Box and Whisker plots of Maryland (statewide) annual mean (upper left), maximum (upper right), minimum (lower left) surface air temperatures, and accumulated total precipitation (lower right) for the period 1895-2023. The label and asterisk in purple represent conditions for 2024. Statistics for the period 1895-2023 are labeled at the left side of each box and whisker plot and their values at their right. Temperatures are in °F and precipitation is in inches. The mean is the green line within the box, while the median is the black line within the box. The lower (Q1) and upper (Q3) quartiles, indicating the values of the variable that separate 25% of the smallest and largest values are the lower and upper horizontal black lines of the box, respectively. The blue and red dots mark the minimum and maximum values in the period at the end of the whiskers; the year of occurrence is shown in parenthesis. The blue and red horizontal lines represent extreme values defined by Q1-1.5×(Q3-Q1) and Q3+1.5×(Q3-Q1), respectively. For reference, the dashed red lines mark the 95th percentile in temperaatures.

7. Trends

A. 1895-2024: Statewide Mean Temperature, Degree-Days, and Precipitation

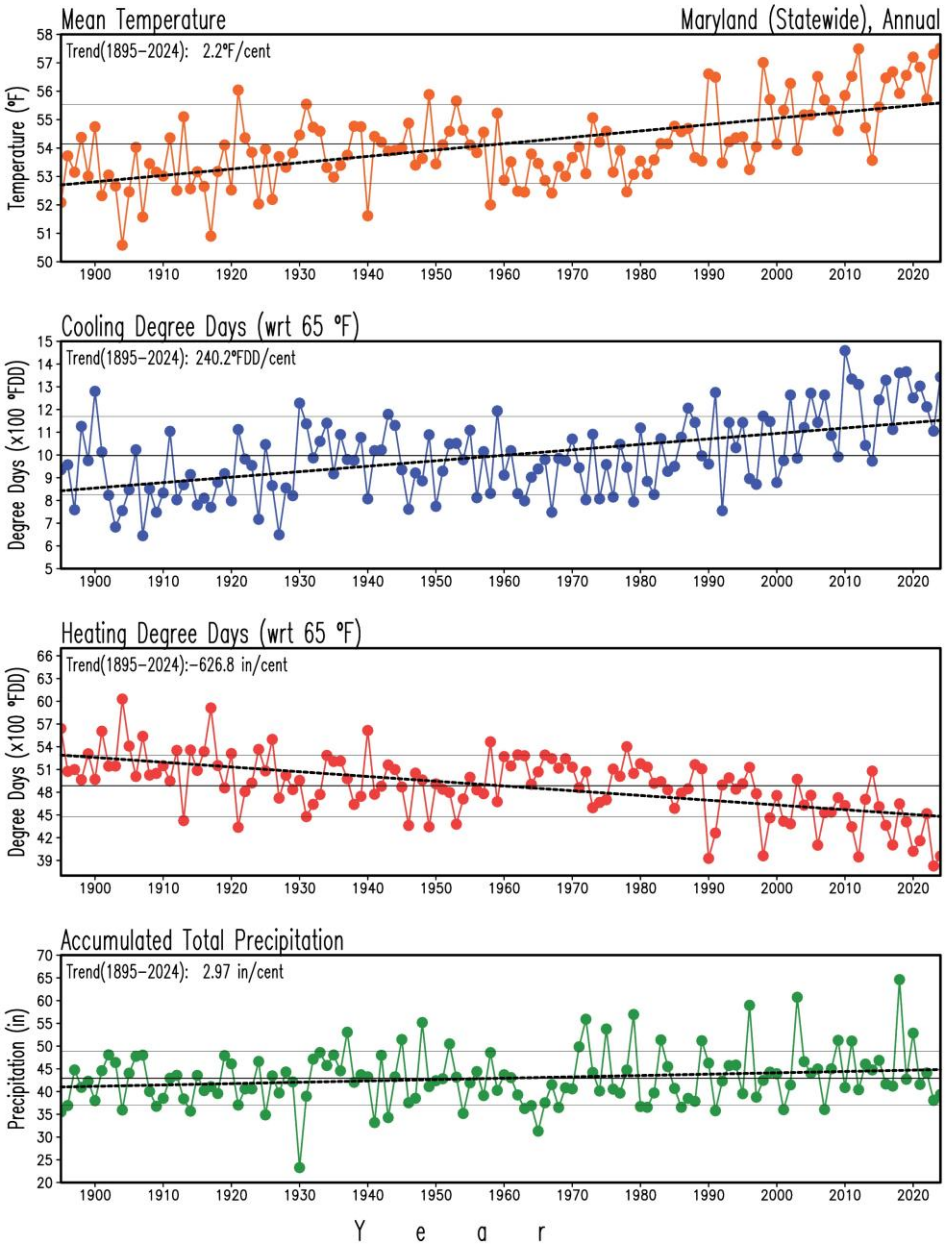

Figure 13. Maryland (statewide) annual mean surface air temperature, cooling degree-days, heating degree days, and accumulated precipitation for the period 1895-2024. Temperature is in °F, cooling and heating degree-days are in °F degree-days (°FDD), and precipitation is in inches. The thin, continuous black lines in each panel display the long-term means (54.1°F, 997.4°FDD, 4885.5°FDD and 42.92 in, 1895-2024), and the double thin, continuous gray lines indicate the standard deviation (1.4°F, 171.9°FDD, 405.7°FDD, and 5.96 in) above/below the long-term mean. The thick dashed black lines show the long-term linear trends. The warming temperature trend (2.2°F/century), the increasing cooling degree-days trend (240.2°FDD/century), the decreasing heating degree-days trend (–626.8°FDD/century), and the accumulated precipitation trend (2.97 in/century) are statistically significant at the 95% level (*Student's t-test* −Santer et al. 2000).

B. 1895-2024: Temperature and Precipitation Maps

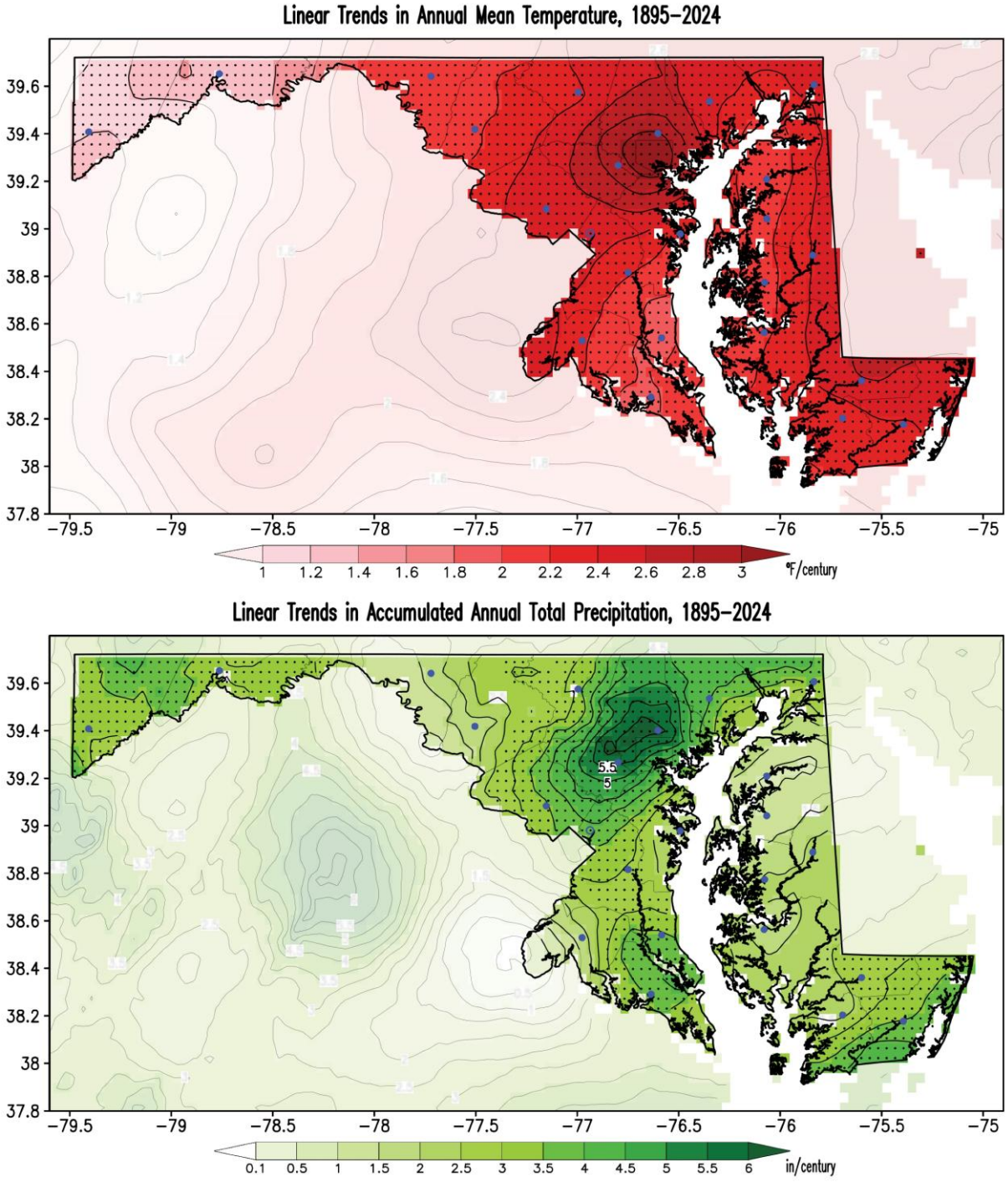

Figure 14. Linear trends in annual surface air mean temperature and accumulated precipitation for the period 1895-2024. Temperatures are in °F/century, and precipitation is in inches/century following the color bars. Red shading in the temperature map marks warming trends. Green shading in the precipitation map shows wetting trends. Stippling in the maps shows regions where trends are statistically significant at the 95% level (*Student's t-test* −Santer et al. 2000). Note that shading outside the state has been washed out to facilitate focusing on Maryland. Filled blue circles mark the county seats.

C. 1951-2024: Statewide Growing Season, Vegetation Period, Dry Spells & Extreme Precipitation

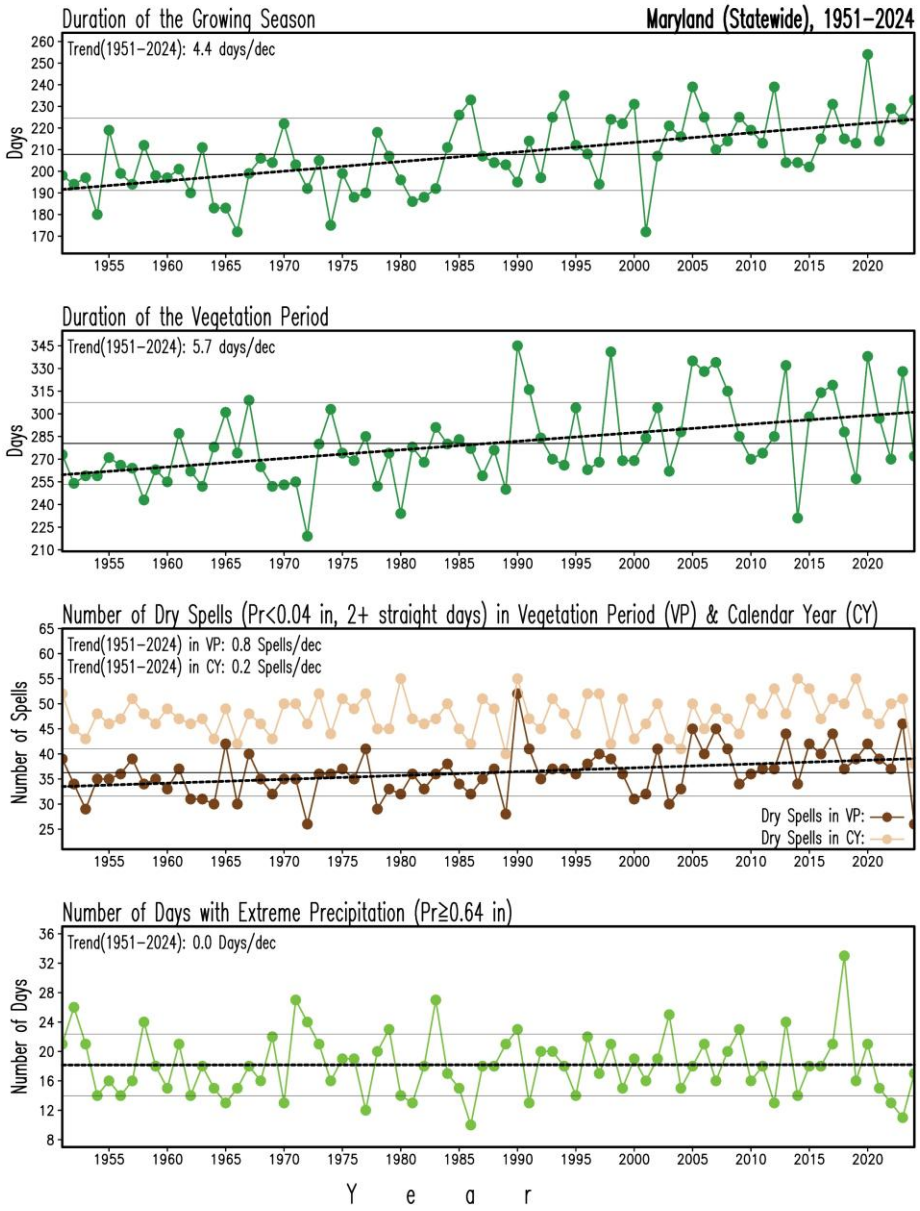

Figure 15. Maryland (statewide) duration of the growing season, duration of the vegetation period, number of dry spells in the vegetation period, and number of days with extreme precipitation for the period 1951-2024. The thin, continuous black lines in each panel display the long-term means (209 days, 280 days, 36 spells, and 18 days, 1951-2024), and the double thin, continuous gray lines indicate the standard deviation (16.7 days, 27.1 days, 4.7 spells, and 4.2 days) above/below the long-term mean. The thick dashed black lines show the long-term linear trends for the period 1951-2024. For comparison, the number of dry spells for the calendar year is displayed with a light brown line in the third panel from above. The increasing trends in the duration of the growing season (4.4 days/decade) and vegetation period (5.7 days/decade), the increasing trend in the number of dry spells within the vegetation period (0.8 spells/decade) are statistically significant at the 95% level (*Student's t-test* −Santer et al. 2000) but no the increase in the number of dry spells in the calendar year (0.2 spells/decade); the number of days with extreme precipitation has no trend (0.0 days/decade).

Appendix A. 2024 Data Tables: Statewide, Climate Divisions, and Counties

A. Mean Temperature and Precipitation

Region	Mean Air Temperature (°F)	Rank (#)
Statewide	57.5	130
Climate Division 1	58.9	124
Climate Division 2	58.9	128
Climate Division 3	59.6	130
Climate Division 4	59.1	130
Climate Division 5	58.2	129
Climate Division 6	56.9	130
Climate Division 7	55.1	129
Climate Division 8	51.3	130
Allegany	54.5	129
Anne Arundel	59.3	129
Baltimore	57.1	130
Baltimore City	59.2	128
Calvert	59.3	130
Caroline	58.2	128
Carroll	55.8	130
Cecil	56.9	129
Charles	59.7	130
Dorchester	59.3	127
Fredrick	56.3	130
Garrett	51.3	130
Harford	57.0	130
Howard	57.0	130
Kent	58.1	129
Montgomery	57.6	130
Prince George's	58.8	130
Queen Anne's	58.4	129
Saint Mary's	59.7	129
Somerset	59.4	124
Talbot	59.2	129
Washington	55.7	129
Wicomico	58.7	124
Worcester	58.8	124

Region	Accumulated Precipitation (in)	Rank (#)
Statewide	39.36	35
Climate Division 1	37.93	31
Climate Division 2	36.88	15
Climate Division 3	35.35	17
Climate Division 4	38.33	34
Climate Division 5	36.96	21
Climate Division 6	42.07	61
Climate Division 7	38.34	65
Climate Division 8	45.89	70
Allegany	37.48	66
Anne Arundel	39.35	46
Baltimore	44.51	76
Baltimore City	44.76	83
Calvert	36.25	17
Caroline	36.92	14
Carroll	43.07	70
Cecil	40.49	40
Charles	34.86	15
Dorchester	36.42	15
Fredrick	42.51	70
Garrett	45.84	70
Harford	40.01	41
Howard	42.68	71
Kent	36.86	19
Montgomery	39.81	52
Prince George's	37.62	28
Queen Anne's	37.18	22
Saint Mary's	35.74	17
Somerset	38.09	34
Talbot	38.27	27
Washington	39.08	69
Wicomico	36.79	15
Worcester	38.63	36

Table A1. Annual-mean surface air temperature (left) and annual-accumulated precipitation (right) at Maryland (statewide), climate division, and county levels for 2024. Temperatures are in °F, and precipitation is in inches. The rank is the order that the variable for 2024 occupies among the 130 years after the 130 values have been arranged from the lowest to the highest in the *standard competition ranking method*. The closer to 130 the rank is, the greater (i.e., the warmer/wetter) the value of the surface variable is in the record; similarly, the closer to 1 the rank is, the smaller (i.e., the colder/drier) the value of the surface variable is in the record.

B. Maximum and Minimum Temperatures

Region	Maximum Air Temperature (°F)	Rank (#)
Statewide	67.6	128
Climate Division 1	69.0	128
Climate Division 2	68.9	128
Climate Division 3	69.4	129
Climate Division 4	69.0	129
Climate Division 5	67.8	126
Climate Division 6	66.8	129
Climate Division 7	66.1	128
Climate Division 8	61.8	130
Allegany	65.8	128
Anne Arundel	69.0	129
Baltimore	67.4	128
Baltimore City	69.1	128
Calvert	69.0	129
Caroline	68.6	125
Carroll	66.2	129
Cecil	66.0	123
Charles	69.7	129
Dorchester	69.4	128
Fredrick	66.3	129
Garrett	61.8	130
Harford	66.8	125
Howard	67.5	129
Kent	67.4	125
Montgomery	67.4	130
Prince George's	69.0	129
Queen Anne's	68.1	128
Saint Mary's	69.3	128
Somerset	69.2	128
Talbot	68.5	128
Washington	66.4	127
Wicomico	69.4	127
Worcester	68.5	128

Region	Minimum Air Temperature (°F)	Rank (#)
Statewide	47.4	129
Climate Division 1	48.8	122
Climate Division 2	48.8	127
Climate Division 3	49.8	130
Climate Division 4	49.2	130
Climate Division 5	48.5	130
Climate Division 6	46.9	130
Climate Division 7	44.1	130
Climate Division 8	40.8	130
Allegany	43.2	129
Anne Arundel	49.7	130
Baltimore	46.9	129
Baltimore City	49.2	127
Calvert	49.6	129
Caroline	47.7	127
Carroll	45.4	130
Cecil	47.7	129
Charles	49.6	130
Dorchester	49.1	127
Fredrick	46.3	130
Garrett	40.8	130
Harford	47.3	129
Howard	46.6	130
Kent	48.7	130
Montgomery	47.8	130
Prince George's	48.6	129
Queen Anne's	48.7	130
Saint Mary's	50.0	130
Somerset	49.5	122
Talbot	49.8	130
Washington	45.0	130
Wicomico	47.9	121
Worcester	49.0	122

Table A2. Annual-mean maximum (left) and minimum (right) surface air temperatures at Maryland (statewide), climate division, and county levels for 2024. Temperatures are in °F. The rank is the order that the variable for 2024 occupies among the 130 years after the 130 values have been arranged from the lowest to the highest using the *standard competition ranking method*. The closer to 130 the rank is, the greater (i.e., the warmer) the value of the surface variable is in the record; similarly, the closer to 1 the rank is, the smaller (i.e., the colder) the value of the surface variable is in the record.

Appendix B. 2024 Bar Graphs: Statewide, Climate Divisions, and Counties

A. Temperatures and Precipitation

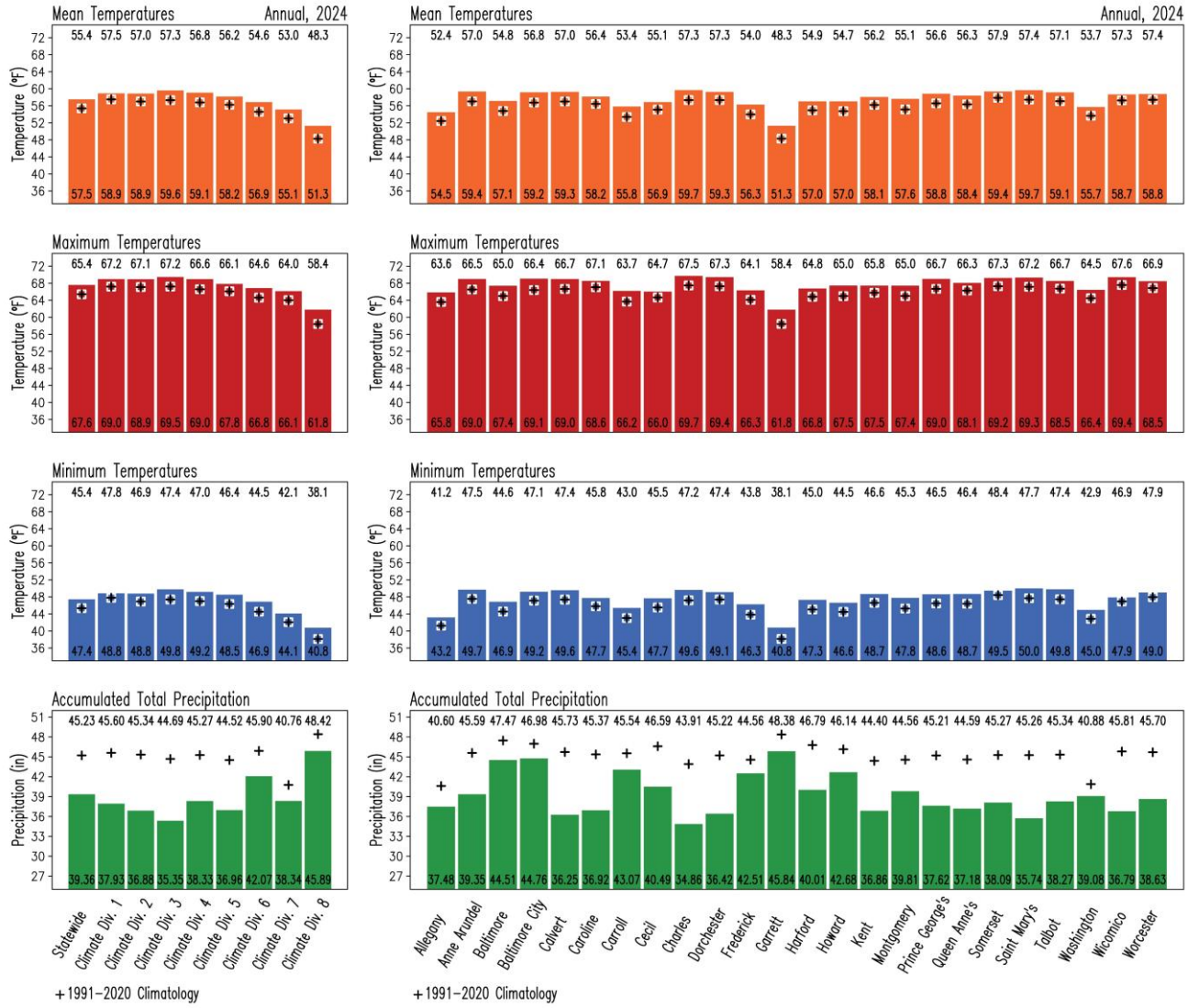

Figure B1. Annual surface variables in Maryland for 2024. Color bars represent the variables as follows: annual-mean mean surface air temperature (orange), maximum surface air temperature (red), minimum surface air temperature (blue) and annual-accumulated total precipitation (green) at statewide and climate division (left column), and county (right column) levels. Temperatures are in °F and precipitation is in inches. The numbers at the base of the bars indicate the magnitude of the variable for 2024. For comparison, the corresponding 1991-2020 climatological annual values are displayed as black addition signs, and their magnitudes are shown at the top of the panels.

B. Temperatures and Precipitation Anomalies

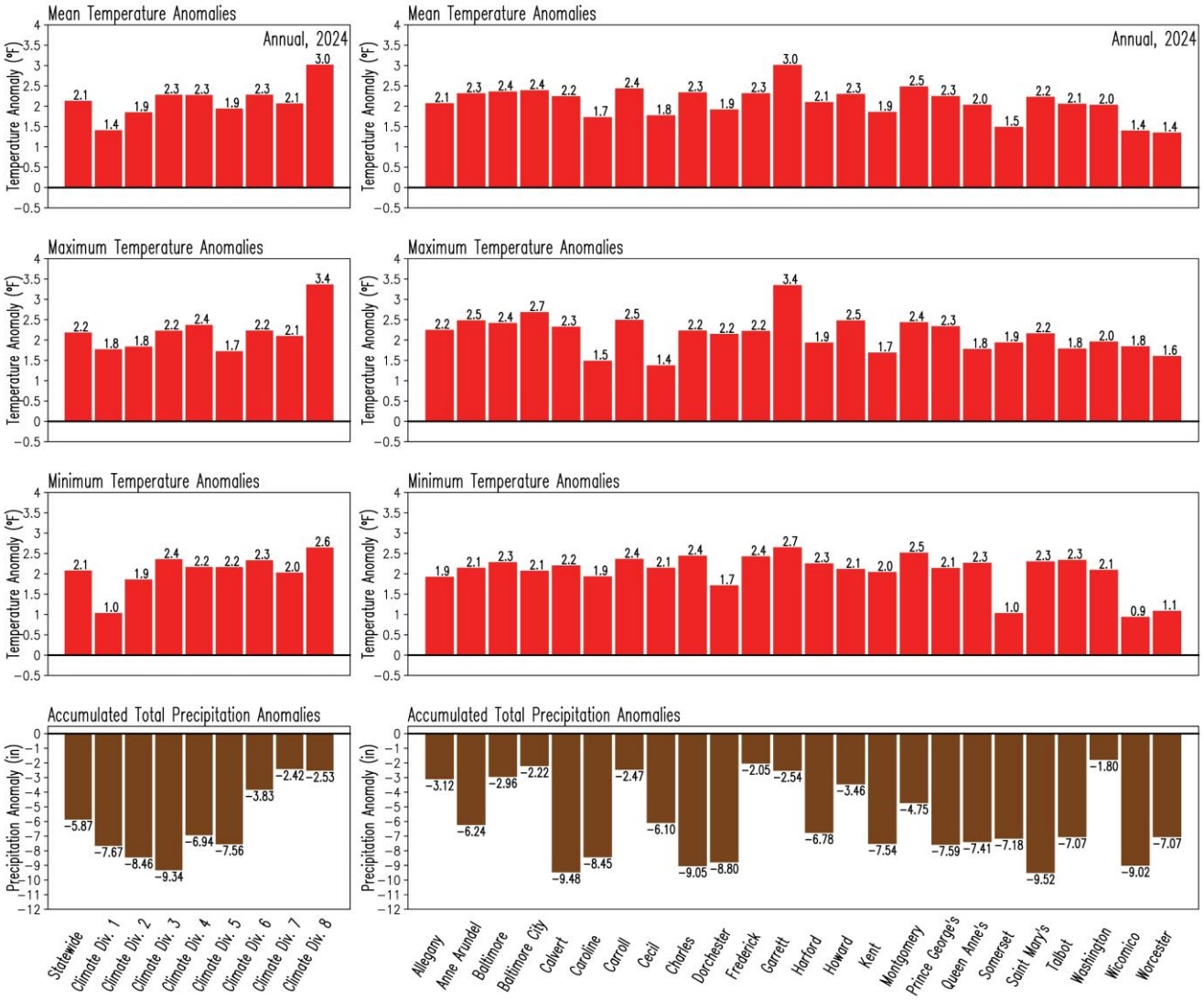

Figure B2. Anomalies of the annual surface variables in Maryland for 2024. Anomalies are with respect to the 1991-2020 annual climatology. Red color represents positive anomalies for mean surface air temperature (upper row), maximum surface air temperature (second row from top), and minimum surface air temperature (third row from top), while brown color indicates negative anomalies in accumulated precipitation (bottom row) at statewide and climate division (left column), and at county (right column) levels. Temperatures are in °F, and precipitation is in inches. The numbers outside of the bars indicate the magnitude of the anomaly for 2024.

Appendix C. Annual 1991-2020 Climatology Maps and 2024 Precipitation Anomaly as Percentage of Climatology

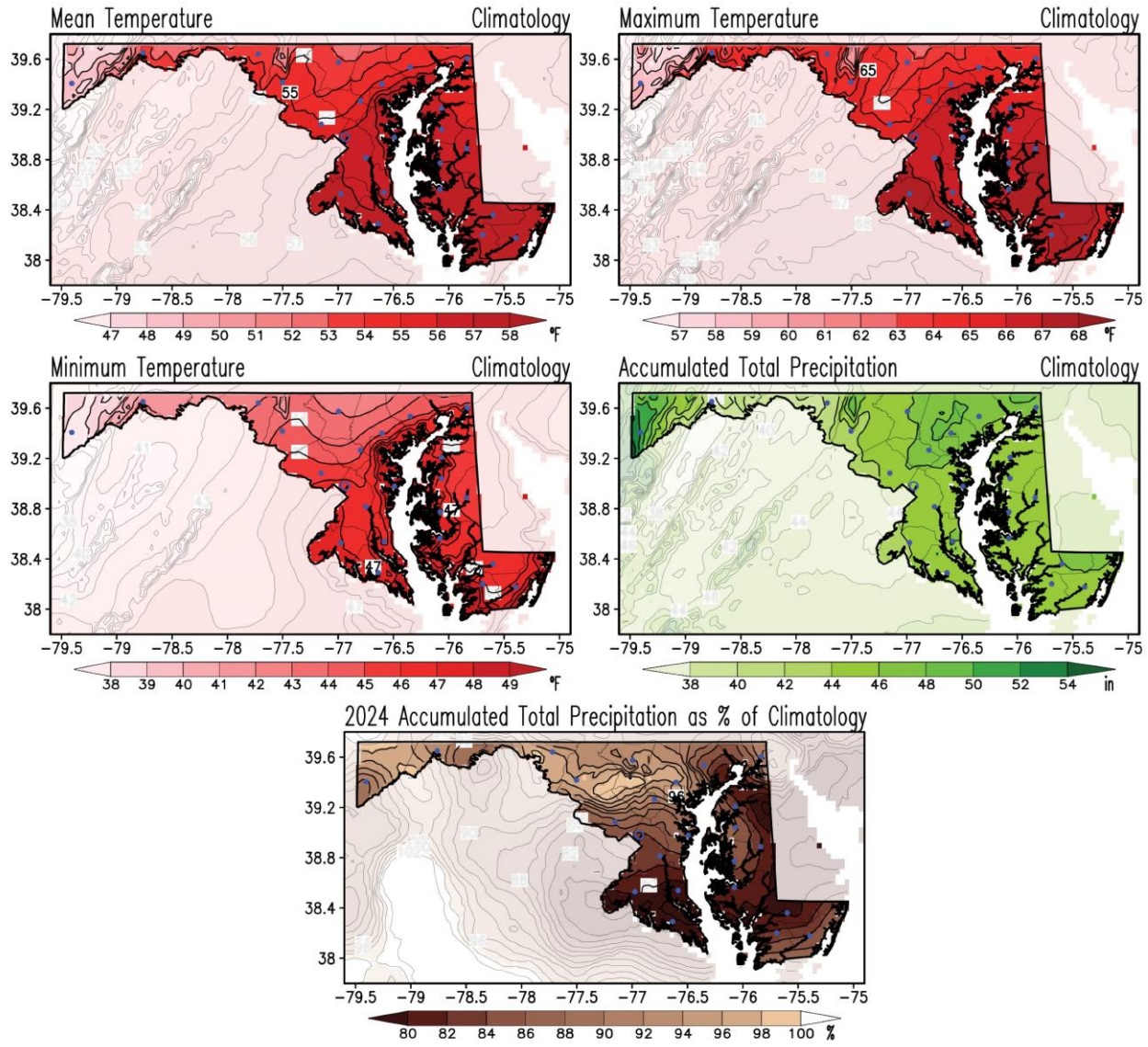

Figure C1. Climatology of the annual-mean mean, maximum and minimum surface air temperatures, and annual-accumulated precipitation for the period 1991-2020 (upper and middle rows), and precipitation anomalies in 2024 as a percentage of climatology (bottom row). Temperatures are in °F, and precipitation is in inches according to the color bars. This is the current climate normal against which the 2024 conditions are compared to obtain the 2024 annual anomalies. The precipitation as a percentage is obtained by dividing the total precipitation (from Figure 4) by the climatology (from the middle right panel) and multiplying that ratio by 100 so units are in percent of climatology (%); brown shading in this map shows drier than normal conditions. Note that shading outside the state has been washed out to facilitate focusing on Maryland. Filled blue circles mark the county seats.

Appendix D. Annual Standard Deviation and 2024 Standardized Anomalies Maps

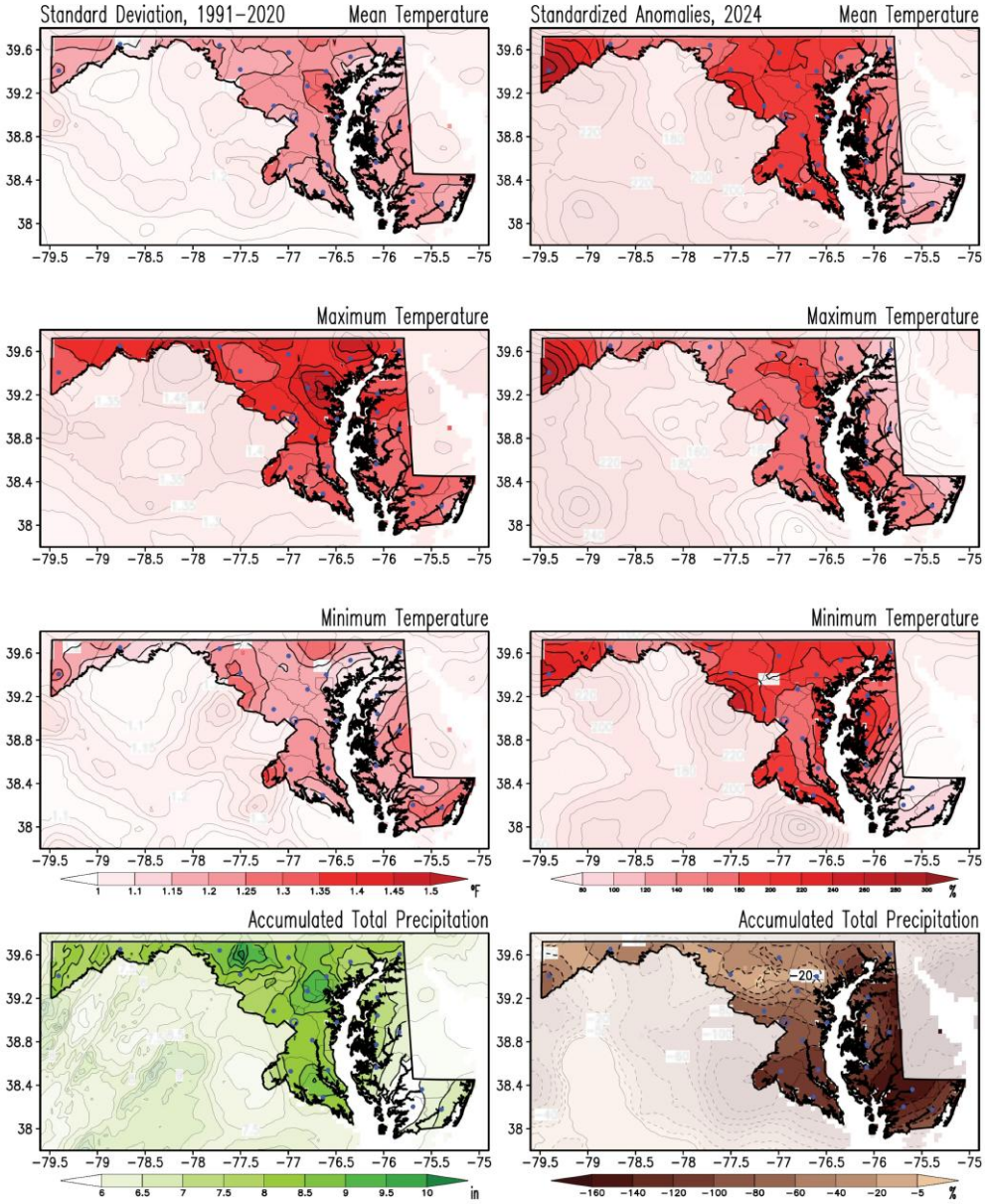

Figure D1. Standard deviation and standardized annual anomalies of annual-mean temperatures and annual-accumulated total precipitation for 2024. Standard deviations for annual mean, maximum, and minimum surface air temperatures and accumulated precipitation were obtained for the 1991-2020 period (left column). Anomalies for 2024 (right column) are obtained as a percentage of the standard deviations. The standard deviations in temperatures are in °F, and those in precipitation are in inches according to the color bars. Red shading in the anomaly temperature maps marks warmer than normal conditions; brown shading in the anomaly precipitation map marks drier than normal conditions. The standardized anomalies are obtained by dividing the raw anomalies (from Figures 1 to 4) by the standard deviation (from left column panels) and multiplying that ratio by 100; hence, units are in percent (%). Note that shading outside the state has been washed out to facilitate focusing on Maryland. Filled blue circles mark the county seats.

References

Arguez A., I. Durre, S. Applequist, R. S. Vose, M. F. Squires, X. Yin, R. R. Heim Jr, and T. W. Owen, 2012. NOAA's 1981-2010 U. S. Climate Normals. An Overview. *Bulletin of the American Meteorological Society*. 93, 1687-1697, doi:10.1175/BAMS-D-11-00197.1

Barriopedro, D., R. García-Herrera, C. Ordóñez, D. G. Miralles, and S. Salcedo-Sanz, 2023: Heat waves: Physical understanding and scientific challenges. Reviews of Geophysics, 61, e2022RG000780. https://doi.org/10.1029/2022RG000780

CPC, 2023. Degree Days Explanation. https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/cdus/degree_days/ddayexp.shtml

Durre, I., A. Arguez, C. J. Schreck III, M. F. Squires, and R. S. Vose, 2022: Daily high-resolution temperature and precipitation fields for the Contiguous United States from 1951 to Present. Journal of Atmospheric and Oceanic Technology, doi:10.1175/JTECH-D-22-0024.1

IPAD, 2023. Metadata for Corn Growth Stage Model. https://ipad.fas.usda.gov/cropexplorer/Definitions/csc.htm

Körner, C., P. Möhl, and E. Hiltbrunner, 2023: Four ways to define the growing season. *Ecology Letters*, 26, 1277–1292. https://doi.org/10.1111/ele.14260

Kunkel, K. E., and A. Court, 1990. Climatic Means and Normals—A Statement of the American Association of State Climatologists (AASC), *Bulletin of the American Meteorological Society*, 71(2), 201-204. https://journals.ametsoc.org/view/journals/bams/71/2/1520-0477-71_2_201.xml.

OSU, 2024. The Ohio State Phenology Calendar. https://weather.cfaes.osu.edu/gdd/glossary.asp

Santer, B. D., and co-authors, 2000: Statistical significance of trends and trend differences in layer-averaged atmospheric temperature time series. *J. Geophys. Res.*, 105, 7337–7356, doi:10.1029/1999JD901105.

Tschurr, F., I. Feigenwinter, A. M. Fischer, and S. Kotlarski, 2020: Climate Scenarios and Agricultural Indices: A Case Study for Switzerland. *Atmosphere*, 11, 535. https://doi.org/10.3390/atmos11050535

USDA, 2023. Growing Season Dates and Length. https://www.nrcs.usda.gov/wps/portal/wcc/home/climateSupport/wetlandsClimateTables/growingSeasonDatesLength

USEPA. 2023: U.S. Environmental Protection Agency. Climate Change Indicators in the United States. Accessed in May 2023. https://www.epa.gov/climate-indicators.

Vose and co-authors, 2014. NOAA Monthly U.S. Climate Gridded Dataset (NClimGrid), Version 3. *NOAA National Centers for Environmental Information*. DOI:10.7289/V5SX6B56 .

WMO, 2017. WMO Guidelines on the Calculation of Climate Normals. WMO-No. 1203, Series. 29pp. https://library.wmo.int/doc_num.php?explnum_id=4166