**MDSCO-2023-Y**

# Maryland Climate Bulletin Annual 2023

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DEPARTMENT OF ATMOSPHERIC & OCEANIC SCIENCE
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# Summary

Statewide averages show that 2023 was warmer and drier than normal (i.e., 1991-2020 averages). Annual mean temperatures were in the 50 to 62°F range; annual maximum temperatures were between 59 and 70°F, and annual minimum temperatures were in the 39 to 51°F range. Annual-accumulated total precipitation was between 31 and 44 inches.

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

- Mean temperature was warmer than normal in the entire state, particularly over portions of Dorchester, Calvert, and Saint Mary's counties (above 2.6°F), parts of Anne Arundel, Howard, Baltimore counties, and Baltimore City (above 2.4°F), and portions of Garrett, Montgomery, Carroll, Baltimore, Howard, Anne Arundel, Charles, Calvert, Saint Mary's, Dorchester, Wicomico, Somerset, and Worcester counties (around 2.2°F).

- Maximum temperature was also warmer than normal everywhere, especially over Baltimore City, parts of Anne Arundel, Howard, Baltimore, Calvert, Saint Mary's, and Dorchester counties (around 3.2°F), Carroll, Howard, portions of Garrett, Frederick, Baltimore, Anne Arundel, Charles, Calvert, Saint Mary's, Dorchester, Wicomico, Somerset, and Worcester counties (above 2.6°F).

- Minimum temperature was warmer than normal throughout the state, too, particularly over parts of Calvert, Saint Mary's, and Dorchester counties (above 2.2°F), over Baltimore City, Baltimore, portions of Howard, Anne Arundel, Montgomery, Charles, Calvert, Saint Mary's, Dorchester, Worcester, Queen Anne's and Caroline counties (above 1.8°F), and Garrett County (around 1.6°F).

- Precipitation was below normal over the whole state, particularly over portions of Garrett County, Frederick, Carroll, Baltimore, Howard, and Montgomery counties, and western Charles County (above 10 in deficit).

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

- The monthly evolution of statewide temperatures and total precipitation in 2023 showed that in nine of the twelve months, the state was warmer than normal, particularly in the winter months, and that in eight of the twelve months, the state was drier than normal, particularly in October, and at the start and end of spring months.

- All eight climate divisions were warmer and drier than normal in 2023.

- The statewide annual temperature and precipitation anomalies have remained warmer and drier than normal since 2021. The large annual temperature and precipitation anomalies in 2021 (1.5°F, −3.66 in) were reduced in 2022 (0.1°F, −1.1 in), but they increased again in 2023 (1.9°F, −7.13 in); the anomalies in 2023 surpassed their standard deviations (1.4°F, 5.98 in) for the 1895-2023 period.

*Statewide Daily Evolution of 2023* (Figures 8–11)

- Statewide daily maximum temperatures (greater than 86°F) showed the state had more hot days (45 vs. ~41) and heat waves (10 vs. ~9) than the 1991-2020 climatology. The first heat wave started on June 26 and the last on September 4, with a mean duration of 3.8 days and a maximum of 7 days. The 1991-2020 climatology indicates that the first heat wave starts on ~May 24 and the last on September 3, with a mean duration of ~5 days and a maximum of ~11 days.

- Statewide daily maximum temperatures (greater than 80°F) also showed the state had more warm days (102 vs. ~93) than the 1991-2020 climatology but an equal number of warm-day spells (12). The first warm-day spell started on April 6 and the last on October 3, with a mean duration of 8.2 days and a maximum duration of 38 days. The 1991-2020 climatology indicates that the first warm-day spell starts on April 30 and the last on September 21, with a mean duration of ~9 days and a maximum of ~33 days.

- Statewide daily minimum temperatures (greater than 68°F) also showed the state had more warm nights (31 vs. ~18) and warm-night spells (7 vs. ~4) than the 1991-2020 climatology. The first warm-night spell started on July 2 and the last on September 5, with a mean duration of 4.1 days and a maximum of 8 days. The 1991-2020 climatology indicates that the first warm-night spell starts on June 23 and the last on August 28, with a mean duration of ~4 days and a maximum of ~8 days.

- Statewide daily minimum temperatures (less or equal to 32°F) showed the state had fewer freezing days (62 vs. ~90), more light freezing days (28 vs. ~23), more moderate freezing days (29 vs. ~27), and much fewer severe freezing days (5 vs. ~40) than the 1991-2020 climatology.

- Statewide daily minimum temperatures (greater than 32°F) indicated that the growing season lasted more days (224 vs. ~217) than the 1991-2020 climatology. It started on March 23 and ended on November 1, while the 1991-2020 climatology indicates it starts on April 1 and ends on November 3.

- Statewide daily mean temperatures (equal to or greater than 41°F) showed that the vegetation period lasted longer (328 vs. 293 days) than the 1991-2020 climatology. It started on January 1 and ended on November 24, while the 1991-2020 climatology indicates it starts on February 16 and ends on December 5.

- Statewide daily total precipitation indicated that dry spells were more abundant than in the 1991-2020 climatology within the year (51 vs. ~48) and within the vegetation period (46 vs. ~38). The mean and maximum duration of the dry spells were 4 and 11 days in both the vegetation period and the whole year. In comparison, the 1991-2020 climatology suggests mean and maximum durations of 4.5 and 16 days for the vegetation period and 4.6 and 17.1 days for the whole year.

- Statewide daily precipitation showed that days with extreme precipitation equal to or greater than 0.64 in (the 95th percentile in the 1951-2000 period) were fewer than the 1991-2020 climatology (11 vs. ~19 days) and the same number of days for extreme precipitation equal or greater than 1 in (7 vs. ~7 days).

- Cumulative growing degree days (base 50°F and modified) increased faster than the 1991-2020 climatology at the start of the growing season from late March to late April, then the accumulation rate went down until early July. The cumulative growing days in 2023 were greater than the 1991-2020 climatology from the start of the growing season to early June and from early September to the end of the growing season in early November; the cumulative degree days were below normal in the middle portion of the growing season, from mid-June to early September. The modified growing days remained above normal throughout the growing season except for a few days at the end of June.

*Historical Context* (Figure 12, Tables A1 and A2)

- Mean, maximum, and minimum statewide temperatures in 2023 (57.3, 67.8, and 46.9°F) were above the long-term (1895-2022) averages, within 5% of the highest values, and very close to the historical records. The accumulated total precipitation in 2023 (38.10 in) was below the long-term average and within 25% of the smaller values.

- This year, the statewide maximum temperature was the warmest on record, the mean temperature was the second warmest, and the minimum temperature was the fifth warmest. Baltimore City, Calvert, Carroll, Montgomery, and Saint Mary's counties established annual mean and maximum temperature records, and Saint Mary's County got its second warmest minimum temperature. Mean and maximum temperatures reached their second warmest values for numerous counties, while minimum temperatures reached values within the five warmest.

- While statewide precipitation was far from the records (twenty-sixth driest), Frederick and Washington counties reached the ninth and tenth driest years on record.

*Century-Plus Trends, 1895-2023* (Figures 13, 14)

- Statewide annual temperature, cooling, heating degree days, and accumulated precipitation showed significant trends. A warming trend (2.2°F/century), an increasing trend in cooling degree days (233.2°FDD/century), a decreasing trend in heating degree days (−607.8°FDD/century), and a wetting trend in precipitation (3.17 in/century).

- Regionally, annual mean temperatures showed significant warming trends everywhere in the state. 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, Baltimore, Anne Arundel, and Prince George's, and over the eastern shore counties of Queen Anne's, Talbot, Caroline, Dorchester, Wicomico, and Worcester.

- Regionally, annual accumulated precipitation had significant wetting trends over large regions in the state. In particular, over parts of Baltimore City, Baltimore, and Howard counties (above 5.5 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, Somerset and Worcester counties (around 4.0 in/century).

# 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. It documents the surface climate conditions observed across the state on a monthly, seasonal, and annual basis.

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 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 2023 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 and the comparison via scatter plots of the year's annual statewide and climate division averages are displayed (Section 4). Extreme heat, cold, precipitation, and agricultural indicators such as vegetation period, growing season, 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. Ancillary statewide, climate division, and county-level information is provided via tables and plots in Appendices A-B; climatology and variability maps are in Appendices C-D.

# 2. Data

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), which is available in a preliminary status at https://www.ncei.noaa.gov/data/nclimgrid-monthly/access/
  Data was downloaded on 1/11/2024.

- NOAA Monthly U.S. Climate *Divisional* Dataset (NClimDiv – Vose et al. 2014), which is available in a preliminary status (v1.0.0-20240105) at: https://www.ncei.noaa.gov/pub/data/cirs/climdiv/

Data was downloaded on 1/11/2024.

- NOAA area averages of daily temperatures and precipitation dataset (NClimGrid−Daily −Durre et al. 2022, 2022a), which 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 1/22/2024.

Some definitions:

*About the anomalies*: Anomalies for a given month, season, or year (e.g., 2023) 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 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*.

*About hot days, warm days, and warm nights*. 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 (identified from daily statewide-averaged temperatures (e.g., Tschurr et al. 2020, Barriopedro et al. 2023). 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. 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*. Tracking freezing days is important as the growing season can be approximated as the period between the date of the last killing frost in the spring and the date of the first frost in the fall using the 32°F threshold (USEPA, 2023). A freezing day is defined as a day when the minimum surface air temperature is less than or equal to 32°F. Freezing categories are further defined and approximated depending on how low the minimum temperature reaches (USDA, 2023). A light freeze is defined when the minimum air temperature is between 29° and 32°F; tender plants are killed with little destructive effect on other vegetation. A moderate freeze is defined as when the minimum air temperature is less than 29°F but greater than or equal to 25°F; it has a widely destructive effect on most vegetation, with heavy damage to fruit blossoms and tender and semi-hardy plants. A severe freeze is defined when the minimum temperature is less than 25°F, causing heavy damage to most plants; at these temperatures, the ground freezes solid, with the frozen ground's depth dependent on the freeze's duration and severity, soil moisture, and soil type.

*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 drops below the freezing point of 32°F (USEPA, 2023).

*About the vegetation period*. This is defined as the period between the first occurrence of a 6-day period with daily mean temperatures above 41°F and the first occurrence of a 6-day period with daily mean temperatures below 41°F after the first of July (Tschurr et al., 2020).

*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 the longest dry spell are particularly important during the vegetation period (Tschurr et al., 2020).

About e*xtreme precipitation.* This is defined as the yearly number of days with statewide averaged daily total precipitation equal to or greater than 1 in. However, a threshold of 0.64 in is also used, representing the 95th percentile of statewide averaged daily total precipitation for 1951-2022.

# 3. 2023 Annual Mean Maps

## A. Mean Temperatures

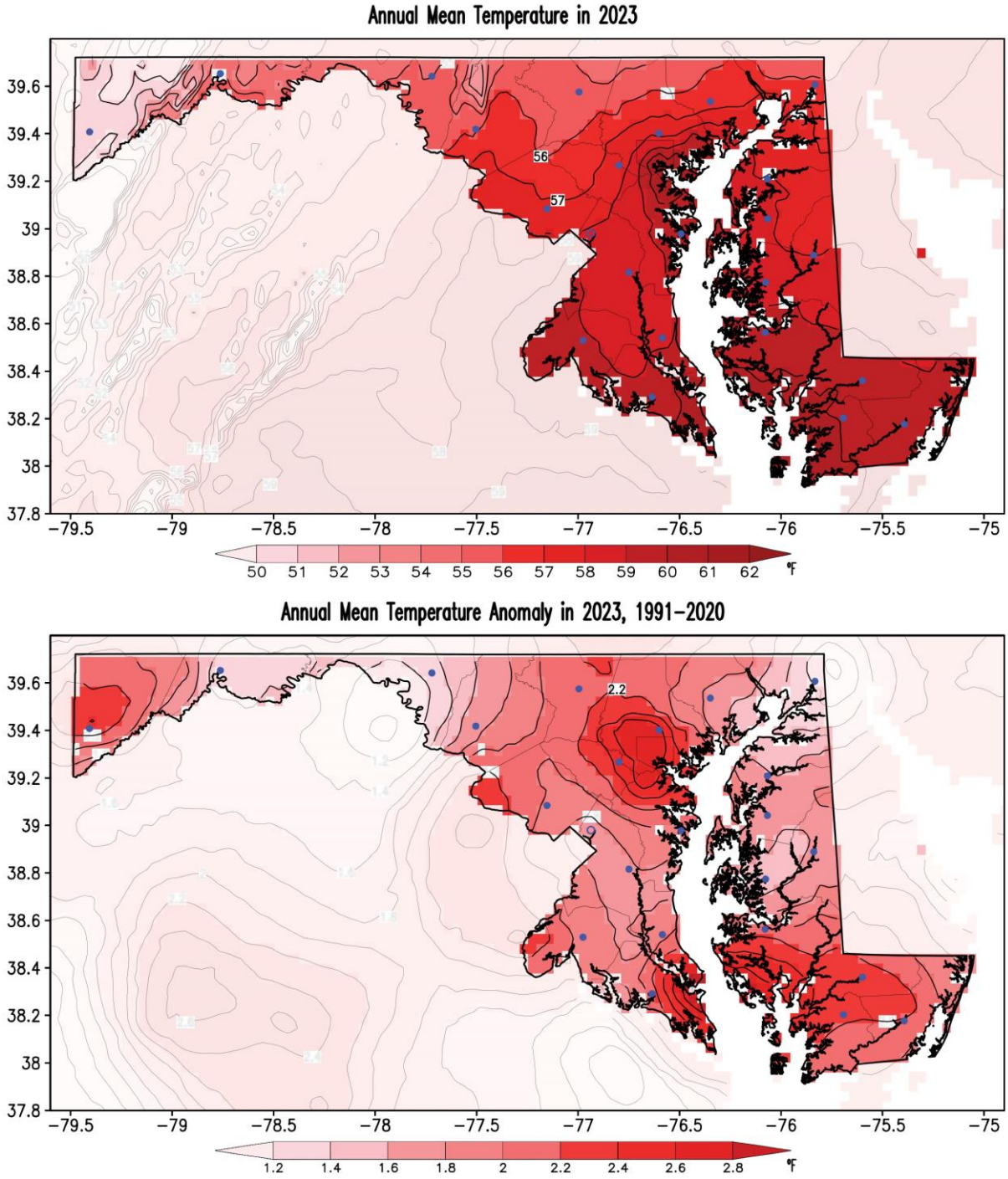


**Figure 1.** Annual mean of the mean surface air temperature (top panel) and its anomaly with respect to the 1991-2020 climatology (bottom panel) for 2023. Temperatures are in °F following the color bar. Red shading in the anomaly map marks warmer than normal conditions. Note shading outside the state has been washed out to facilitate focusing on Maryland. Filled blue circles mark the county seats.

B. Maximum Temperatures

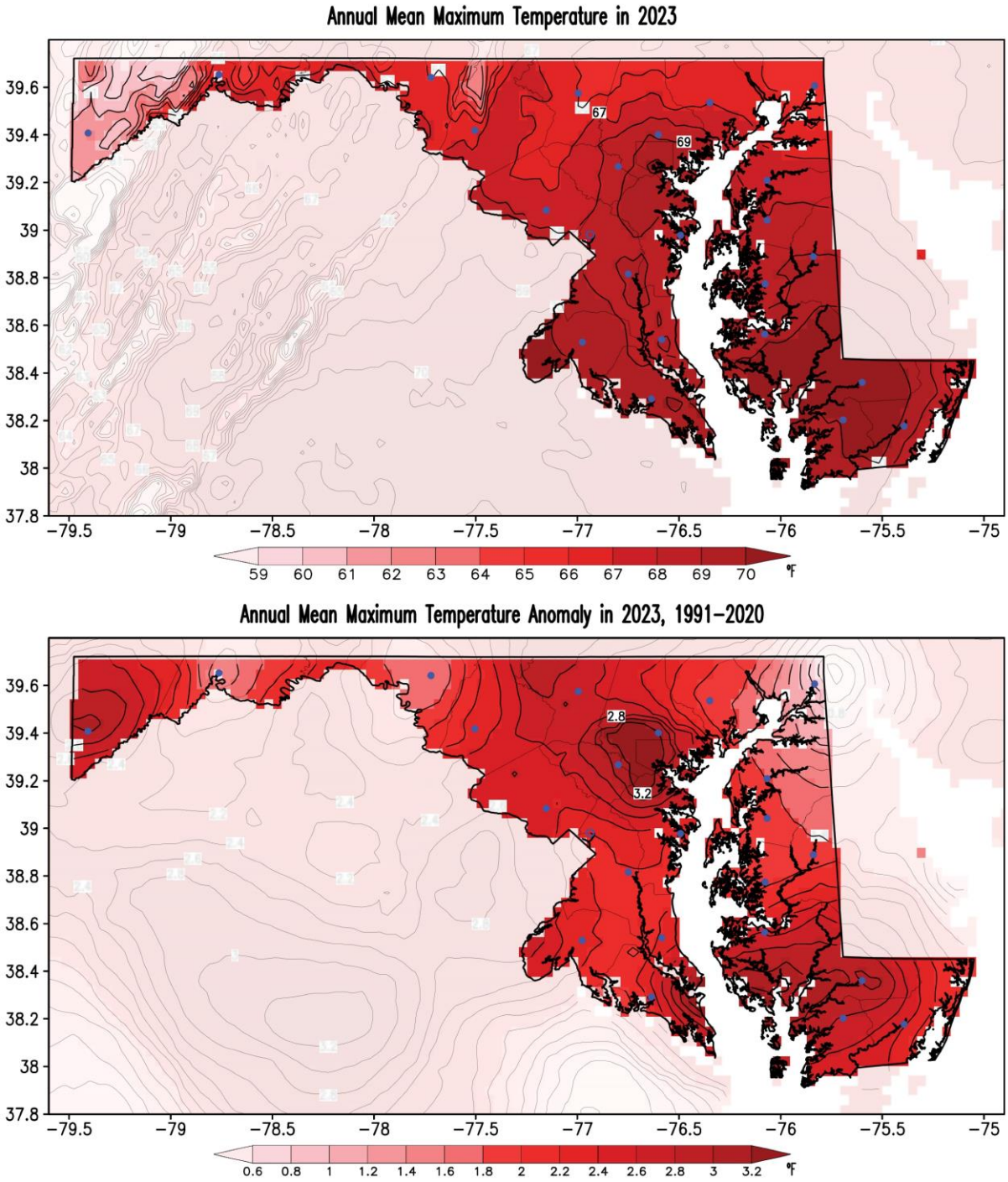


**Figure 2.** Annual mean of the maximum surface air temperature (top panel) and its anomaly with respect to the 1991-2020 climatology (bottom panel) for 2023. Temperatures are in °F following the color bar. Red shading in the anomaly map marks warmer than normal conditions. Note shading outside the state has been washed out to facilitate focusing on Maryland. Filled blue circles mark the county seats.

C. Minimum Temperatures

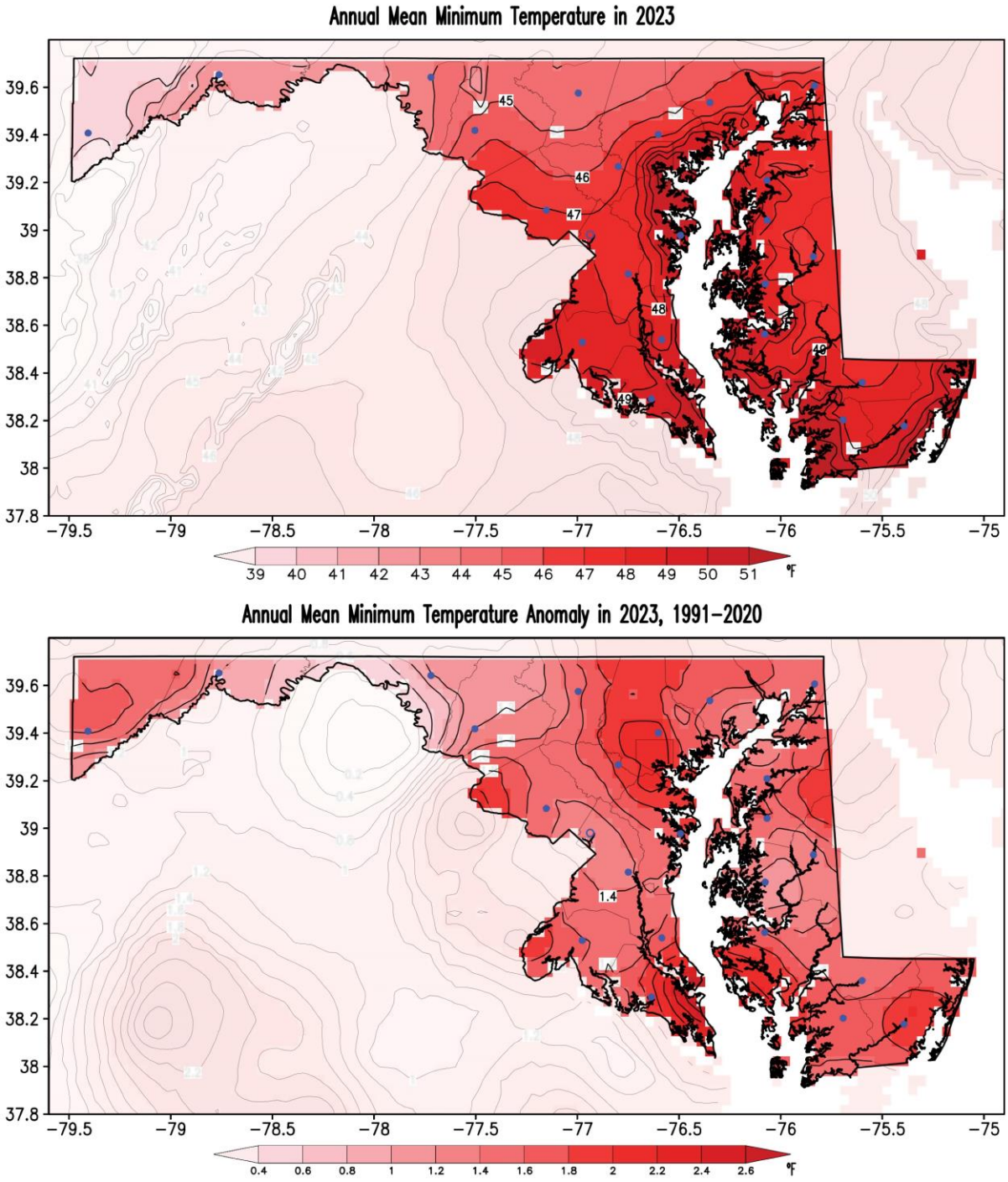


**Figure 3.** Annual mean of the minimum surface air temperature (top panel) and its anomaly with respect to the 1991-2020 climatology (bottom panel) for 2023. Temperatures are in °F following the color bar. Red shading in the anomaly map marks warmer than normal conditions. Note shading outside the state has been washed out to facilitate focusing on Maryland. Filled blue circles mark the county seats.

D. Precipitation

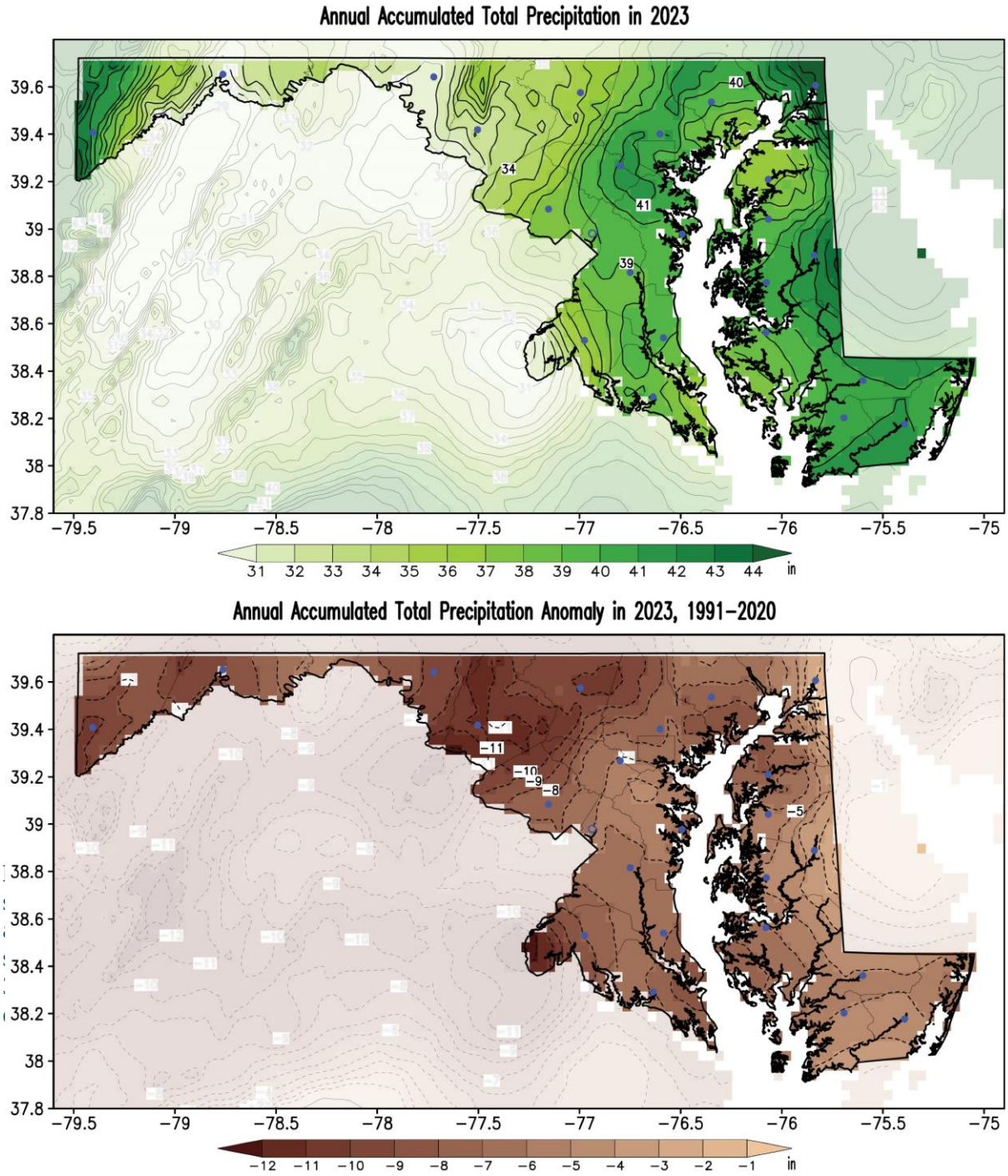


**Figure 4.** Annual accumulated total precipitation (top panel) and its anomaly with respect to the 1991-2020 climatology (bottom panel) for 2023. Precipitation is in inches following the color bar. Brown shading in the anomaly map marks drier than normal conditions. Note shading outside the state has been washed out to facilitate focusing on Maryland. Filled blue circles mark the county seats.

# 4. Statewide and Climate Divisions Averages in 2023

## A. Statewide Monthly Evolution of Anomalies

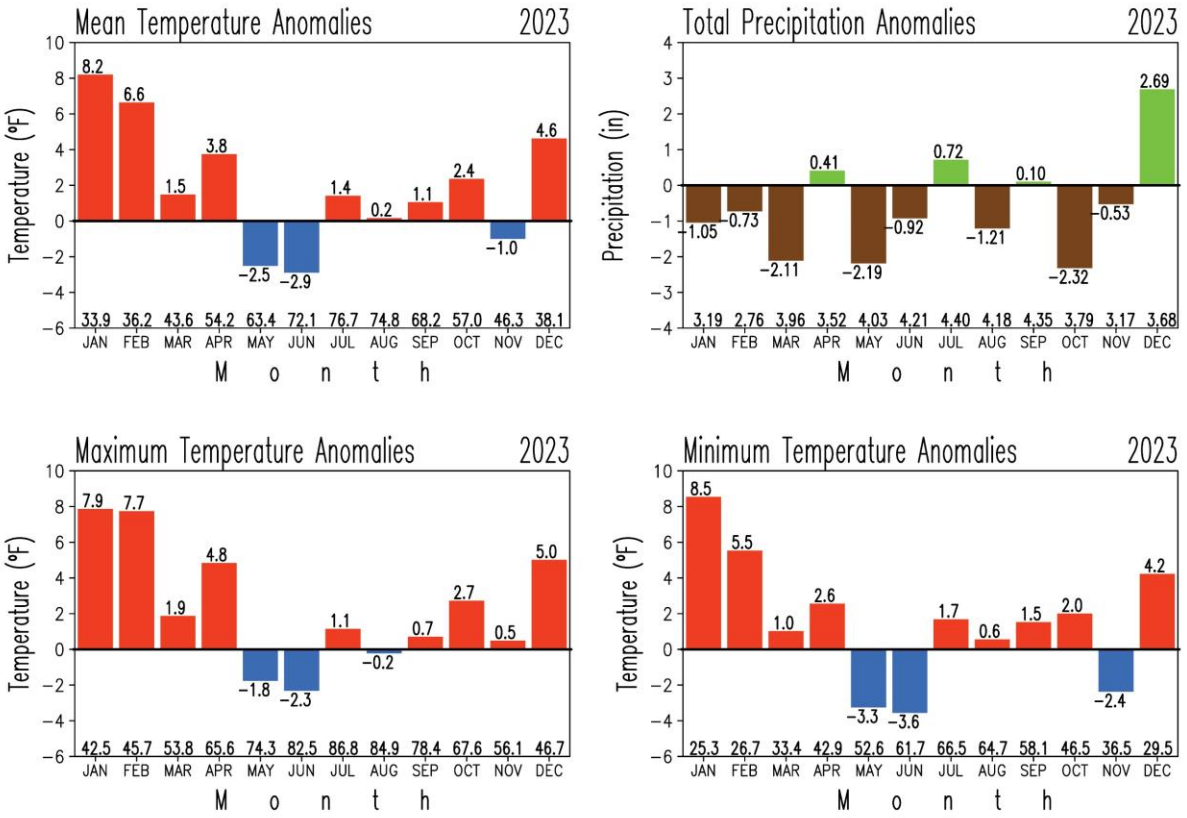


**Figure 5**. Maryland (statewide) monthly evolution of surface variables and their anomalies in 2023. Anomalies are with respect to the 1991-2020 climatology. Red/blue color represents positive/negative anomalies for mean surface air temperature (upper left), maximum surface air temperature (bottom 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. Nine of the twelve months were warmer than normal, notably in the winter months of January, February, and December, while only three months, May, June, and August or November, were colder than normal. On the other hand, eight months were drier than normal, notably in March, May, and October, and four months were wetter than normal, particularly in December.

B. 2023 Scatter Plots

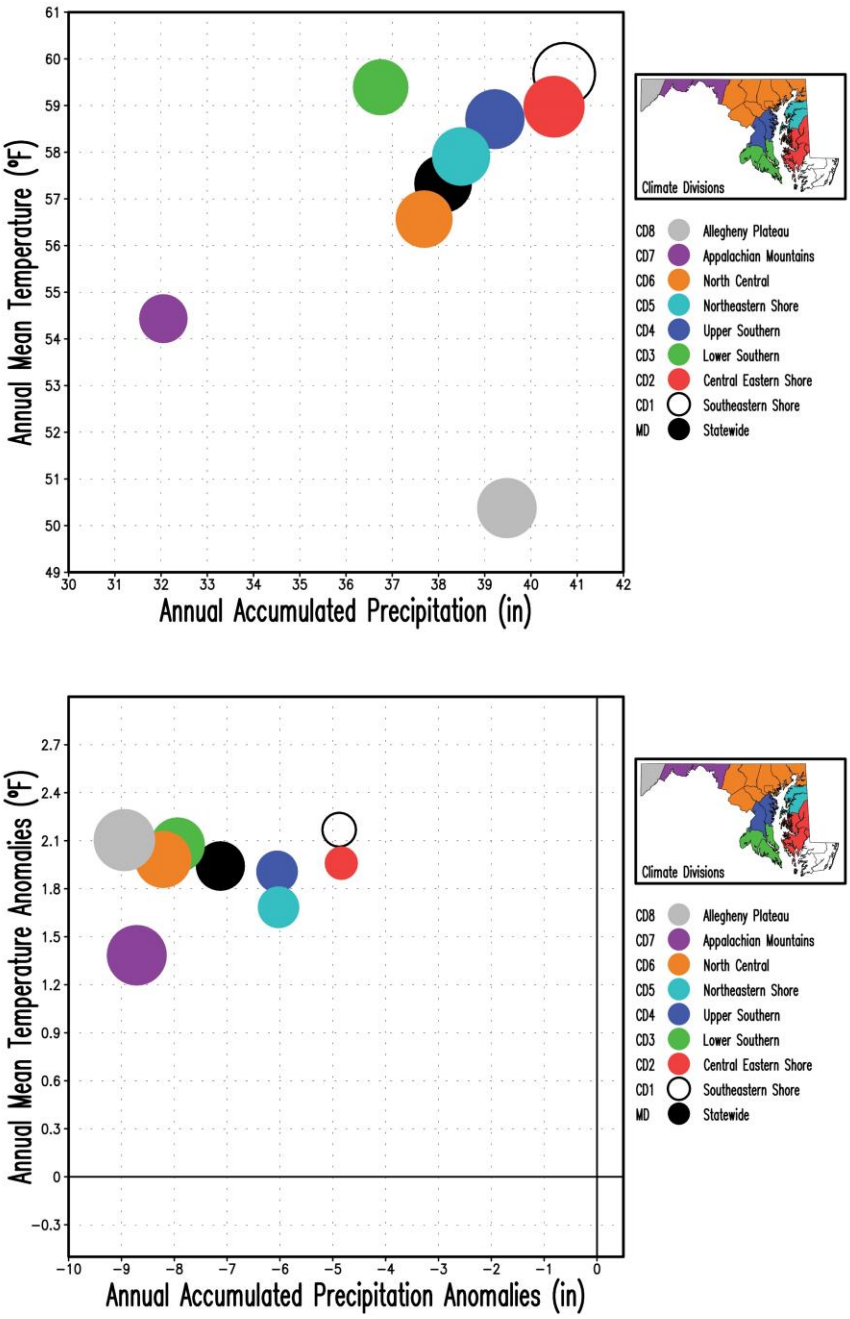


**Figure 6.** Scatter plots of Maryland (statewide) and Climate Divisions (CD#) annual mean surface air temperature vs. annual accumulated total precipitation for 2023. The upper panel shows the mean temperature and total precipitation, and the bottom panel displays their anomalies with respect to the 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 (40.72 inches in CD1, top panel) and by the maximum precipitation anomaly (|−8.94| inches in CD8, 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. 2021−2023 Scatter Plots

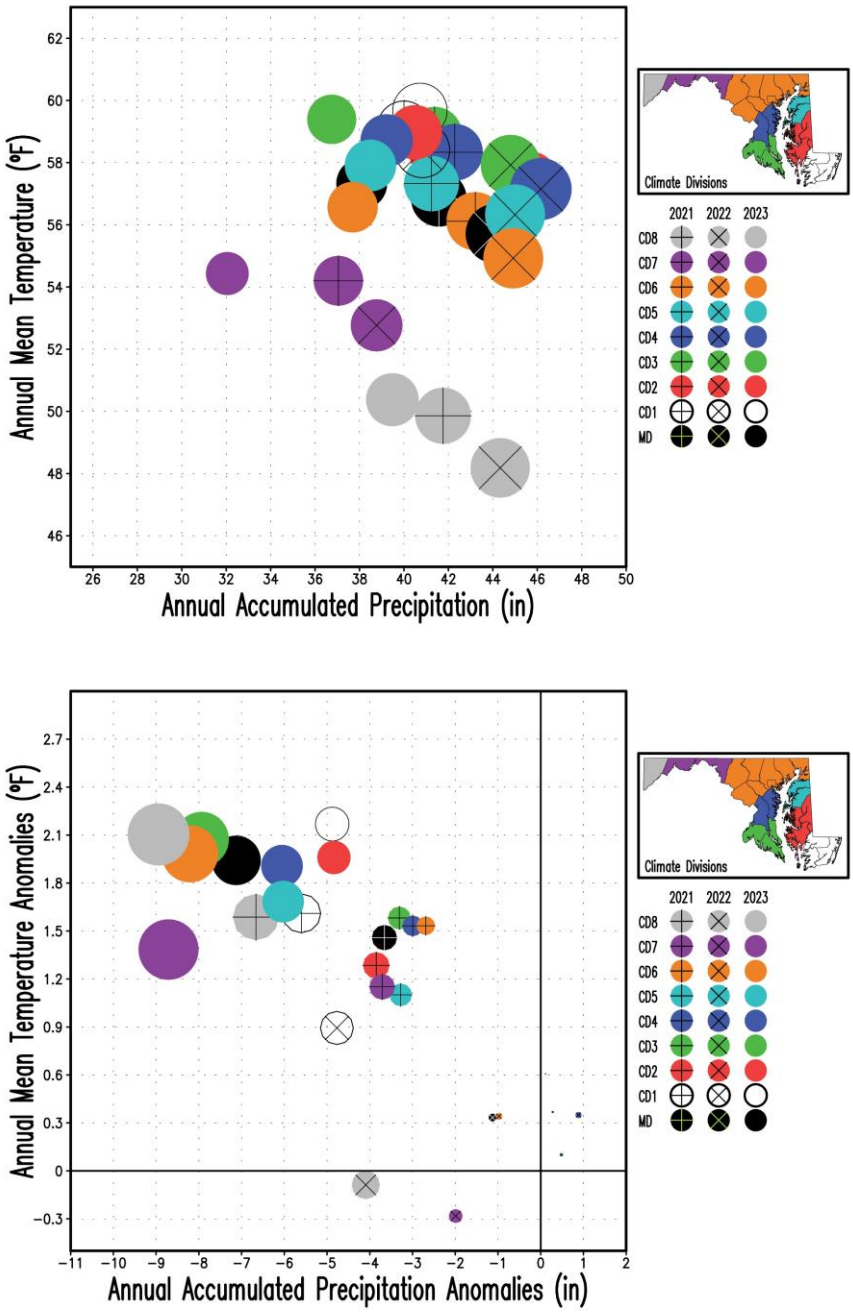


**Figure 7**. Scatter plots of Maryland (statewide) and Climate Divisions (CD#) annual mean surface air temperature vs. annual accumulated total precipitation for 2021, 2022, and 2023. The upper panel shows the mean temperature and total precipitation, and the bottom panel displays their anomalies with 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 (|−8.94| inches in CD8 in 2023, bottom panel) among the nine regions and three years. The year 2023 is displayed with filled circles only, while years 2022 and 2021 are displayed with superposed multiplication and addition signs, respectively.

# 5. Statewide Daily Evolution in 2023

## A. Hot Days, Warm Days, and Warm Nights

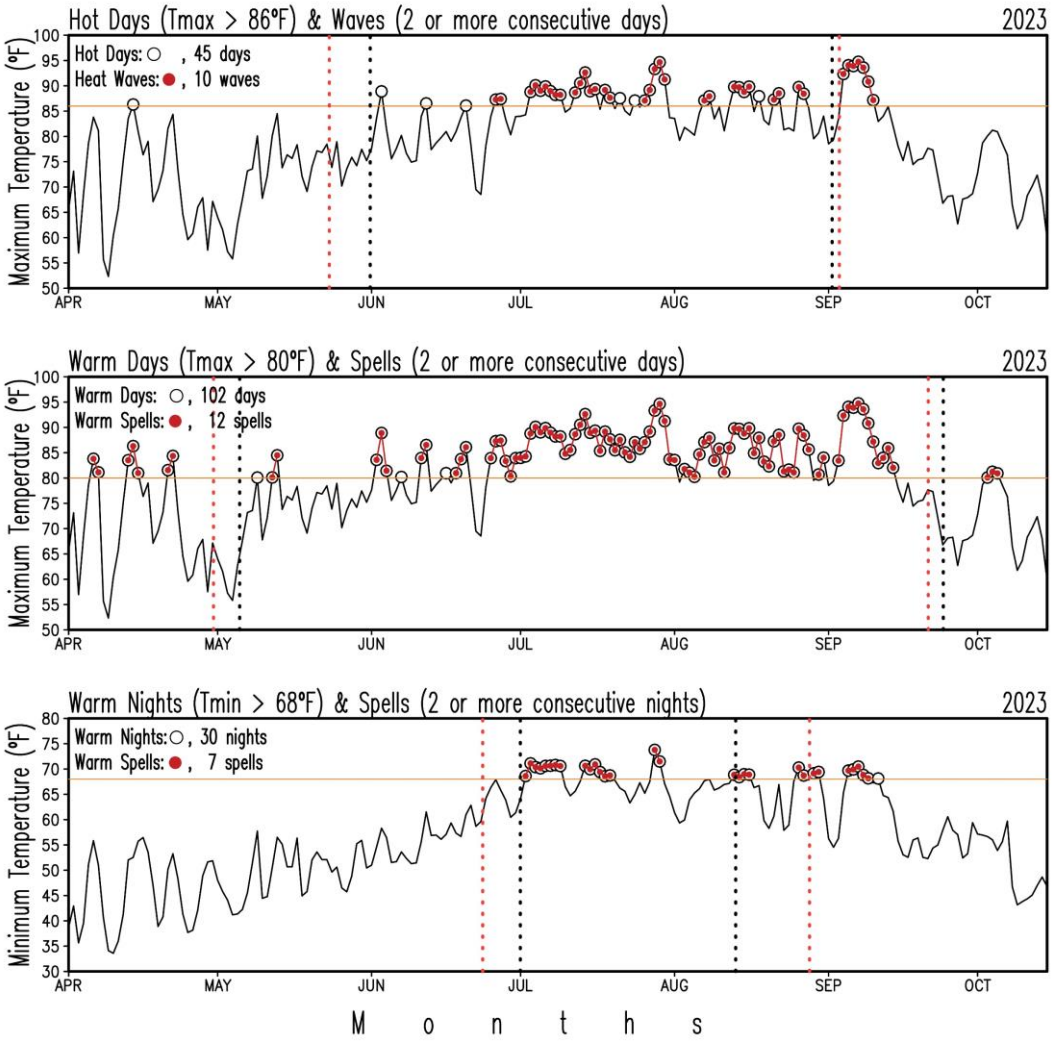


**Figure 8.** Maryland (statewide) number of hot days (upper panel), warm days (middle panel), and warm nights (bottom panels), and their consecutive occurrence in 2023. The continuous orange lines mark the 86, 80 and 68°F threshold temperatures. The open circles display the temperatures above the threshold temperature, and those filled with a red filled circle show the waves and spells. The year had 45 hot days, 10 heat waves, 102 warm days, 12 warm day spells, 30 warm nights, and 7 warm night spells. The climatological counts for the period 1991-2020 are ~41 hot days, 9 heat waves, ~93 warm days and 12 warm day spells, 18 warm nights, and 4 warm night spells. The vertical red and black dotted lines mark the 1991-2020 and 1951-2000 climatological positions of the start and end of the waves and spells. The heat waves in this year started and ended later than normal; the warm day spells started and ended earlier than normal, while the warm night spells started and ended later than normal. Note that the current climatological start and end of the waves and spells (red dotted lines) start earlier and end later than their 20th-century climatology for the period 1951-2000 (black dotted lines), except by the warm day spells that end earlier than the 1951-2000 climatology. 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. The threshold temperatures are an attempt to track the extreme heat for crops and humans (e.g., Tschurr et al. 2020, Barriopedro et al. 2023).

B. Freezing Days and the Growing Season

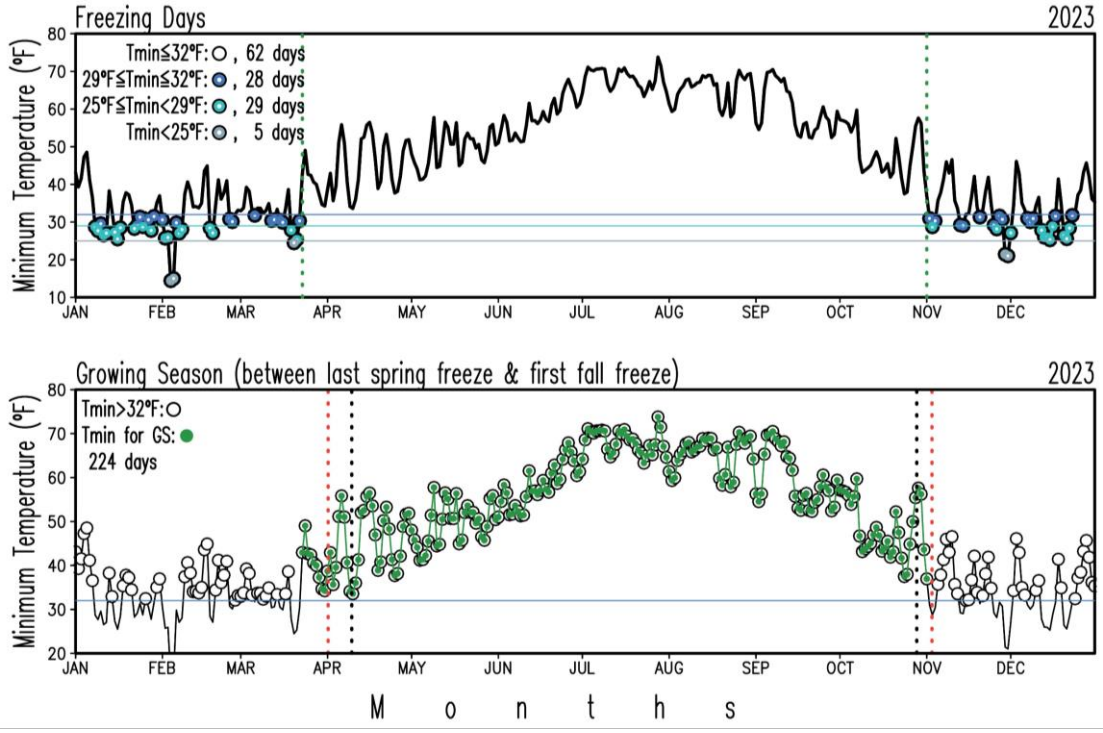


**Figure 9.** Maryland (statewide) number of freezing days (upper panel) and the growing season (lower panel) in 2023. A freezing day is defined as a day when the minimum surface air temperature is smaller or equal to 32°F. The growing season can be approximated as the period between the date of the last killing frost in the spring and the date of the first frost in the fall using the 32°F threshold. A *light freeze* is defined when the minimum air temperature is between 29° and 32°F; a *moderate freeze* is defined as when the minimum air temperature is less than 29°F but equal to or larger than 25°F; a *severe freeze* is defined when the minimum temperature is smaller than 25°F. The horizontal continuous lines mark the threshold temperatures of 32°, 29° and 25°F. The open circles in the upper panel display temperatures smaller or equal to 32°F; those filled with the darkest blue circles show the days under light freeze conditions; those filled with cyan circles display the days under moderate freeze conditions; and those filled with gray circles show the days under severe freeze conditions. This year had 62 freezing days, of which 28 days were under light freeze conditions, 29 days under moderate freeze conditions, and 5 days under severe freeze conditions; the climatological counts for the period 1991-2020 are ~90 freeze days, ~23 light freeze days, ~27 moderate freeze days, and 40 severe freeze days. The vertical green dotted lines mark the start and end of the growing season in 2023. The open circles in the lower panel display temperatures greater than 32°F; those filled with the green-filled circles display the growing season. This year, the growing season lasted 224 days; the climatological growing season for the period 1991-2020 lasts ~217 days. The vertical red and black dotted lines mark the 1991-2020 and 1951-2000 climatological positions, respectively, of the start and end of the growing season. The 2023 growing season started earlier than the current climatology. Note that the current climatological start of the growing season (red dotted lines) occurs earlier and ends later than their 20th-century climatology for the period 1951-2000 (black dotted lines).

## C. Vegetation Period, Dry Days and Extreme Precipitation

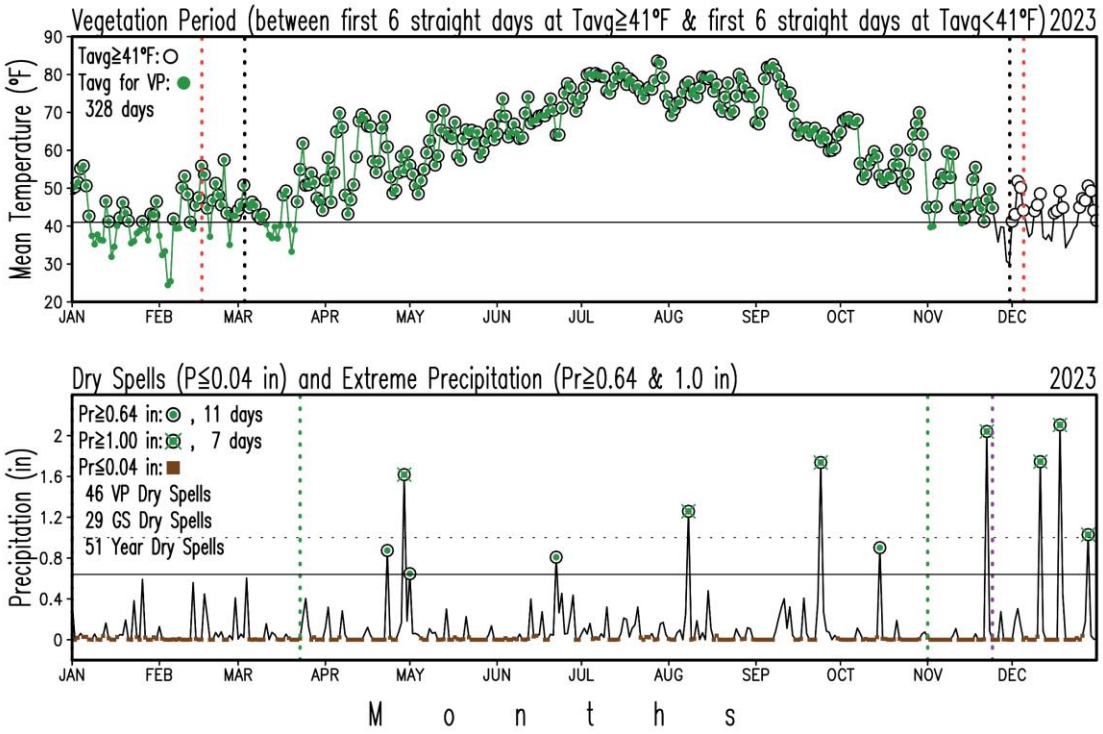


**Figure 10**. Maryland (statewide) vegetation period (upper panel), dry spells, and extreme precipitation (lower panel) in 2023 from daily mean temperature and daily total precipitation. The vegetation period (Tschurr et al., 2020) is defined as the period between the first occurrence of a 6-day-period with daily mean temperatures above 41°F and the first occurrence of a 6-day-period with daily mean temperatures below 41°F after the first of July. The open circles in the upper panel display mean temperatures larger or equal to 41°F, and the green-filled circles mark the vegetation period. This year, the vegetation period started on January 1st and lasted 328 days; the climatological duration of the vegetation period for the period 1991-2020 is 293 days. The vertical red and black dotted lines mark the 1991-2020 and 1951-2000 climatological positions, respectively, of the start and end of the vegetation period. The 2023 vegetation period started earlier than the current climatology. Note that the current climatological start of the growing season (red dotted lines) occurs earlier and ends later than their 20th-century climatology for 1951-2000 (black dotted lines). Daily total precipitation is used to identify dry spells and extreme precipitation events (lower panel). Dry spells (consecutive days with daily total precipitation less than or equal to 0.04 in) are the brown-filled squares, and extreme precipitation days equal to or larger than 0.64 in (1 in) are the green–filled circles (multiplication sign superposed to the green-filled circles). The dotted green and purple lines mark this year's growing season and vegetation period, respectively. This year had 46 dry spells within the vegetation period, 29 within the growing season, and 51 within the calendar year; the longest dry spell lasted 11 days within the vegetation period. The climatological number of dry spells for 1991-2020 is ~38, with the longest lasting 16 days within the vegetation period. This year had 11(7) days with precipitation larger or equal to 0.64(1.0) in; the climatological number of extreme precipitation events is 19(7) days with precipitation larger or equal to 0.64(1.0) in.

## D. Growing Degree Days

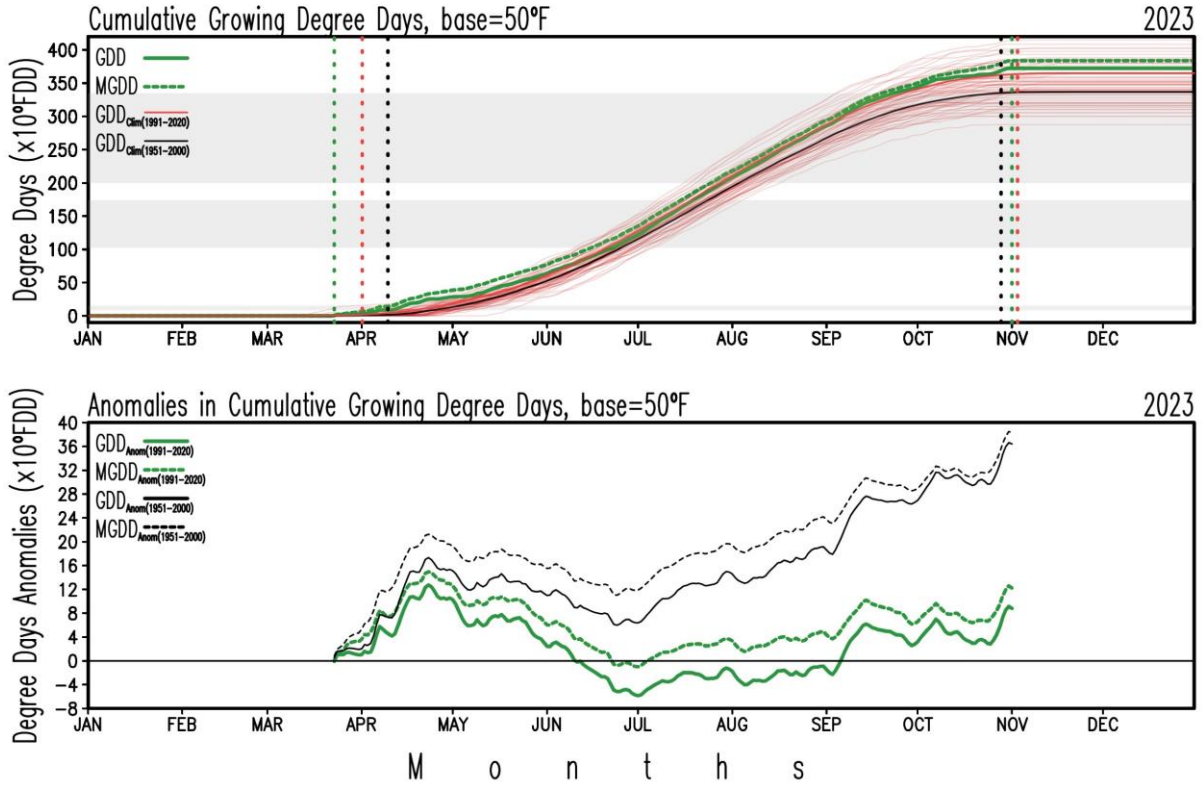


**Figure 11**. Maryland (statewide) cumulative growing degree days during the growing season (upper panel) and its anomaly with respect to the 1991-2020 climatology (lower panel) for 2023. Cumulative growing degree days estimate the growth and development of certain crops and pests during the growing season. The cumulative growing degree days are displayed with the continuous green line, while the modified growing degree days are shown with the dashed green line in the upper panel; the red line shows the 1991-2020 climatological cumulative growing degree days, and the black line shows the 1951-2000 climatological cumulative growing degree days; the thin red lines display the cumulative growing degree days every year since 1951 to 2022. 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). The vertical dotted green, red, and black lines mark the start and end of the growing season for 2023 and the 1991-2020 and 1951-2000 climatologies. Anomalies with respect to the 1991-2020 climatology in the cumulative growing degree days (bottom panel) are displayed with the continuous green line, while those for the modified cumulative growing degree days are shown with the dashed green line; the corresponding anomalies with respect to the 1951-2000 climatology are the lines in black. Note that the warmer anomalies in April and the colder anomalies in May and June (Figure 5) are behind the peak and subsequent decrease in growing degree days from April to the end of June.

# 6. 2023 Statewide Averages in the Historical Record

## A. Box and Whisker Plots

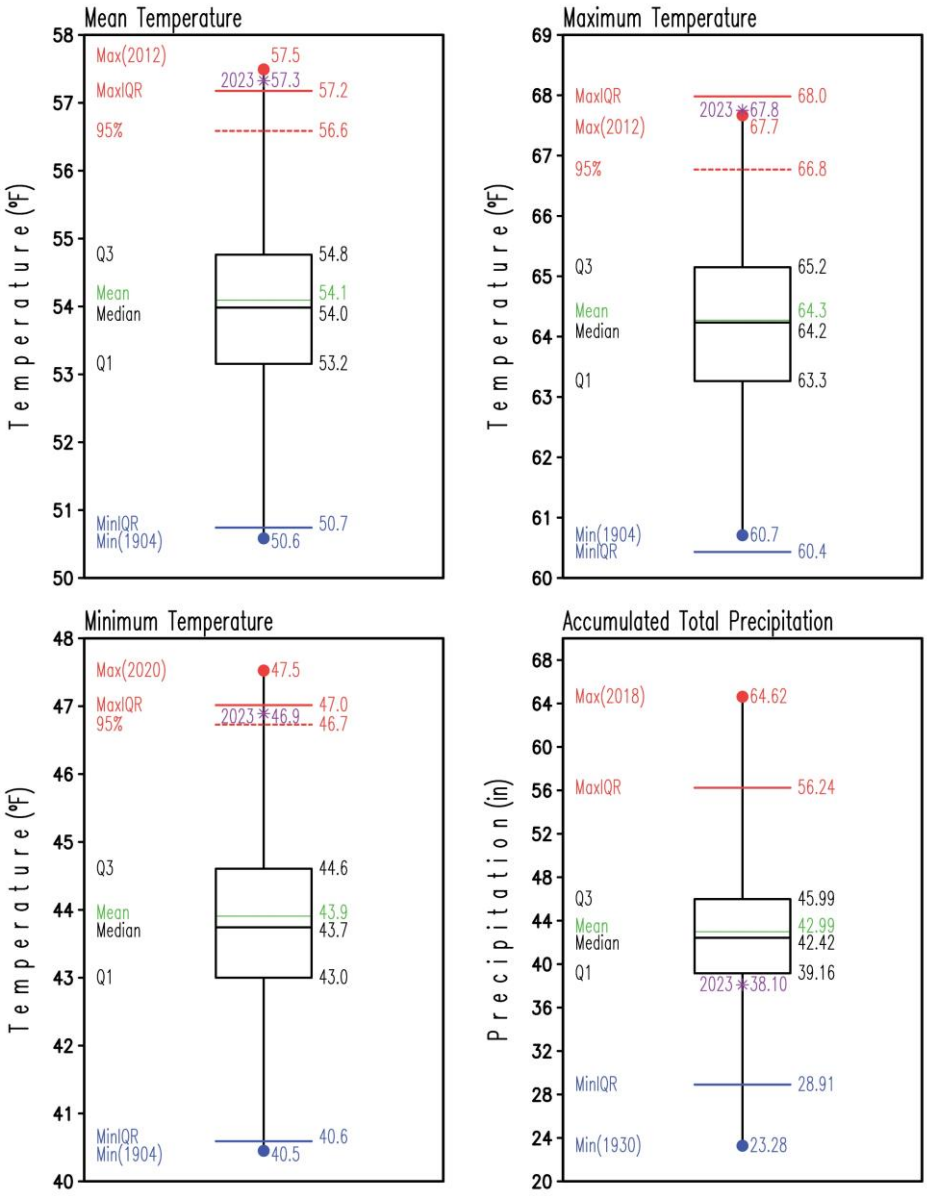


**Figure 12.** Box and Whisker plots of Maryland (statewide) annual mean (upper left), maximum (upper right), minimum (lower left) surface air temperatures, and accumulated total precipitation (lower right) for the period 1895-2022. The label and asterisk in purple represent conditions for 2023. Statistics for the period 1895-2022 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. The dashed red line marks the 95th percentile.

# 7. 1895-2023 Trends

## A. Statewide Mean Temperature, Degree-Days, and Precipitation

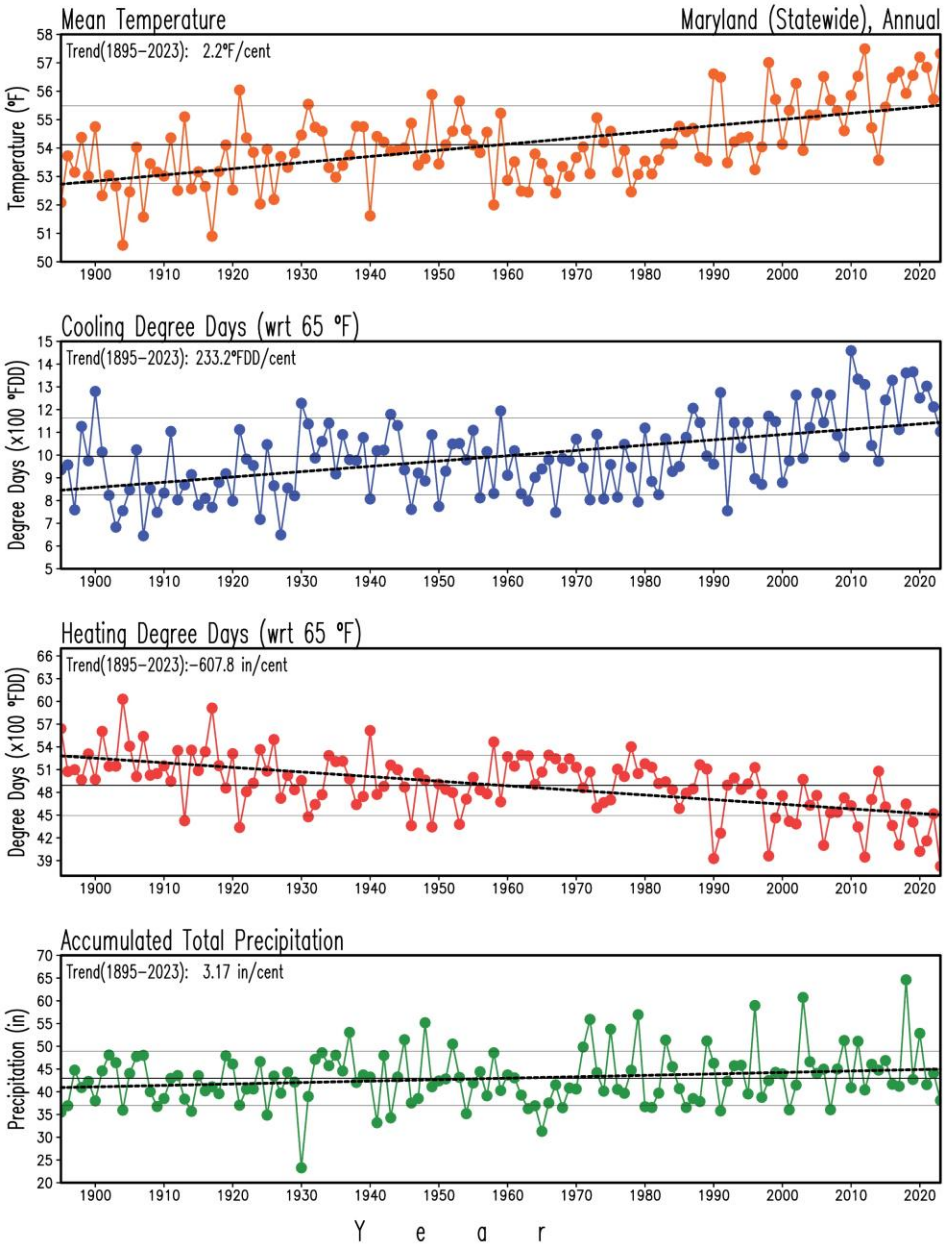


**Figure 13.** Maryland (statewide) annual mean surface air temperature, cooling degree-days, heating degree days and accumulated precipitation for the period 1895-2023. Temperature is in °F, cooling and heating degree-days are in °F degree-days (°FDD), and precipitation is in inches. The thin, continuous black lines in each panel display the long-term means (54.1°F, 994.7°FDD, 4892.6°FDD and 42.95 in, 1895-2023), and the double thin, continuous gray lines indicate the standard deviation (1.4°F, 169.8°FDD, 398.9°FDD, and 5.98 in) above/below the long-term mean. The thick dashed black lines show the long-term linear trend. The warming temperature trend (2.2°F/century), the increasing cooling degree-days trend (233.2°FDD/century), decreasing heating degree-days trend (–607.8°FDD/century), and the accumulated precipitation trend (3.17 in/century) are statistically significant at the 95% level (*Student's t-test* −Santer et al. 2000).

B. Temperature and Precipitation Maps

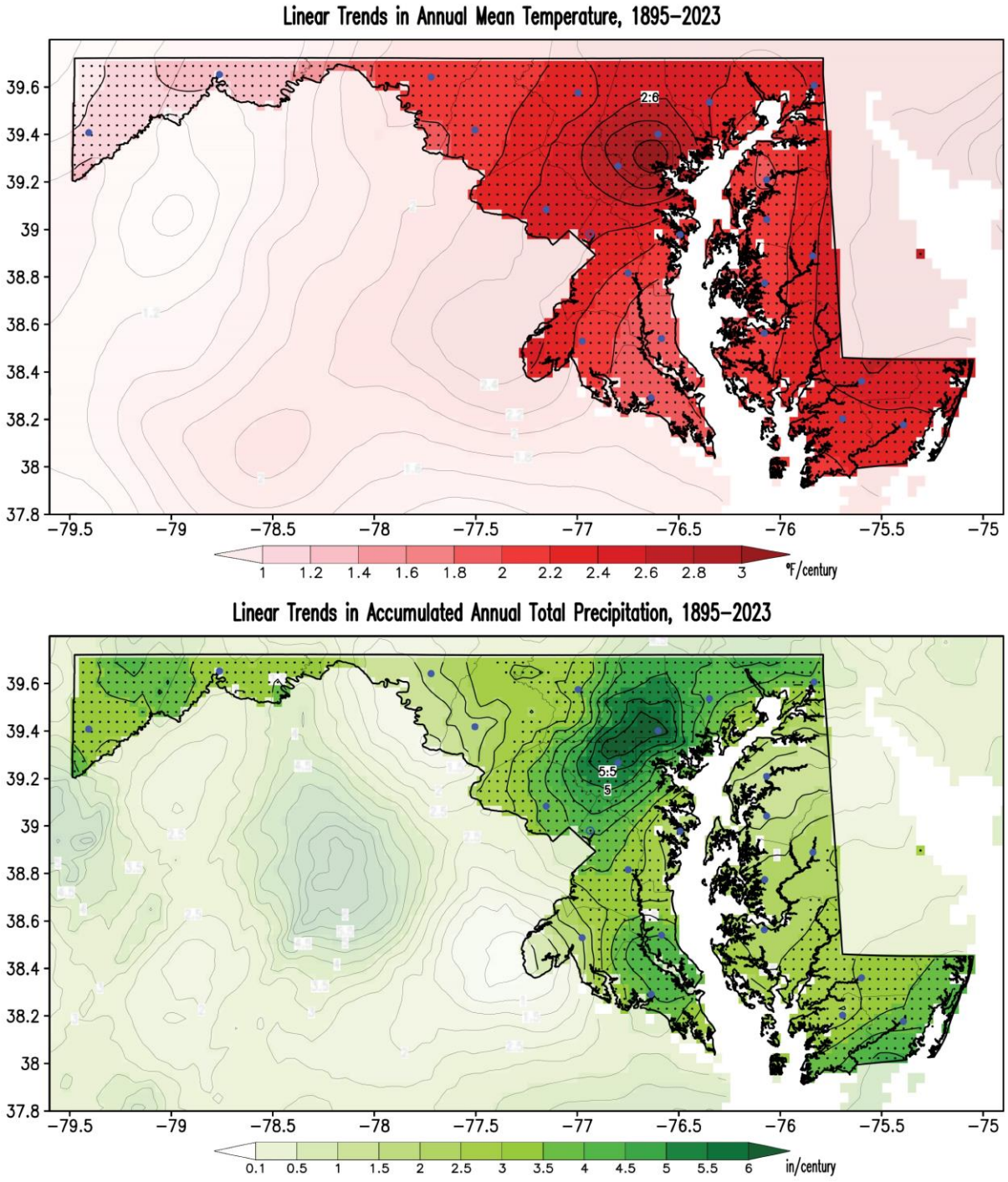


**Figure 14.** Linear trends in annual surface air mean temperature and accumulated precipitation for the period 1895-2023. Temperatures are in °F/century, and precipitation is in inches/century following the color bars. Red shading in the temperature map marks warming trends. Green shading in the precipitation 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.

# Appendix A. 2023 Data Tables: Statewide, Climate Divisions, and Counties

A. Mean Temperature and Precipitation

| Region | Mean Air Temperature (°F) | Rank (#) |
|---|---|---|
| **Statewide** | 57.3 | 128 |
| **Climate Division 1** | 59.7 | 128 |
| **Climate Division 2** | 59.0 | 128 |
| **Climate Division 3** | 59.4 | 129 |
| **Climate Division 4** | 58.7 | 128 |
| **Climate Division 5** | 57.9 | 128 |
| **Climate Division 6** | 56.6 | 128 |
| **Climate Division 7** | 54.4 | 126 |
| **Climate Division 8** | 50.4 | 129 |
| **Allegany** | 53.9 | 126 |
| **Anne Arundel** | 59.1 | 128 |
| **Baltimore** | 57.1 | 128 |
| **Baltimore City** | 59.4 | 129 |
| **Calvert** | 59.1 | 129 |
| **Caroline** | 58.1 | 127 |
| **Carroll** | 55.5 | 129 |
| **Cecil** | 56.5 | 125 |
| **Charles** | 59.3 | 128 |
| **Dorchester** | 59.6 | 128 |
| **Fredrick** | 55.8 | 128 |
| **Garrett** | 50.4 | 129 |
| **Harford** | 56.7 | 126 |
| **Howard** | 57.0 | 128 |
| **Kent** | 57.8 | 128 |
| **Montgomery** | 57.2 | 129 |
| **Prince George's** | 58.4 | 128 |
| **Queen Anne's** | 58.1 | 128 |
| **Saint Mary's** | 59.6 | 129 |
| **Somerset** | 60.1 | 128 |
| **Talbot** | 58.7 | 126 |
| **Washington** | 55.0 | 124 |
| **Wicomico** | 59.5 | 128 |
| **Worcester** | 59.5 | 128 |

| Region | Accumulated Precipitation (in) | Rank (#) |
|---|---|---|
| **Statewide** | 38.10 | 26 |
| **Climate Division 1** | 40.72 | 46 |
| **Climate Division 2** | 40.50 | 43 |
| **Climate Division 3** | 36.75 | 25 |
| **Climate Division 4** | 39.22 | 43 |
| **Climate Division 5** | 38.49 | 33 |
| **Climate Division 6** | 37.69 | 26 |
| **Climate Division 7** | 32.05 | 12 |
| **Climate Division 8** | 39.48 | 17 |
| **Allegany** | 32.32 | 17 |
| **Anne Arundel** | 39.92 | 52 |
| **Baltimore** | 39.62 | 41 |
| **Baltimore City** | 40.31 | 46 |
| **Calvert** | 38.55 | 33 |
| **Caroline** | 41.92 | 61 |
| **Carroll** | 35.84 | 21 |
| **Cecil** | 42.35 | 53 |
| **Charles** | 35.16 | 16 |
| **Dorchester** | 39.24 | 32 |
| **Fredrick** | 33.75 | 9 |
| **Garrett** | 39.44 | 16 |
| **Harford** | 39.44 | 36 |
| **Howard** | 39.14 | 37 |
| **Kent** | 37.72 | 27 |
| **Montgomery** | 36.33 | 25 |
| **Prince George's** | 38.84 | 41 |
| **Queen Anne's** | 38.87 | 34 |
| **Saint Mary's** | 38.23 | 37 |
| **Somerset** | 40.52 | 48 |
| **Talbot** | 40.31 | 46 |
| **Washington** | 31.76 | 10 |
| **Wicomico** | 40.78 | 43 |
| **Worcester** | 40.78 | 48 |

**Table A1.** Annual-mean surface air temperature (left) and annual-accumulated precipitation (right) at Maryland (statewide), climate division, and county levels for 2023. Temperatures are in °F, and precipitation is in inches. The rank is the order that the variable for 2023 occupies among the 129 years after the 129 values have been arranged from the lowest to the highest in the *standard competition ranking method*. The closer to 129 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** | 67.8 | 129 |
| **Climate Division 1** | 69.8 | 128 |
| **Climate Division 2** | 69.5 | 129 |
| **Climate Division 3** | 69.6 | 129 |
| **Climate Division 4** | 68.9 | 128 |
| **Climate Division 5** | 67.9 | 126 |
| **Climate Division 6** | 67.0 | 129 |
| **Climate Division 7** | 65.9 | 127 |
| **Climate Division 8** | 61.1 | 128 |
| **Allegany** | 65.5 | 125 |
| **Anne Arundel** | 69.0 | 128 |
| **Baltimore** | 67.7 | 129 |
| **Baltimore City** | 69.7 | 129 |
| **Calvert** | 69.0 | 129 |
| **Caroline** | 69.0 | 128 |
| **Carroll** | 66.4 | 129 |
| **Cecil** | 65.9 | 122 |
| **Charles** | 69.8 | 129 |
| **Dorchester** | 70.1 | 129 |
| **Fredrick** | 66.5 | 129 |
| **Garrett** | 61.1 | 128 |
| **Harford** | 66.8 | 126 |
| **Howard** | 67.8 | 129 |
| **Kent** | 67.5 | 126 |
| **Montgomery** | 67.5 | 129 |
| **Prince George's** | 68.9 | 128 |
| **Queen Anne's** | 68.1 | 127 |
| **Saint Mary's** | 69.5 | 129 |
| **Somerset** | 70.0 | 129 |
| **Talbot** | 68.8 | 128 |
| **Washington** | 66.3 | 126 |
| **Wicomico** | 70.5 | 129 |
| **Worcester** | 69.2 | 128 |

| Region | Minimum Air Temperature (°F) | Rank (#) |
|---|---|---|
| **Statewide** | 46.9 | 125 |
| **Climate Division 1** | 49.5 | 123 |
| **Climate Division 2** | 48.5 | 125 |
| **Climate Division 3** | 49.2 | 126 |
| **Climate Division 4** | 48.5 | 125 |
| **Climate Division 5** | 47.9 | 127 |
| **Climate Division 6** | 46.1 | 125 |
| **Climate Division 7** | 42.9 | 118 |
| **Climate Division 8** | 39.6 | 125 |
| **Allegany** | 42.3 | 119 |
| **Anne Arundel** | 49.2 | 126 |
| **Baltimore** | 46.4 | 126 |
| **Baltimore City** | 49.2 | 127 |
| **Calvert** | 49.2 | 127 |
| **Caroline** | 47.2 | 125 |
| **Carroll** | 44.5 | 125 |
| **Cecil** | 47.1 | 126 |
| **Charles** | 48.8 | 124 |
| **Dorchester** | 49.1 | 126 |
| **Fredrick** | 45.1 | 121 |
| **Garrett** | 39.7 | 125 |
| **Harford** | 46.6 | 125 |
| **Howard** | 46.1 | 126 |
| **Kent** | 48.2 | 127 |
| **Montgomery** | 46.8 | 125 |
| **Prince George's** | 47.9 | 123 |
| **Queen Anne's** | 48.0 | 126 |
| **Saint Mary's** | 49.6 | 128 |
| **Somerset** | 50.1 | 125 |
| **Talbot** | 48.6 | 123 |
| **Washington** | 43.6 | 119 |
| **Wicomico** | 48.5 | 123 |
| **Worcester** | 49.7 | 123 |

**Table A2**. Annual-mean maximum (left) and minimum (right) surface air temperatures at Maryland (statewide), climate division, and county levels for 2023. Temperatures are in °F. The rank is the order that the variable for 2023 occupies among the 129 years after the 129 values have been arranged from the lowest to the highest using the *standard competition ranking method*. The closer to 129 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. 2023 Bar Graphs: Statewide, Climate Divisions, and Counties

## A. Temperatures and Precipitation

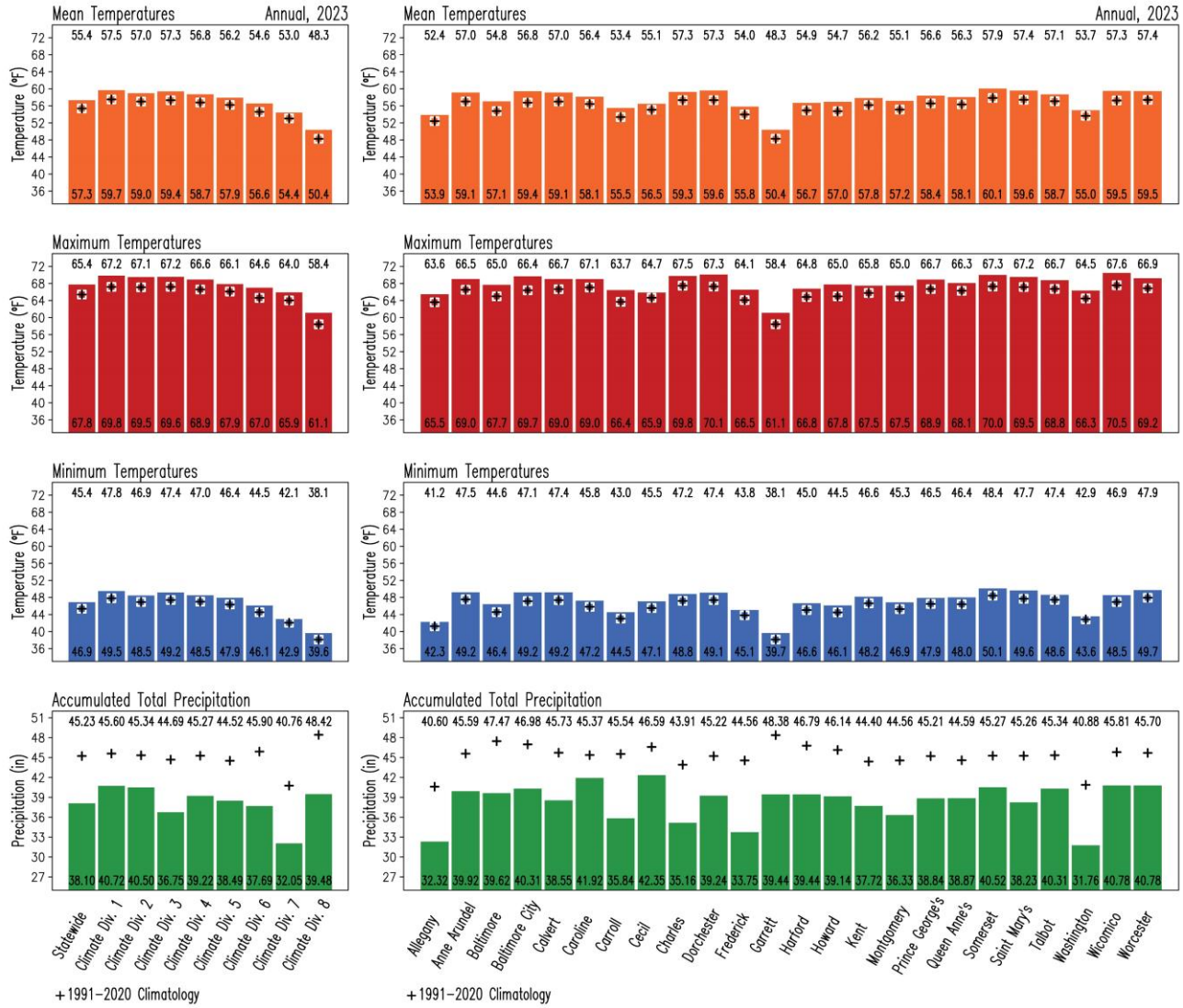


**Figure B1.** Annual surface variables in Maryland for 2023. Color bars represent the variables as follows: annual-mean mean surface air temperature (orange), maximum surface air temperature (red), minimum surface air temperature (blue) and annual-accumulated total precipitation (green) at statewide and climate division (left column), and at 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 2023. For comparison, the corresponding 1991-2020 climatological annual values are displayed as black addition signs, and their magnitude are shown at the top of the panels.

## B. Temperatures and Precipitation Anomalies

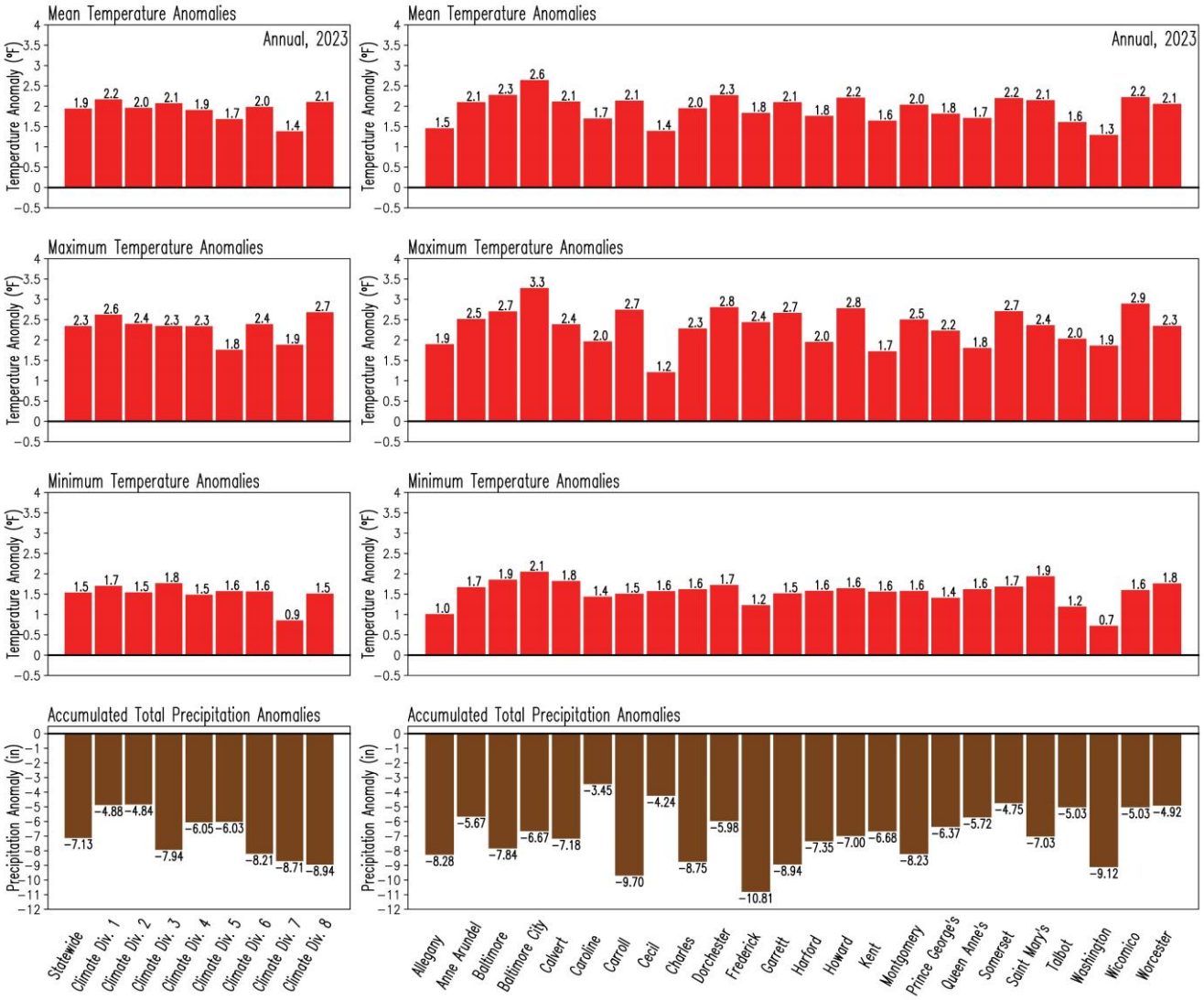


**Figure B2.** Anomalies of the annual surface variables in Maryland for 2023. Anomalies are with respect to the 1991-2020 annual climatology. Red color represents positive anomalies for mean surface air temperature (upper row), maximum surface air temperature (second row from top), and minimum surface 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 2023.

# Appendix C. Annual 1991-2020 Climatology Maps and 2023 Precipitation Anomaly as Percentage of Climatology

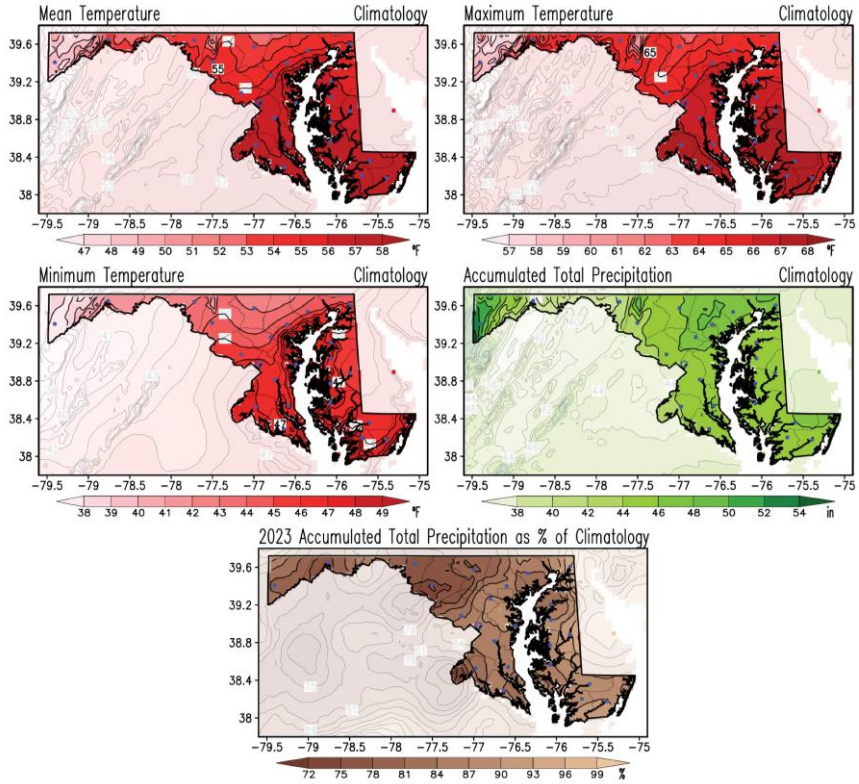


**Figure C1.** Climatology of the annual-mean mean, maximum and minimum surface air temperatures, and annual-accumulated precipitation for the period 1991-2020 (upper and middle rows), and precipitation anomalies in 2023 as percentage of climatology (bottom row). Temperatures are in °F, and precipitation is in inches according to the color bars. This is the current climate normal against which the 2023 conditions are compared to obtain the 2023 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.

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, 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).

# Appendix D. Annual Standard Deviation and 2023 Standardized Anomalies Maps

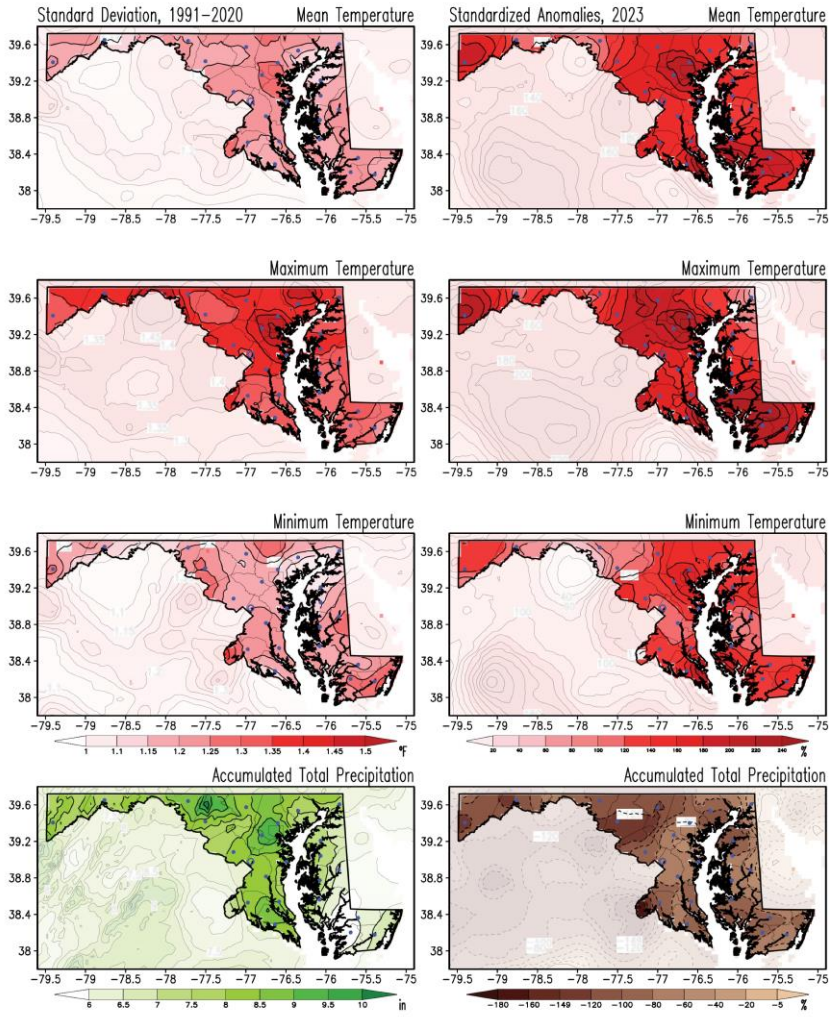


**Figure D1. S**tandard deviation and standardized annual anomalies of annual-mean temperatures and annual-accumulated total precipitation for 2023. Standard deviations for annual mean, maximum, and minimum surface air temperatures and accumulated precipitation were obtained for the 1991-2020 period (left column). Anomalies for 2023 (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.

The monthly standard deviation measures a climate variable's 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*.

# 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 https://www1.ncdc.noaa.gov/pub/data/normals/1981-2010/documentation/1981-2010-normals-overview.pdf.

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

Durre, I., M. F. Squires, R. S. Vose, A. Arguez, W. S. Gross, J. R. Rennie, and C. J. Schreck, 2022a: NOAA's nClimGrid-Daily Version 1 – Daily gridded temperature and precipitation for the Contiguous United States since 1951. NOAA National Centers for Environmental Information, since 6 May 2022, doi:10.25921/c4gt-r169

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

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. Retrieved Aug 20, 2022, from 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

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