

Chesapeake Bay Program | Indicator Analysis and Methods Document
Precipitation (Total Precipitation) | Updated February 2023

Indicator Title: [Precipitation \(Total Precipitation\)](#)

Relevant Outcome(s): [Climate Monitoring and Assessment](#)

Relevant Goal(s): [Climate Resiliency](#)

Location within Framework (i.e., Influencing Factor, Output or Performance): [Influencing Factor](#)

A. Data Set and Source

- (1) Describe the data set. What parameters are measured? What parameters are obtained by calculation? For what purpose(s) are the data used? [This metric is based on precipitation measurements collected from land-based weather stations, using standard meteorological instruments. Data were compiled in the nClimDiv data set, which is overseen by the U.S. National Oceanographic and Atmospheric Administration \(NOAA\) and maintained by its National Centers for Environmental Information \(NCEI\). NOAA's nClimDiv gridded analysis averages climate data over climate regions over the entire United States. Using these climate division-specific data, the slope of each precipitation trend was calculated from annual climate division anomalies \(in inches\) by ordinary least-squares regression, then multiplied by the length of the entire period of record to get total change in inches. The total change was then converted to percent change, using average precipitation during the standard baseline period \(1901–2000\) as the denominator.](#)

[This part of the indicator has been adapted from a national indicator maintained by the U.S. EPA. For more detailed information about EPA's indicator, see \[www.epa.gov/climate-indicators/climate-change-indicators-us-and-global-precipitation\]\(http://www.epa.gov/climate-indicators/climate-change-indicators-us-and-global-precipitation\).](#)

- (2) List the source(s) of the data set, the custodian of the source data, and the relevant contact at the Chesapeake Bay Program.
 - Source: [NOAA NCEI](#)
 - Custodian: [Lisa Bacanskas, Office of Atmospheric Programs, U.S. EPA](#)
 - Chesapeake Bay Program Contact (name, email address, phone number):
 - [Jamileh Soueidan, NOAA Chesapeake Bay Office/ Chesapeake Research Consortium \(\[Jamileh.soueidan@noaa.gov\]\(mailto:Jamileh.soueidan@noaa.gov\)\)](#)
 - [Julie Reichert-Nguyen, NOAA Chesapeake Bay Office \(\[Julie.reichert-nguyen@noaa.gov\]\(mailto:Julie.reichert-nguyen@noaa.gov\)\)](#)

- (3) Please provide a link to the location of the data set. Are metadata, data-dictionaries and embedded definitions included?

The map in this indicator is based on *n*ClimDiv monthly data by climate division, which are publicly available from NCEI at: www.ncdc.noaa.gov/cag. For access to underlying *n*ClimDiv data and documentation, see: www.ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php. Processed results for the nation are available in spreadsheet and map files on EPA's "Climate Change Indicators in the United States" website at www.epa.gov/climate-indicators/climate-change-indicators-us-and-global-precipitation.

B. Temporal Considerations

- (4) Data collection date(s): Data are collected continuously using standard meteorological instruments at permanent weather stations. Data have been collected since the 1800s at many stations. This indicator uses 1901 as a consistent starting point to balance the number of sites and the length of record.
- (5) Planned update frequency (e.g., annual, biannual, etc.):
- Source Data: NOAA *n*ClimDiv climate data updated monthly and compiled annually for the previous full year
 - Indicator: To be determined
- (6) Date (month and year) next data set is expected to be available for reporting: To be determined.

C. Spatial Considerations

- (7) What is the ideal level of spatial aggregation (e.g., watershed-wide, river basin, state, county, hydrologic unit code)? NOAA's data are spatially aggregated within climate divisions. Each state in the contiguous 48 states has one to 10 climate divisions. NOAA's algorithm is optimized to provide topographically sensitive spatial averages at this scale.
- (8) Is there geographic (GIS) data associated with this data set? If so, indicate its format (e.g., point, line polygon). Yes, polygon data.
- (9) Are there geographic areas that are missing data? If so, list the areas. No, all climate divisions within the Chesapeake Bay watershed are presented, but data collection is exclusively land-based.
- (10) Please submit any appropriate examples of how this information has been mapped or otherwise portrayed geographically in the past. See the map published as part of EPA's national indicator at www.epa.gov/climate-indicators/climate-change-indicators-us-and-global-precipitation.

D. Communicating the Data

- (11) What is the goal, target, threshold or expected outcome for this indicator? How was it established? **No explicit target.** Total annual precipitation is expected to change as regional and global circulation patterns change with a warmer climate. The purpose of this indicator is to monitor the extent to which this key aspect of regional climate is changing—which can inform management decisions designed to increase climate resiliency and protect human and ecological health.
- (12) What is the current status in relation to the target established in the outcome? Why? Would you define our outlook toward achieving the outcome as on course, off course, uncertain, or completed? Upon what basis are you forecasting the outlook?
- There is no specific target or threshold identified for this outcome (see question 11). The precipitation trends captured by this indicator are a reflection of regional and global climate change trends. The objective of this indicator is to track the climate change trends that can impact the region in an effort to inform management decisions and adaptation efforts.
- Outlook for this outcome is on course. Through updating this indicator, there is progress made towards assessing climate change trends related to changes in physical parameters (e.g., precipitation). Furthermore, this indicator supports efforts by the Climate Resiliency Workgroup and partners, as it provides regional information about which areas may be more impacted by precipitation change. Additionally, it provides supporting evidence for further management actions, the development of finer-scaled or downscaled models, and adaptation efforts to address the increased precipitation. Within the 2023-2024 Draft Logic and Action Plan, there are actions that relate to how the Climate Resiliency Workgroup plans to continue to make progress towards achieving this outcome, including supporting efforts in identifying strategies to track resilience effectiveness.
- (13) Has a new goal, target, threshold or expected outcome been established since the last reporting period? Why? **No.** See answer to question 11.
- (14) Has the methodology of data collection or analysis changed since the last reporting period? How? Why? **No.**
- (15) What is the long-term data trend (since the start of data collection)? **Of the 33 climate divisions that lie at least partly within the Chesapeake Bay watershed, all but one have experienced an increase in total precipitation since 1901. However, only 16 divisions had increases that were statistically significant (to a 95 percent**

confidence level). The largest increases in total precipitation within the Chesapeake Bay watershed have occurred in New York and portions of Pennsylvania, where increases have been statistically significant. In contrast, the southwestern portion of the watershed has experienced less change.

- (16) What change(s) does the most recent data show compared to the last reporting period? To what do you attribute the change? Would you characterize that change in the recent progress² as an increase, decrease, no change, or completed for this outcome?

This indicator views data in a long-term context suitable for climatological analysis. Authoritative scientific literature (e.g., assessments by the Intergovernmental Panel on Climate Change and the U.S. Global Change Research Program) has established that climate change is contributing to increases in total precipitation in some regions and decreases in others. Precipitation trends are driven by global climate change trends. Within the Chesapeake Bay, 32 of the 33 climate divisions have experienced increasing precipitation trends since 1901, with significant increases occurring in 16 of those 33 divisions. This is a change from the previous update in 2017, where only seven climate divisions experienced statistically significant increases.

The main goal of this indicator is to monitor regional precipitation trends within the Chesapeake Bay Watershed. The Climate Resiliency Workgroup and partners utilize this indicator as a means of understanding regional precipitation trends, which can help guide discussions on adaptation strategies needed to enhance resiliency of Chesapeake Bay to climate change impacts. Thus, we characterize our recent progress towards the outcome as increasing, as we are continually monitoring climate change trends (e.g., total annual precipitation) within the Bay and utilizing the information to guide the workgroup's efforts.

- (17) What is the key story told by this indicator?

This indicator is useful as it tracks total annual precipitation trends within the Chesapeake Bay and displays which regions are undergoing significant increases in the total annual precipitation amounts. This indicator provides foundational evidence and justification for climate resiliency efforts within the Bay and allows for decision-makers to target general regions that could benefit from adaptation measures (e.g., urban stormwater management).

E. Adaptive Management

- (18) What factors influence progress toward the goal, target, threshold or expected outcome?

There are no set goals, targets, thresholds or expected outcomes associated with this indicator. Progress made towards the Monitoring and Assessment Outcome is achieved through updating the associated indicators, disseminating the information to relevant stakeholders, and developing new indicators, and linking these indicators to management actions. Current factors that influence this progress include coordinating across agencies, who act as data providers, and the capacity and resources to update the indicators on ChesapeakeProgress.

(19) What are the current gaps in existing management efforts?

Mitigation of climate change requires coordinated global action that is beyond the purview of the Chesapeake Bay Program, but local and regional actions to reduce greenhouse gas emissions can still contribute to these broader solutions. The climate resiliency goal focuses on assessing and adapting to changing environmental and climate conditions to withstand adverse impacts. Downscaled climate data are needed to translate regional trends to local impacts to inform adaptation decisions. This would assist managers and decision-makers in incorporating climate change considerations in natural resource and stormwater management decisions.

(20) What are the current overlaps in existing management efforts?

Wetland restoration, stormwater management, and land cover/land use-related efforts (e.g., increasing forested lands and converting impervious surfaces to pervious surfaces) are underway to help achieve water quality goals that are central to the *Chesapeake Bay Watershed Agreement*. These activities can also help to mitigate the risk of flooding associated with increased precipitation. Water conservation activities help to mitigate some of the risks associated with decreased precipitation, which could occur in some regions as a result of climate change.

(21) According to the management strategy written for the outcome associated with this indicator, how will we (a) assess our performance in making progress toward the goal, target, threshold or expected outcome, and (b) ensure the adaptive management of our work?

The goal of this indicator is to monitor total annual precipitation trends throughout the Chesapeake Bay Watershed. These trends are influenced by global climate change trends, thus our effort is to monitor the changes to these precipitation trends in and around the Bay. A) As such, this indicator has no threshold, target, goal, or expected outcome. Rather it aims to share information about the regional changes in total annual precipitation. This information is intended to assist decision-makers with climate resiliency efforts, whether that be providing evidence to support a decision, policy, or project, or to help target general regions for climate adaption efforts. B) As far as adaptive management is concerned, the CRWG reviews progress made towards the Monitoring and Assessment Outcome by updating current indicators and sharing the data with relevant stakeholders, using the data to

inform current and future efforts, and making progress in conceptualizing and developing new indicators.

F. Analysis and Interpretation

Please provide appropriate references and location(s) of documentation if hard to find.

- (22) What method is used to transform raw data into the information presented in this indicator? Please cite methods and/or modeling programs. NOAA calculated monthly precipitation totals for each site. In populating the *nClimDiv* data set, NOAA employed a homogenization algorithm to identify and correct for substantial shifts in local-scale data that might reflect changes in instrumentation, station moves, or urbanization effects. These adjustments were performed according to published, peer-reviewed methods.

In this indicator, precipitation data are presented as trends in anomalies. An anomaly represents the difference between an observed value and the corresponding value from a baseline period. This indicator uses a baseline period of 1901 to 2000. The choice of baseline period will not affect the statistical significance of the overall trend in anomalies. To generate the precipitation trend, NOAA converted total annual precipitation measurements, measured in millimeters, into anomalies. Millimeters were then converted into inches for use in this indicator.

To achieve uniform spatial coverage (i.e., not biased toward areas with a higher concentration of measuring stations), NOAA calculated area-weighted averages of grid-point estimates interpolated from station data. The map shows the 2021 total annual precipitation anomaly trends when compared to a baseline period from 1901 to 2000. It is based on the *nClimDiv* gridded data set, which is derived from a high-resolution (5-kilometer) interpolated grid that accounts for station density and topography, with results averaged within each climate division. See: www1.ncdc.noaa.gov/pub/data/cirs/climdiv/divisional-readme.txt for more information. The slope of each climate division's precipitation trend was calculated from annual climate division anomalies (in inches) by ordinary least-squares regression, then multiplied by the length of the entire period of record to get total change in inches. The total change was then converted to percent change, using average annual precipitation during the standard baseline period (1901–2000) as the denominator.

- (23) Is the method used to transform raw data into the information presented in this indicator accepted as scientifically sound? If not, what are its limitations? Yes. The *nClimDiv* methods have been peer reviewed for publication in the scientific literature, and a national version of this indicator has also been peer reviewed for inclusion in EPA's climate change indicator suite, which requires each indicator to meet a set of 10 criteria for data quality (see the technical documentation overview

at www.epa.gov/climate-indicators/downloads-indicators-technical-documentation).

(24) How well does the indicator represent the environmental condition being assessed?

This indicator uses an acknowledged method to analyze trends in precipitation. It accounts for factors that can influence total precipitation which include: the temperature and humidity regimes of surrounding regions; regional and global atmospheric circulation patterns; the magnitude and frequency of inter-annual and decadal-scale oscillation patterns (such as El Niño, La Niña, Pacific Decadal Oscillation, etc.); and climate change. To reduce the influence of some of the non-climatic factors on this indicator, this indicator uses data from land-based weather stations that are sited to minimize the influence of localized wind patterns, orientation, and physical obstructions that could skew precipitation totals.

However, this is not the only method to analyze precipitation trends. Another option would be to compare shorter timespans or non-linear statistical methods to detect changes in the shape of the trend (e.g., acceleration) over time. Each approach has advantages and disadvantages.

Factors that may impact the confidence, application, or conclusions drawn from this indicator are as follows:

- Biases in measurements may have occurred as a result of changes over time in instrumentation, measuring procedures, and the exposure and location of the instruments. Where possible, data have been adjusted to account for changes in these variables.
- Uncertainties in precipitation data increase as one goes back in time, as there are fewer stations early in the record. However, these uncertainties are not sufficient to undermine the fundamental trends in the data.

(25) Are there established reference points, thresholds, ranges or values for this indicator that unambiguously reflect the desired state of the environment? **No.**

(26) How far can the data be extrapolated? Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)? **No attempt has been made to extrapolate data beyond the sampled sites and the timeframe of analysis.** The *n*ClimDiv algorithm that forms the foundation of this indicator involves interpolation between stations to develop a high-resolution gridded precipitation product. This method was carefully designed to account for topography and other factors, and it has been peer reviewed.

G. Quality

Please provide appropriate references and location(s) of documentation if hard to find.

- (27) Were the data collected and processed according to a U.S. Environmental Protection Agency-approved Quality Assurance Project Plan? If so, please provide a link to the QAPP and indicate when the plan was last reviewed and approved. **If not, please complete questions 28-31. No.**
- (28) *If applicable:* Are the sampling, analytical and data processing procedures accepted as scientifically and technically valid? **Yes. All measurements are made according to standard NOAA procedures. Analytical and data processing procedures have been peer reviewed and accepted as valid.**
- (29) *If applicable:* What documentation describes the sampling and analytical procedures used? **See the technical documentation for EPA's "U.S. and Global Precipitation" indicator at: www.epa.gov/climate-indicators/downloads-indicators-technical-documentation, as well as the NOAA and scientific literature references cited therein.**
- (30) *If applicable:* To what extent are procedures for quality assurance and quality control of the data documented and accessible? **NCEI's databases have undergone extensive quality assurance procedures to identify errors and biases in the data and to either remove these stations from the time series or apply correction factors. The nClimDiv data set follows the U.S. Historical Climatology Network's (USHCN's) methods to detect and correct station biases brought on by changes to the station network over time. The transition to a grid-based calculation did not significantly change national averages and totals, but it has led to improved historical temperature values in certain regions, particularly regions with extensive topography above the average station elevation—topography that is now being more thoroughly accounted for. An assessment of the major impacts of the transition to nClimDiv can be found at: www.ncdc.noaa.gov/monitoring-references/docs/GrDD-Transition.pdf.**
- (31) Are descriptions of the study design clear, complete and sufficient to enable the study to be reproduced? **Yes. The technical documentation for EPA's "U.S. and Global Precipitation" indicator at www.epa.gov/climate-indicators/downloads-indicators-technical-documentation, as well as the NOAA and scientific literature references cited therein, provide thorough documentation to allow methods to be reproduced.**
- (32) Were the sampling, analytical and data processing procedures performed consistently throughout the data record? **Yes, except as corrected for and described in question (30).**

(33) If data sets from two or more sources have been merged, are the sampling designs, methods and results comparable? If not, what are the limitations? [Not applicable, as all data derive from one source.](#)

(34) Are levels of uncertainty available for the indicator and/or the underlying data set? If so, do the uncertainty and variability impact the conclusions drawn from the data or the utility of the indicator? [Uncertainties in precipitation data increase as one goes back in time, as there are fewer stations early in the record. However, these uncertainties are not sufficient to undermine the fundamental trends in the data.](#)

Error estimates are not readily available for this indicator. Vose and Menne (2004) suggest that the station density in the U.S. climate network is sufficient to produce a robust spatial average.

Annual precipitation anomalies naturally vary from location to location and from year to year as a result of normal variation in weather patterns, multi-year climate cycles such as the El Niño–Southern Oscillation and Pacific Decadal Oscillation, and other factors. This indicator accounts for these factors by presenting a long-term record (more than a century of data) and averaging consistently over time and space.

Vose, R.S., and M.J. Menne. 2004. A method to determine station density requirements for climate observing networks. *J. Climate* 17(15):2961–2971.

(35) For chemical data reporting: How are data below the MDL reported (i.e., reported as 0, censored, or as < MDL)? If parameter substitutions are made (e.g., using orthophosphate instead of total phosphorus), how are data normalized? How does this impact the indicator? [Not applicable, as no chemical data have been collected.](#)

(36) Are there noteworthy limitations or gaps in the data record? [No.](#)

H. Additional Information (*Optional*)

(37) Please provide any further information you believe is necessary to aid in communication and prevent any potential misrepresentation of this indicator. [This indicator uses ordinary least-squares regression to calculate the slope of the observed trends in precipitation. A simple t-test can determine whether the trends for any climate division are significant at the 95-percent confidence level \(\$p < 0.05\$ \). Among the individual climate divisions shown in the map, 49 percent of divisions have statistically significant precipitation trends.](#)

¹*Outlook:* Outlook is the forecasted trajectory for whether the Chesapeake Bay Program is on course to achieving the outcome. An outcome's outlook may be on course, off

course, uncertain, or completed. This information will be incorporated into the outcome's progress page. An outcome's course outlook is reviewed and updated during the outcome's Strategy Review System (SRS) Quarterly Progress Meeting in addition to when recent progress is assessed.

²*Recent Progress:* Recent Progress describes the change in the indicator based on the most recent data collected since the last reporting period. The recent progress icon will reflect this change as an increase, decrease, no change, or completed, depending upon this progress. This information will be discussed at the outcome's Strategy Review System (SRS) Quarterly Progress Meeting.