Temperature and Precipitation

Air temperature and precipitation are are fundamental measurements for describing the climate, and can have wide-ranging effects on human life and ecosystems. For example, increases in air temperature can lead to more intense heat waves, which can cause illness and death, especially in vulnerable populations. Rainfall, snowfall, and the timing of snowmelt can all affect the amount of water available for drinking, irrigation, and industry. Annual and seasonal temperature and precipitation patterns also determine the types of animals and plants (including crops) that can survive in particular locations. Changes in temperature and precipitation can disrupt a wide range of natural processes, particularly if these changes occur more quickly than plant and animal species can adapt.

Concentrations of heat-trapping greenhouse gases are increasing in the Earth's atmosphere (see the Atmospheric Concentrations of Greenhouse Gases indicator). In response, average temperatures at the Earth's surface are rising and are expected to continue rising. As average temperatures at the Earth's surface rise, more evaporation occurs, which, in turn, increases overall precipitation. Therefore, a warming climate is expected to increase precipitation in many areas. However, because climate change causes shifts in wind patterns and ocean currents that drive the world's climate system, some areas are warming more than others, some have experienced cooling, and precipitation patterns will vary across the world. In addition, higher temperatures lead to more evaporation, so increased precipitation will not necessarily increase the amount of water available for drinking, irrigation, and industry. Increased evaporation can also produce more intense precipitation events—for example, heavier rain and snow storms that can damage crops and increase flood risk—even if the total amount of precipitation in an area does not increase.

This indicator shows trends in temperature and precipitation based on instrumental records. Air temperature and precipitation trends are summarized for entire the contiguous U.S., nine regions of the contiguous U.S. (these climate regions are different from the 10 EPA Regions), Alaska, and smaller regions within each state, which are known as climate divisions. For context, this indicator shows trends in global temperature (over land and sea) and global precipitation (over land). This indicator uses instrumental records that start at 1901 except for Alaska, where reliable statewide records are available back to 1925. The indicator extends through 2015. For comparison, this indicator also displays satellite measurements that can be used to estimate the temperature of the Earth's lower atmosphere since 1979.

This indicator shows annual anomalies, or differences, compared with the average temperature and precipitation from 1901 to 2000. For example, an anomaly of +2.0 degrees means the average temperature was 2 degrees higher than the long-term average. Anomalies have been calculated for each weather station. Daily temperature measurements at each site were used to calculate monthly anomalies, which then were averaged to find an annual temperature anomaly for each year. Precipitation anomalies were calculated from total annual precipitation at each site, in inches. Anomalies for the contiguous 48 states and Alaska have been determined by calculating average anomalies for areas within each state based on station density, interpolation, and topography. These regional anomalies are then averaged together in proportion to their area to develop national results. Similarly, global anomalies have been determined by dividing the world into a grid, averaging the data for each cell of the grid, and then averaging the grid cells together.

Long-term trends in temperature and precipitation were calculated from the annual data by linear regression (the straight line that fits the data best). For each of the nine climate regions and Alaska,

this indicator also shows a smoothed time series, which was created using a nine-year weighted average.

What the Data Show

Since 1901, the average surface temperature across the contiguous 48 states has risen at an average rate of 0.14°F per decade (1.4°F per century) (Exhibit 1). Average temperatures have risen more quickly since the late 1970s (0.29 to 0.46°F per decade since 1979). Eight of the top 10 warmest years on record for the contiguous 48 states have occurred since 1998, and 2012 and 2015 were the two warmest years on record.

Warming has occurred throughout the U.S., with seven of the 10 climate regions (including Alaska) showing a statistically significant increase of more than 1°F since the start of the 20th century (Exhibit 3). The Northeast, the West, and Alaska have seen temperatures increase the most, while some parts of the Southeast have experienced little change (Exhibits 3 and 4).

Global average surface temperature has risen at an average rate of 0.15°F per decade since 1901 (Exhibit 2), similar to the rate of warming within the contiguous 48 states. Since the late 1970s, however, the United States has warmed faster than the global rate. Worldwide, 2015 was the warmest year on record and 2006–2015 was the warmest decade on record since thermometer-based observations began. Satellite measurements of the Earth's lower atmosphere reveal temperature trends similar to those observed through ground-based monitoring (Exhibits 1 and 2).

As mean temperatures have risen, mean precipitation also has increased. This is expected because evaporation increases with increasing temperature, and there must be an increase in precipitation to balance the enhanced evaporation (IPCC, 2013). Since 1901, global precipitation has increased at an average rate of 0.08 inches per decade, while precipitation in the contiguous 48 states has increased at a rate of 0.17 inches per decade (Exhibits 5 and 6). Some parts of the United States have experienced greater increases in precipitation than others, while a few areas, such as the Southwest, have seen a decrease in precipitation (Exhibits 7 and 8). Four of the 10 climate regions in Exhibit 3 have experienced statistically significant changes—all increases.

Limitations

- Data from the early 20th century are somewhat less precise than more recent data because there were fewer stations collecting measurements at the time, especially in the Southern Hemisphere. The overall trends are still reliable, however. Where possible, the data have been adjusted to account for any biases that might be introduced by factors such as station moves, urbanization near the station, changes in measuring instruments, and changes in the exact times at which measurements are taken.
- Hawaii and U.S. territories are not included, due to limitations in available data.

Data Sources

The data for this indicator were provided by the National Oceanic and Atmospheric Administration's (NOAA's) National Centers for Environmental Information (NCEI), which maintains a large collection of climate data online at: https://www.ncei.noaa.gov/. NCEI calculated global, U.S., and regional temperature and precipitation time series based on monthly values from a network of long-term monitoring stations. Data from individual stations were obtained from the Global

Historical Climate Network and *n*ClimDiv, which are NCEI's online data sets (NOAA, 2016). Satellite data were analyzed by two independent groups—the Global Hydrology and Climate Center at the University of Alabama in Huntsville (UAH) and Remote Sensing Systems (RSS)—resulting in slightly different trend lines.

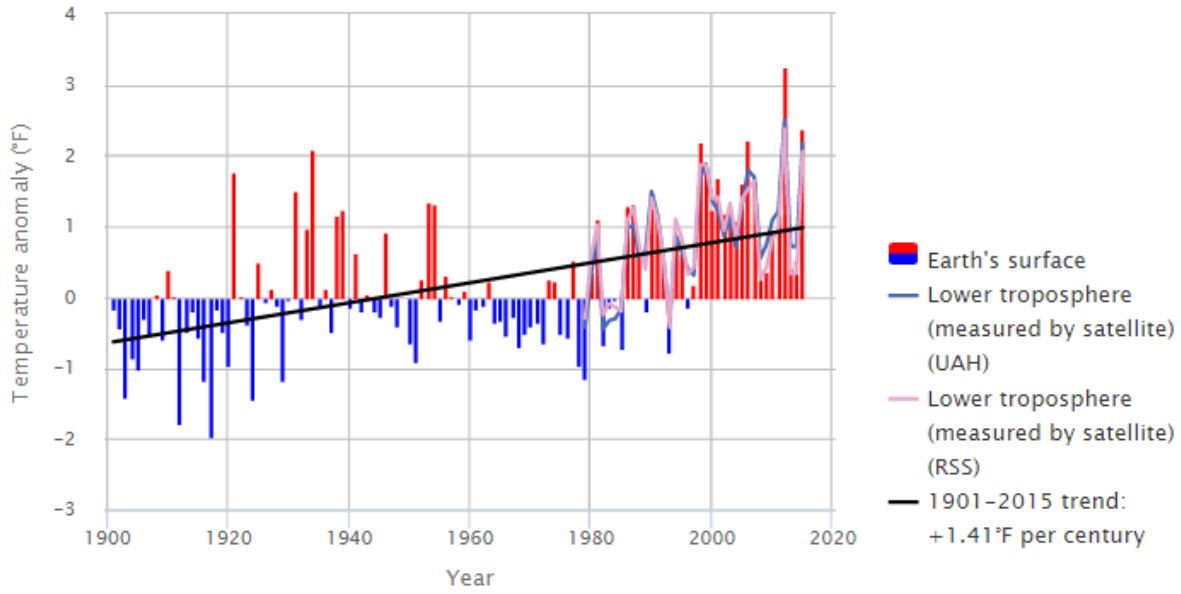
References

Blunden, J., and D.S. Arndt, eds. 2016. State of the climate in 2015. B. Am. Meteorol. Soc. 97(8):S1-S275.

IPCC (Intergovernmental Panel on Climate Change). 2013. Climate change 2013: The physical science basis. Working Group I contribution to the IPCC Fifth Assessment Report. Cambridge, United Kingdom: Cambridge University Press. www.ipcc.ch/report/ar5/wg1.

NOAA (National Oceanic and Atmospheric Administration). 2016. National Centers for Environmental Information. Accessed February 2016. www.ncei.noaa.gov.

Exhibit 1. Annual temperature anomalies in the contiguous U.S., 1901–2015



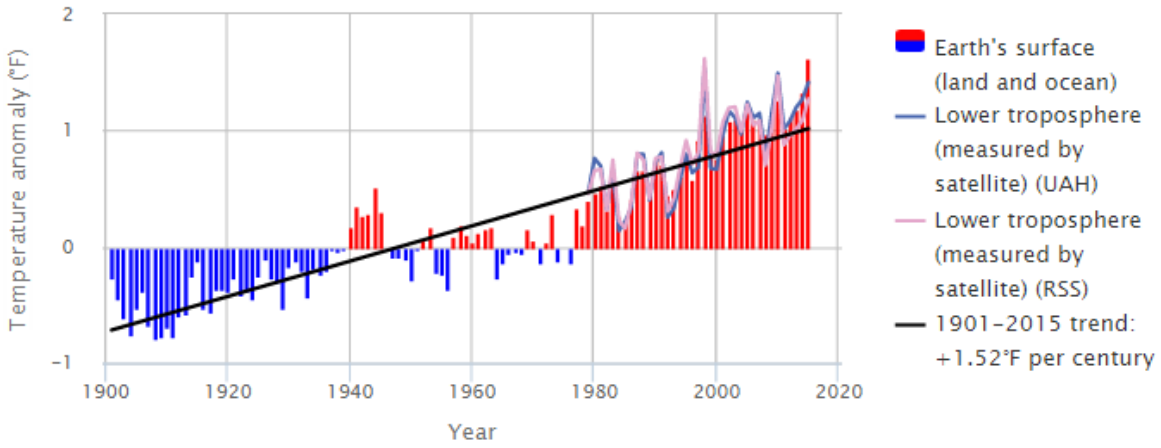
Anomalies are calculated with respect to the 1901–2000 average.

Surface data come from land-based weather stations. Satellite measurements cover the lower troposphere, which is the lowest level of the Earth's atmosphere. "UAH" and "RSS" represent two different methods of analyzing the original satellite measurements.

Analysis shows that this trend is statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: NOAA, 2016

Exhibit 2. Annual temperature anomalies worldwide, 1901–2015



Anomalies are calculated with respect to the 1901–2000 average.

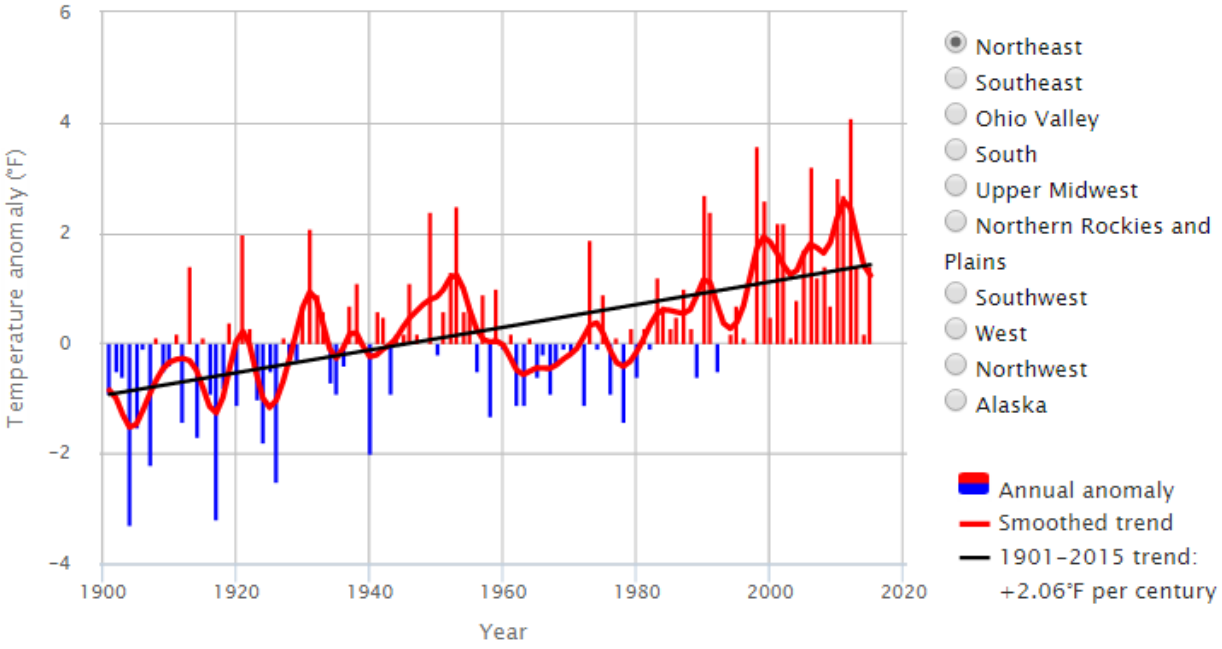
Surface data come from a combined set of land-based weather stations and sea surface temperature measurements. Satellite measurements cover the lower troposphere, which is the lowest level of the Earth's atmosphere."UAH" and "RSS" represent two different methods of analyzing the original satellite measurements.

Analysis shows that this trend is statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: NOAA, 2016

Exhibit 3. Annual temperature anomalies in the U.S. by region, 1901–2015

Northeast



Anomalies are calculated with respect to the 1901–2000 average.

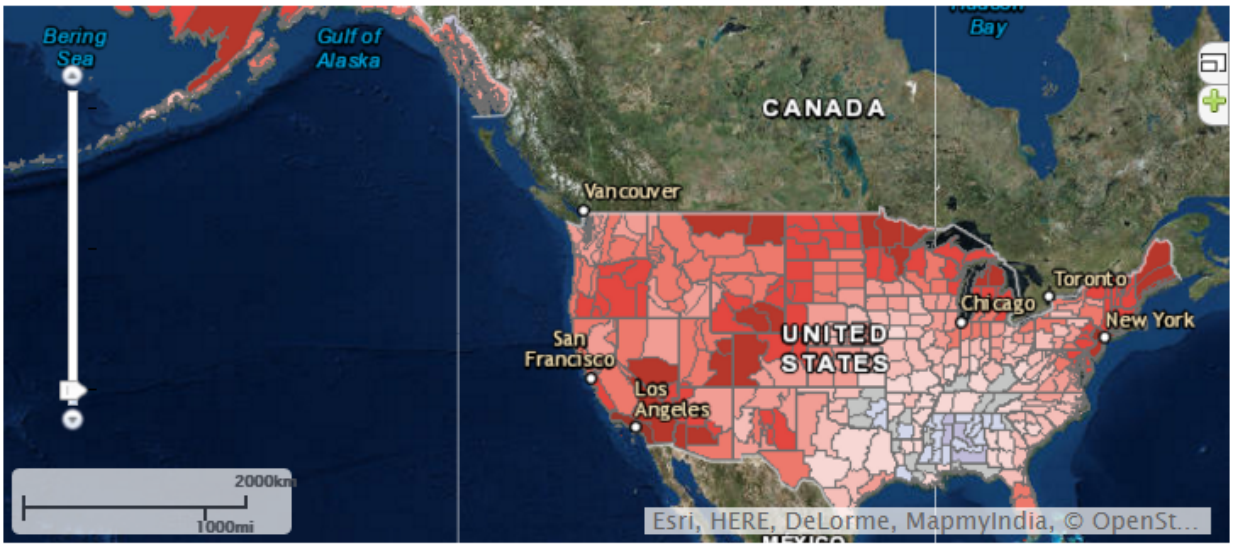
Time series were smoothed using a nine-point binomial filter.

Analysis shows that this trend is statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: NOAA, 2016

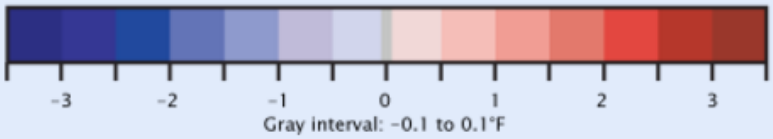
Visit http://www.epa.gov/roe to see the full exhibit.

Exhibit 4. Rate of temperature change in the U.S., 1901–2015



Opacity: Click here to toggle legend

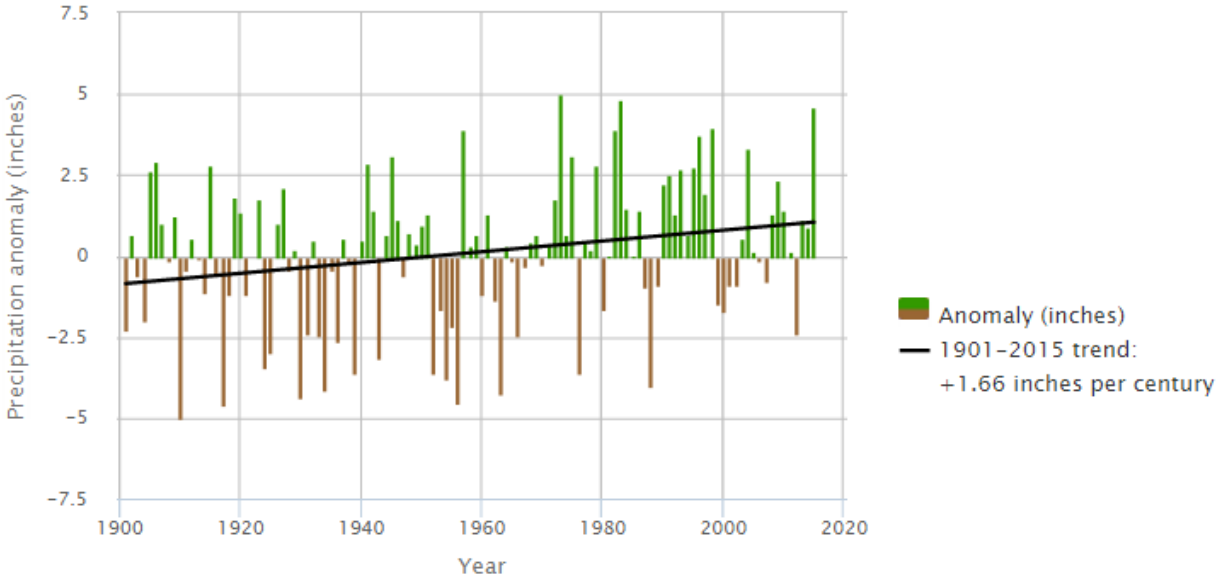
Rate of temperature change (°F per century):



Analysis shows that some of these trends are statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: NOAA, 2016

Exhibit 5. Annual precipitation anomalies in the contiguous U.S., 1901–2015

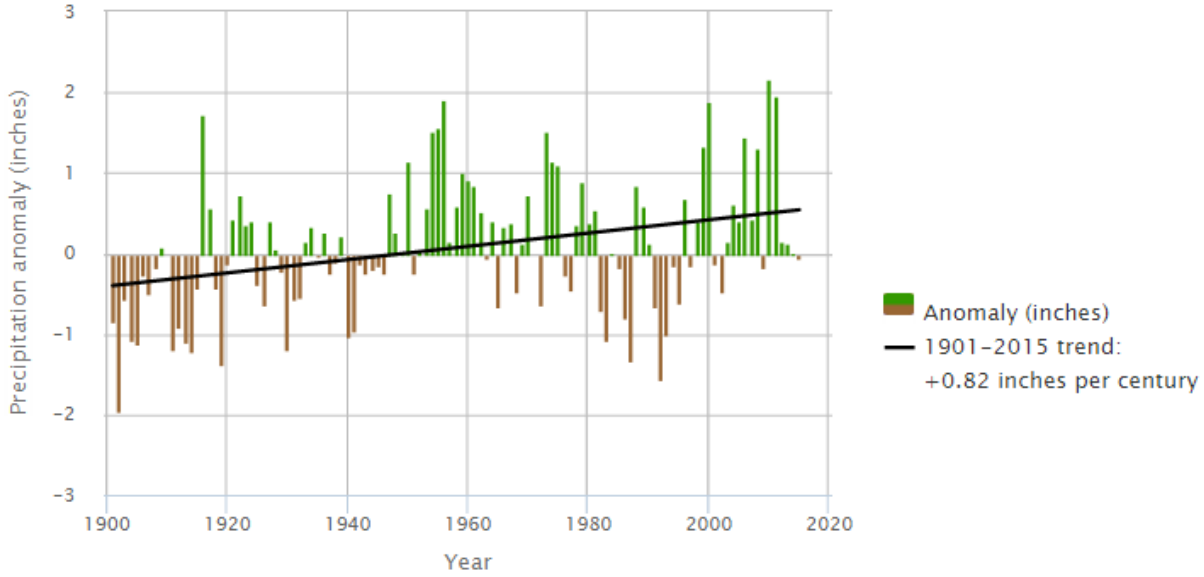


Anomalies are calculated with respect to the 1901–2000 average.

Analysis shows that this trend is statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: NOAA, 2016

Exhibit 6. Annual precipitation anomalies worldwide, 1901–2015



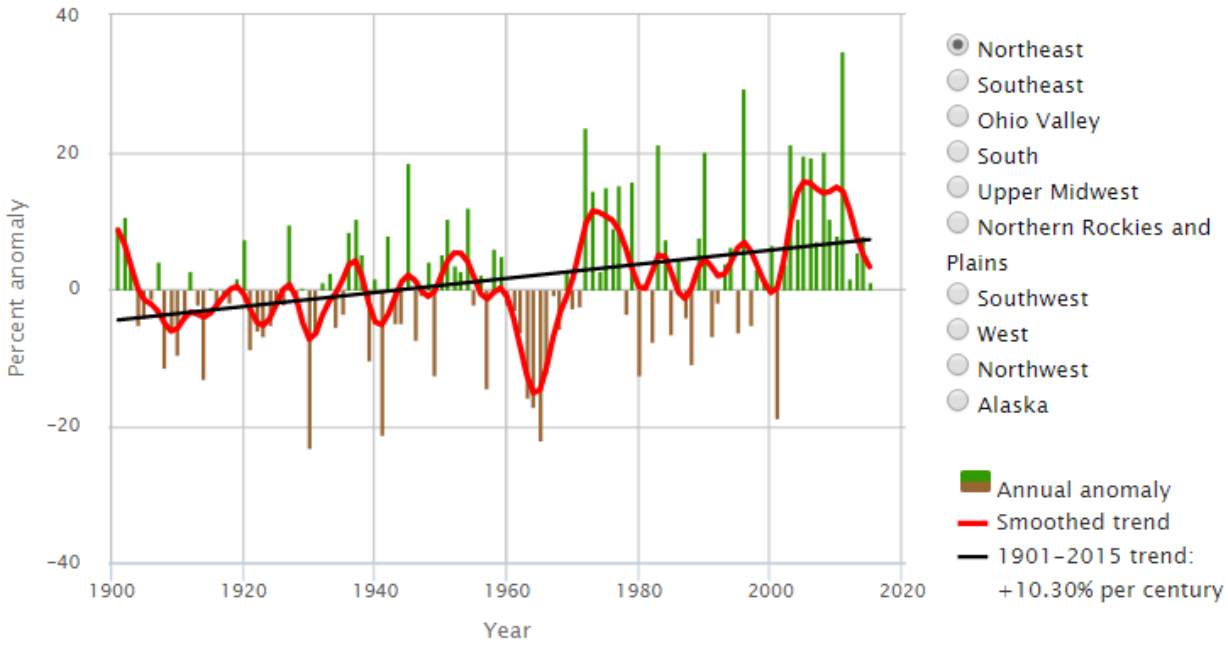
Anomalies are calculated with respect to the 1901–2000 average.

Analysis shows that this trend is statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: Blunden and Arndt, 2016

Exhibit 7. Annual precipitation anomalies in the U.S. by region, 1901–2015

Northeast



Anomalies are calculated with respect to the 1901–2000 average.

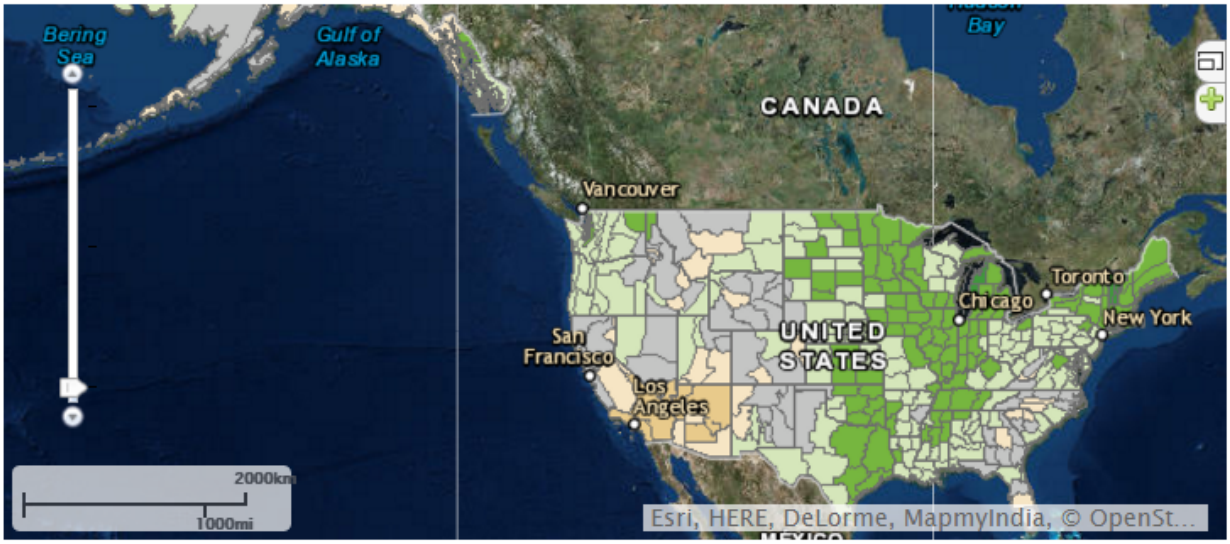
Time series were smoothed using a nine-point binomial filter.

Analysis shows that this trend is statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: NOAA, 2016

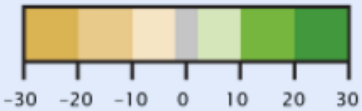
Visit http://www.epa.gov/roe to see the full exhibit.

Exhibit 8. Rate of precipitation change in the U.S., 1901–2015



Opacity: Click here to toggle legend

Percent change in precipitation:



Gray interval: -2 to 2%

Analysis shows that some of these trends are statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: NOAA, 2016