U.S. and Global Precipitation

Identification

1. Indicator Description

This indicator describes changes in total precipitation over land for the United States and the world from 1901 to 2012. In this indicator, precipitation data are presented as trends in anomalies. Precipitation is an important component of climate, and changes in precipitation can have wide-ranging direct and indirect effects on the environment and society.

Components of this indicator include:

- Changes in precipitation in the contiguous 48 states over time (Figure 1)
- Changes in worldwide precipitation over land through time (Figure 2)
- A map showing rates of precipitation change across the United States (Figure 3)

2. Revision History

April 2010: Indicator posted
December 2011: Updated with data through 2010
May 2012: Updated with data through 2011
August 2013: Updated indicator on EPA's website with data through 2012

Data Sources

3. Data Sources

This indicator is based on precipitation anomaly data provided by the National Oceanic and Atmospheric Administration's (NOAA's) National Climatic Data Center (NCDC).

4. Data Availability

Data for this indicator were provided to EPA by NOAA's NCDC. NCDC calculated these time series based on monthly values from two NCDC-maintained databases: the U.S. Historical Climatology Network (USHCN) Version 2.5 and the Global Historical Climatology Network–Monthly (GHCN-M) Version 2. Both of these databases can be accessed online.

Contiguous 48 States

Underlying precipitation data for the contiguous 48 states come from the USHCN. Currently, the data are distributed by NCDC on various computer media (e.g., anonymous FTP sites), with no confidentiality issues limiting accessibility. Users can link to the data online at: www.ncdc.noaa.gov/oa/climate/research/ushcn. Appropriate metadata and "readme" files are

appended to the data. For example, see: ftp://ftp.ncdc.noaa.gov/pub/data/ushcn/v2/monthly/readme.txt.

Alaska, Hawaii, and Global

GHCN precipitation data can be obtained from NCDC over the Web or via anonymous FTP. For access to GHCN data, see: www.ncdc.noaa.gov/ghcnm/v2.php. There are no known confidentiality issues that limit access to the data set, and the data are accompanied by metadata.

Methodology

5. Data Collection

This indicator is based on precipitation measurements collected from thousands of weather stations throughout the United States and over land worldwide using standard meteorological instruments. Data for the contiguous 48 states were compiled in the USHCN. Data for Alaska, Hawaii, and the rest of the world were taken from the GHCN. Both of these networks are overseen by NOAA and have been extensively peer reviewed. As such, they represent the most complete long-term instrumental data sets for analyzing recent climate trends. More information on these networks can be found below.

Contiguous 48 States

USHCN Version 2.5 contains total monthly precipitation data from approximately 1,200 stations within the contiguous 48 states. The period of record varies for each station but generally includes most of the 20th century. One of the objectives in establishing the USHCN was to detect secular changes of regional rather than local climate. Therefore, stations included in the network are only those believed to not be influenced to any substantial degree by artificial changes of local environments. Some of the stations in the USHCN are first-order weather stations, but the majority are selected from U.S. cooperative weather stations (approximately 5,000 in the United States). To be included in the USHCN, a station had to meet certain criteria for record longevity, data availability (percentage of available values), spatial coverage, and consistency of location (i.e., experiencing few station changes). An additional criterion, which sometimes compromised the preceding criteria, was the desire to have a uniform distribution of stations across the United States. Included with the data set are metadata files that contain information about station moves, instrumentation, observing times, and elevation. NOAA's website (www.ncdc.noaa.gov/oa/climate/research/ushcn) provides more information about USHCN data collection.

Alaska, Hawaii, and Global

GHCN Version 2 contains monthly climate data from 20,590 weather stations worldwide. Data were obtained from many types of stations.

NCDC has published documentation for the GHCN. For more information, including data sources, methods, and recent improvements, see: www.ncdc.noaa.gov/ghcnm/v2.php and the sources listed therein.

6. Indicator Derivation

NOAA calculated monthly precipitation totals for each site. In populating the USHCN and GHCN, 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. For more information on these quality assurance and error correction procedures, see Section 7.

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 shape or the statistical significance of the overall trend in anomalies. For precipitation (percentage anomalies), it moves the curve up or down and may change the magnitude slightly.

To generate the precipitation time series, NOAA converted measurements into anomalies for total monthly precipitation, in millimeters. Monthly anomalies were added to find an annual anomaly for each year, which was then converted to a percent anomaly—i.e., the percent departure from the average annual precipitation during the baseline period.

To achieve uniform spatial coverage (i.e., not biased toward areas with a higher concentration of measuring stations), NOAA averaged anomalies within grid cells on the map to create "gridded" data sets. The graph for the contiguous 48 states (Figure 1) and the map (Figure 3) are based on an analysis using grid cells that measure 2.5 degrees latitude by 3.5 degrees longitude. The global graph (Figure 2) comes from an analysis of grid cells measuring 5 degrees by 5 degrees. These particular grid sizes have been determined to be optimal for analyzing USHCN and GHCN climate data; see: http://www.ncdc.noaa.gov/oa/climate/research/ushcn/gridbox.html for more information.

Figures 1 and 2 show trends from 1901 to 2012, based on NOAA's gridded data sets. Although earlier data are available for some stations, 1901 was selected as a consistent starting point.

The map in Figure 3 shows long-term rates of change in precipitation over the United States for the 1901–2012 period except for Alaska and Hawaii, for which widespread and reliable data collection did not begin until 1918 and 1905, respectively. A regression was performed on the annual anomalies for each grid cell. Trends were calculated only in those grid cells for which data were available for at least 66 percent of the years during the full period of record. The slope of each trend (percent change in precipitation per year) was calculated from the annual time series by ordinary least-squares regression and then multiplied by 100 to obtain a rate per century. No attempt has been made to portray data beyond the time and space in which measurements were made.

NOAA is continually refining historical data points in the USHCN and GHCN, often as a result of improved methods to reduce bias and exclude erroneous measurements. These improvements frequently result in the designation of new versions of the USHCN and GHCN. As EPA updates this indicator to reflect these upgrades, slight changes to some historical data points may become apparent.

7. Quality Assurance and Quality Control

Both the USHCN and the GHCN have undergone extensive quality assurance procedures to identify errors and biases in the data and either remove these stations from the time series or apply correction factors.

Contiguous 48 States

Quality control procedures for the USHCN are summarized at: www.ncdc.noaa.gov/oa/climate/research/ushcn/. Homogeneity testing and data correction methods are described in numerous peer-reviewed scientific papers by NOAA's NCDC. A series of data corrections was developed to specifically address potential problems in trend estimation in USHCN Version 2.5. They include:

- Removal of duplicate records
- Procedures to deal with missing data
- Testing and correcting for artificial discontinuities in a local station record, which might reflect station relocation or instrumentation changes

Alaska, Hawaii, and Global

QA/QC procedures for GHCN precipitation data are described at: www.ncdc.noaa.gov/ghcnm/v2.php. GHCN data undergo rigorous quality assurance reviews, which include pre-processing checks on source data; removal of duplicates, isolated values, and suspicious streaks; time series checks that identify spurious changes in the mean and variance; spatial comparisons that verify the accuracy of the climatological mean and the seasonal cycle; and neighbor checks that identify outliers from both a serial and a spatial perspective.

Analysis

8. Comparability Over Time and Space

Both the USHCN and the GHCN have undergone extensive testing to identify errors and biases in the data and either remove these stations from the time series or apply scientifically appropriate correction factors to improve the utility of the data. In particular, these corrections address advances in instrumentation and station location changes. See Section 7 for documentation.

9. Sources of Uncertainty

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 U.S. or global precipitation. Vose and Menne (2004) suggest that the station density in the U.S. climate network is sufficient to produce a robust spatial average.

10. Sources of Variability

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.

11. Statistical/Trend Analysis

This indicator uses ordinary least-squares regression to calculate the slope of the observed trends in precipitation. A simple t-test indicates that the following observed trends are significant to a 95 percent confidence level:

- U.S. precipitation, 1901-2012: +0.050 %/year ($p = 0.010$)
- Global precipitation, 1901-2012: +0.022 %/year ($p < 0.001$)

To conduct a more complete analysis, however, would potentially require consideration of serial correlation and other more complex statistical factors. Grid cell trends in Figure 3 have not been tested for statistical significance.

12. Data Limitations

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

1. 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. For more information on these corrections, see Section 7.
2. 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.

References

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.