Heavy Precipitation

Identification

1. Indicator Description

This indicator tracks the frequency of heavy precipitation events in the United States between 1895 and 2011. The potential impacts of heavy precipitation include crop damage, soil erosion, flooding, and diminished water quality.

Components of this indicator include:

- Percent of land area in the contiguous 48 states experiencing abnormal amounts of annual rainfall from one-day precipitation events (Figure 1)
- Percent of land area in the contiguous 48 states with unusually high annual precipitation (Figure 2)

2. Revision History

April 2010: Indicator posted
December 2011: Updated with data through 2010
March 2012: Updated with data through 2011

Data Sources

3. Data Sources

This indicator is based on precipitation measurements collected at weather stations throughout the contiguous 48 states. Most of the stations are part of the U.S. Historical Climatology Network (USHCN), a database compiled and managed by the National Oceanic and Atmospheric Administration's (NOAA's) National Climatic Data Center (NCDC). Indicator data were obtained from NCDC.

4. Data Availability

USHCN precipitation data are maintained at NOAA's NCDC, and the data are distributed 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/#access.

Appropriate metadata and "readme" files are appended to the data so that they are discernible for analysis. For example, see: ftp://ftp.ncdc.noaa.gov/pub/data/ushcn/v2/monthly/readme.txt.

Figure 1. Extreme One-Day Precipitation Events in the Contiguous 48 States, 1910–2011

NOAA has calculated each of the components of the U.S. Climate Extremes Index (CEI) and has made these data files publicly available. The data set for extreme precipitation (CEI step 4) can be downloaded from: ftp://ftp.ncdc.noaa.gov/pub/data/cei/dk-step4.01-12.results. A "readme" file (at ftp://ftp.ncdc.noaa.gov/pub/data/cei) explains the contents of the data files.

Figure 2. Unusually High Annual Precipitation in the Contiguous 48 States, 1895–2011

Standardized Precipitation Index (SPI) data are publicly available and can be downloaded from: ftp://ftp.ncdc.noaa.gov/pub/data/cirs. This indicator uses 12-month SPI data, which are found in the file "drd964x.sp12.txt." This FTP site also includes a "readme" file that explains the contents of the data files.

Constructing Figure 2 required additional information about the U.S. climate divisions. The land area of each climate division can be found by going to: www.ncdc.noaa.gov/oa/climate/surfaceinventories.html and viewing the "U.S. climate divisions" file (exact link: ftp://ftp.ncdc.noaa.gov/pub/data/inventories/DIV-AREA.TXT). For a guide to the numerical codes assigned to each state, see: ftp://ftp.ncdc.noaa.gov/pub/data/inventories/COOP-STATE-CODES.TXT.

Methodology

5. Data Collection

This indicator is based on precipitation measurements collected by a network of thousands of weather stations spread throughout the contiguous 48 states. These stations are currently overseen by NOAA, and they use standard gauges to measure the amount of precipitation received on a daily basis. 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).

NOAA's NCDC has published extensive documentation about data collection methods for the USHCN data set. See: www.ncdc.noaa.gov/oa/climate/research/ushcn, which lists a set of technical reports and peer-reviewed articles that provide more detailed information about USHCN methodology. See: www.ncdc.noaa.gov/oa/ncdc.html for information on other types of weather stations that have been used to supplement the USHCN record.

6. Indicator Derivation

Figure 1 and Figure 2 are based on similar raw data (i.e., daily precipitation measurements), but were developed using two different models because they show trends in extreme precipitation from two different perspectives.

Figure 1. Extreme One-Day Precipitation Events in the Contiguous 48 States, 1910–2011

Figure 1 was developed as part of NOAA's CEI, an index that uses six different variables to examine trends in extreme weather and climate. This figure shows trends in the prevalence of extreme one-day precipitation events, based on a component of NOAA's CEI (labeled as Step 4) that looks at the percentage of land area within the contiguous 48 states that experienced a much greater than normal proportion of precipitation derived from extreme one-day precipitation events in any given year.

In compiling the CEI, NOAA applied more stringent criteria to select only those stations with data for at least 90 percent of the days in each year as well as 90 percent of the days during the full period of record. Applying these criteria resulted in the selection of only a subset of USHCN stations. To supplement the USHCN record, the CEI (and hence Figure 1) also includes data from NOAA's Cooperative Summary of the Day (TD3200) and pre-1948 (TD3206) daily precipitation stations. This resulted in a total of over 1,300 precipitation stations.

NOAA scientists computed the data for the CEI and calculated the percentage of land area for each year. They performed these steps by dividing the contiguous 48 states into a 1-degree by 1-degree grid and using data from one station per each grid box, rather than multiple stations. This was done to eliminate many of the artificial extremes that resulted from a changing number of available stations over time.

For each grid cell, the indicator looks at what portion of the total annual precipitation occurred on days that had "extreme" precipitation totals. Thus, the indicator essentially describes what percentage of precipitation is arriving in short, intense bursts. "Extreme" is defined as the highest 10^{th} percentile, meaning an "extreme" one-day event is one in which the total precipitation received at a given location during the course of the day is at the upper end of the distribution of expected values (i.e., the distribution of all one-day precipitation totals at that location during the period of record). After extreme one-day events were identified, the percentage of annual precipitation occurring on extreme days was calculated for each year at each location. The subsequent step looked at the distribution of these percentage values over the full period of record, then identified all years that were in the highest 10^{th} percentile. These years were considered to have a "greater than normal" amount of precipitation derived from extreme precipitation events at a given location. The top 10^{th} percentile was chosen so as to give the overall index an expected value of 10 percent. Finally, data were aggregated nationwide to determine the percentage of land area with "greater than normal" precipitation derived from extreme events in each year.

The CEI can be calculated for individual seasons or for an entire year. This indicator uses the annual CEI, which is shown by the columns in Figure 1. To smooth out some of the year-to-year variability, EPA applied a nine-point binomial filter, which is plotted at the center of each nine-year window. For example, the smoothed value from 2002 to 2010 is plotted at year 2006. NOAA NCDC recommends this approach and has used it in the official online reporting tool for the CEI.

EPA used endpoint padding to extend the nine-year smoothed lines all the way to the ends of the period of record. As recommended by NCDC, EPA calculated smoothed values as follows: If 2011 was the most recent year with data available, EPA calculated smoothed values to be centered at 2008, 2009, 2010, and 2011 by inserting the 2011 data point into the equation in place of the as-yet-unreported annual data points for 2012 and beyond. EPA used an equivalent approach at the beginning of the time series.

The CEI has been extensively documented and refined over time to provide the best possible representation of trends in extreme weather and climate. For an overview of how NOAA constructed Step 4 of the CEI, see: www.ncdc.noaa.gov/oa/climate/research/cei/cei.html. This page provides a list of references that describe analytical methods in greater detail. In particular, see Gleason et al. (2008).

Figure 2. Unusually High Annual Precipitation in the Contiguous 48 States, 1895–2011

Figure 2 shows trends in the occurrence of abnormally high annual total precipitation based on the SPI, which is an index based on the probability of receiving a particular amount of precipitation in a given location. Thus, this index essentially compares the actual amount of annual precipitation received at a particular location with the amount that would be expected based on historical records. An SPI value of zero represents the median of the historical distribution; a negative SPI value represents a drier-than-normal period and a positive value represents a wetter-than-normal period.

The Western Regional Climate Center (WRCC) calculates the SPI by dividing the contiguous 48 states into 344 regions called "climate divisions" and analyzing data from weather stations within each division. A typical division has 10 to 50 stations, some from USHCN and others from the broader set of cooperative weather stations. For a given time period, WRCC calculated a single SPI value for each climate division based on an unweighted average of data from all stations within the division. This procedure has been followed for data from 1931 to present. A regression technique was used to compute divisional values prior to 1931 (Guttman and Quayle, 1996).

WRCC and NOAA calculate the SPI for various time periods ranging from one month to 24 months. This indicator uses the 12-month SPI data reported for the end of December of each year (1895 to 2011). The 12-month SPI is based on precipitation totals for the previous 12 months, so a December 12-month SPI value represents conditions over the full calendar year.

To create Figure 2, EPA identified all climate divisions with an SPI value of +2.0 or greater in a given year, where +2.0 is a suggested threshold for "abnormally high" precipitation (i.e., the upper tail of the historical distribution). For each year, EPA then determined what percentage of the total land area of the contiguous 48 states these "abnormally high" climate divisions represent. This annual percentage value is represented by the thin curve in the graph. To smooth out some of the year-to-year variability, EPA applied a nine-point binomial filter, which is plotted at the center of each nine-year window. For example, the smoothed value from 2002 to 2010 is plotted at year 2006. NOAA NCDC recommends this approach and has used it in the official online reporting tool for the CEI (the source of Figure 1).

EPA used endpoint padding to extend the nine-year smoothed lines all the way to the ends of the period of record. As recommended by NCDC, EPA calculated smoothed values as follows: If 2011 was the most recent year with data available, EPA calculated smoothed values to be centered at 2008, 2009, 2010, and 2011 by inserting the 2011 data point into the equation in place of the as-yet-unreported annual data points for 2012 and beyond. EPA used an equivalent approach at the beginning of the time series.

Like the CEI, the SPI is extensively documented in the peer-reviewed literature. The SPI is particularly useful among drought and precipitation indices because it can be applied over a variety of time frames and because it allows comparison of different locations and different seasons on a standard scale.

For an overview of the SPI and a list of resources describing methods used in constructing this index, see NDMC (2011) and the following websites: http://lwf.ncdc.noaa.gov/oa/climate/research/prelim/drought/spi.html and www.wrcc.dri.edu/spi/explanation.html. For more information on climate divisions and the averaging and regression processes used to generalize values within each division, see Guttman and Quayle (1996).

General Discussion

This indicator does not attempt to project data backward before the start of regular data collection or forward into the future. All values of the indicator are based on actual measured data. No attempt has been made to interpolate days with missing data. Rather, the issue of missing data was addressed in the site selection process by including only those stations that had very few missing data points.

7. Quality Assurance and Quality Control

USHCN precipitation data have undergone extensive quality assurance and quality control (QA/QC) procedures to identify errors and biases in the data and either remove these stations from the time series or apply correction factors. These quality control procedures are summarized at: www.ncdc.noaa.gov/oa/climate/research/ushcn/#processing. A series of data corrections was developed to specifically address potential problems in trend estimation in USHCN Version 2. 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

Data from weather stations also undergo routine QC checks before they are added to historical databases in their final form. These steps are typically performed within four months of data collection (NDMC, 2011).

QA/QC procedures are not readily available for the CEI and SPI, but both of these indices have been published in the peer-reviewed literature, indicating a certain degree of rigor.

Analysis

8. Comparability Over Time and Space

To be included in the USHCN, a station had to meet certain criteria for record longevity, data availability (percentage of missing values), spatial coverage, and consistency of location (i.e., experiencing few station changes). 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.

9. Sources of Uncertainty

Error estimates are not readily available for daily precipitation measurements or for the CEI and SPI calculations that appear in this indicator. In general, uncertainties in precipitation data increase as one goes back in time, as there are fewer stations early in the record. However, these uncertainties should not be sufficient to undermine the fundamental trends in the data. The USHCN has 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 addition, both parts of the indicator have been restricted to stations meeting specific criteria for data availability.

10. Sources of Variability

Precipitation varies 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 (a century of data) and aggregating consistently over time and space.

11. Statistical/Trend Analysis

EPA has determined that the time series in Figure 1 has an increasing trend of approximately half a percentage point per decade and the time series in Figure 2 has an increasing trend of approximately 0.15 percentage points per decade. Both of these trends were calculated by ordinary least-squares regression, which is a common statistical technique for identifying a first-order trend. Analyzing the significance of these trends would potentially require consideration of serial correlation and other more complex statistical factors.

12. Data Limitations

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

1. Both figures are national in scope, meaning they do not provide information about trends in extreme or heavy precipitation on a local or regional scale.
2. Weather monitoring stations tend to be closer together in the eastern and central states than in the western states. In areas with fewer monitoring stations, heavy precipitation indicators are less likely to reflect local conditions accurately.
3. The indicator does not include Alaska, which has seen some notable changes in heavy precipitation in recent years (e.g., Gleason et al., 2008).

References

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