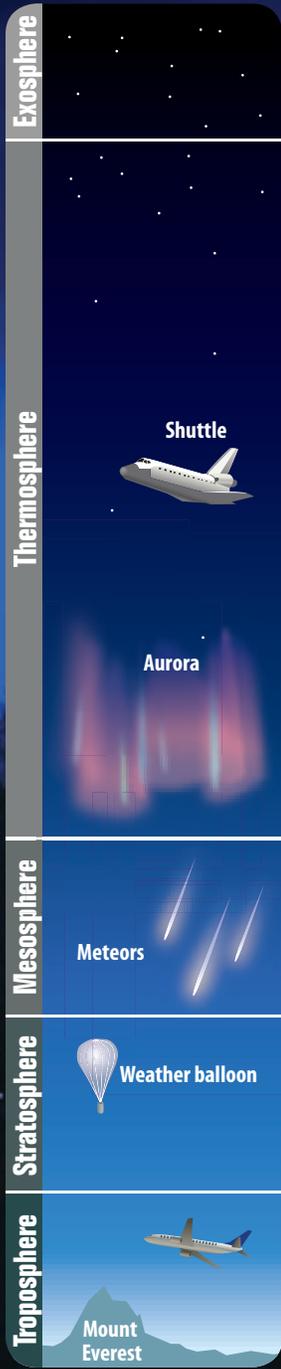
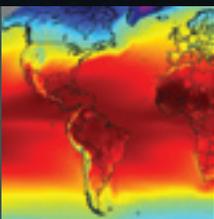


Weather and

Earth's Atmosphere



Source: NOAA, 2009¹



U.S. and Global Temperature



Heat Waves



Drought

Climate

Weather is the state of the atmosphere at any given time and place. Most weather takes place in the lower layer of the atmosphere, the troposphere (see diagram of the Earth's atmosphere at left). Familiar aspects of weather include temperature, precipitation, clouds, and wind. Severe weather conditions include hurricanes, tornadoes, and blizzards.

Climate is the average weather in a given place, usually over a period of more than 30 years. While the weather can change in just a few hours, climate changes occur over longer timeframes. Climate is defined not only by average temperature and precipitation, but also by the type, frequency, and intensity of weather events such as heat waves, cold waves, storms, floods, and droughts. Climate has natural year-to-year variations, and extremes in temperatures and weather events have occurred throughout history.

The Earth's climate depends on the balance between the amount of energy received from the sun and the amount of energy that is absorbed or radiated back into space. Natural influences can alter how much heat is reflected or absorbed by the Earth's surface, including changes in the sun's intensity, volcanic eruptions, and multi-year climate cycles such as El Niño. Human activities such as deforestation and the production of greenhouse gases also affect this balance. These alterations, in turn, affect climate on local, regional, and global scales.

Generally, increases in the Earth's surface temperature will increase evaporation from the oceans and land, leading to more overall precipitation. However, this additional precipitation will not be distributed evenly, and shifting storm patterns will likely cause some areas to experience more severe droughts. Scientists have suggested that extreme weather events such as storms, floods, and hurricanes will likely also become more intense. There is natural variability in the intensity and frequency of such events, however, so care must be taken to determine whether observed trends reflect long-term changes in the Earth's climate system.

Climate variations can directly or indirectly affect many aspects of human society—in both positive and disruptive ways. For example, warmer temperatures might reduce heating costs and improve conditions for growing some crops, yet extreme heat can cause illness or death among vulnerable populations. Precipitation can replenish water supplies and nourish crops, but intense storms can damage property, cause loss of life and population displacement, and temporarily disrupt essential services such as transportation, telecommunications, and energy and water supplies.

Shifting storm patterns will likely cause some areas to experience more droughts. Extreme weather events such as storms, floods, and hurricanes will likely also become more intense.



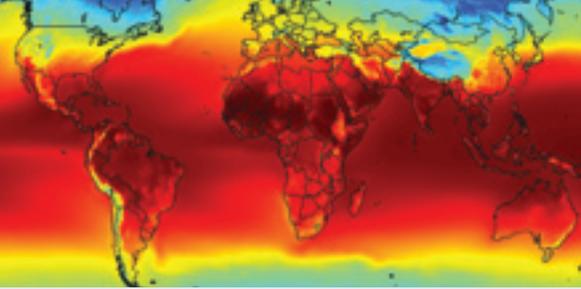
U.S. and Global Precipitation



Heavy Precipitation



Tropical Cyclone Intensity



U.S. and Global

This indicator describes trends in average temperature for the United States and the world.

Background

Temperature is a fundamental component of climate, and it can have wide-ranging effects on human life and ecosystems, as many of the other indicators in this report demonstrate. For example, increases in air temperature can lead to more intense heat waves, which can cause illness and death in vulnerable populations. Temperature patterns also determine what types of animals and plants can survive in a particular place. Changes in temperature can disrupt a wide range of natural processes, particularly if these changes occur abruptly and plant and animal species do not have time to adapt.

As greenhouse gases trap more energy in the Earth's atmosphere, average temperatures at the Earth's surface are expected to rise. However, because climate change (both natural and human-driven) can shift the wind patterns and ocean currents that drive the world's climate system, some areas might experience more warming than others, and some might experience cooling. Changes in air temperature can, in turn, cause changes in sea surface temperature, precipitation patterns, and other aspects of climate.

About the Indicator

This indicator examines U.S. and global temperature patterns from 1901 to the present. Data were provided by the National Oceanic and Atmospheric Administration, which keeps historical records from weather stations around the world. U.S. surface measurements come from stations on land, while global surface trends also incorporate observations from buoys and ships on the ocean, thereby providing data from sites spanning the entire surface of the Earth. For comparison, this indicator also displays data from satellites that have measured the temperature of the Earth's lower atmosphere since 1979.

This indicator shows annual anomalies, or differences, compared with the average temperature from 1901 to 2000. Anomalies are calculated in degrees for each location, then averaged together.

Figure 1. Temperatures in the Lower 48 States, 1901–2009

This figure shows how average temperatures in the lower 48 states have changed since 1901. Surface data come from land-based weather stations, while satellite measurements cover the lower troposphere, which is the lowest level of the Earth's atmosphere (see diagram on p. 20). "UAH" and "RSS" represent two different methods of analyzing the original satellite measurements. This graph uses the 1901 to 2000 average as a baseline for depicting change. Choosing a different baseline period would not change the shape of the trend.

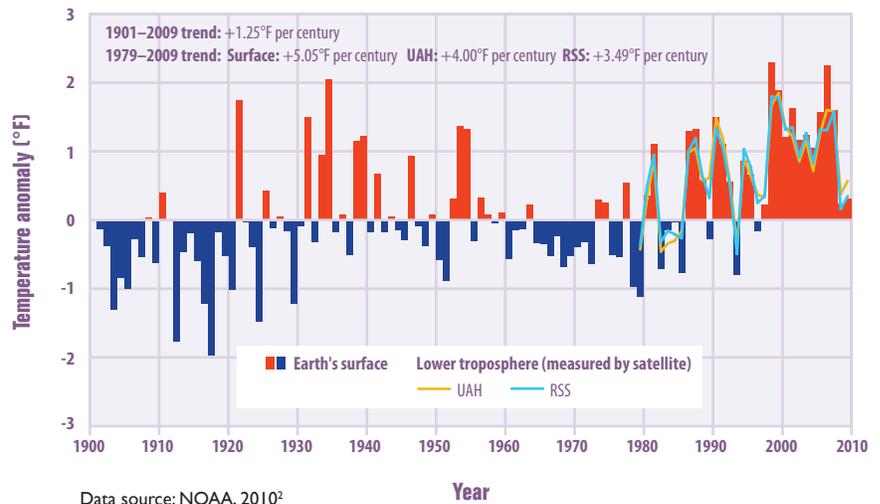
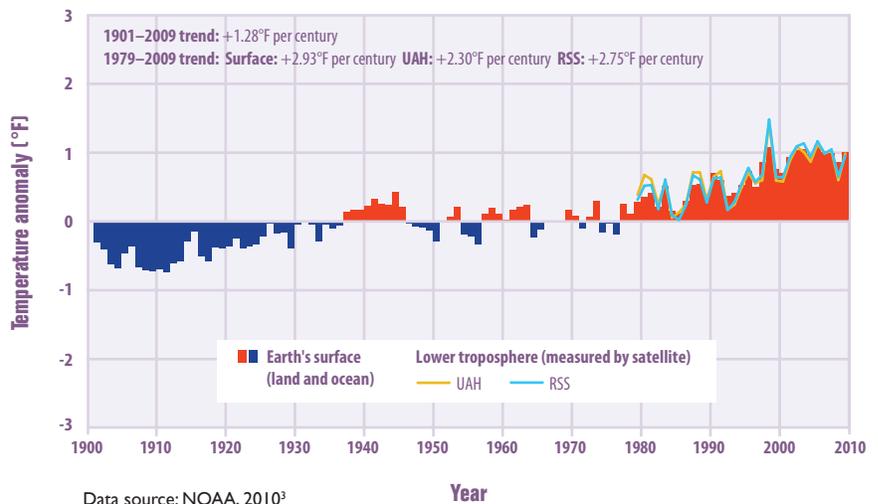


Figure 2. Temperatures Worldwide, 1901–2009

This figure shows how average temperatures worldwide have changed since 1901. Surface global data come from a combined set of land-based weather stations and sea surface temperature measurements, while satellite measurements cover the lower troposphere, which is the lowest level of the Earth's atmosphere (see diagram on p. 20). "UAH" and "RSS" represent two different methods of analyzing the original satellite measurements. This graph uses the 1901 to 2000 average as a baseline for depicting change. Choosing a different baseline period would not change the shape of the trend.



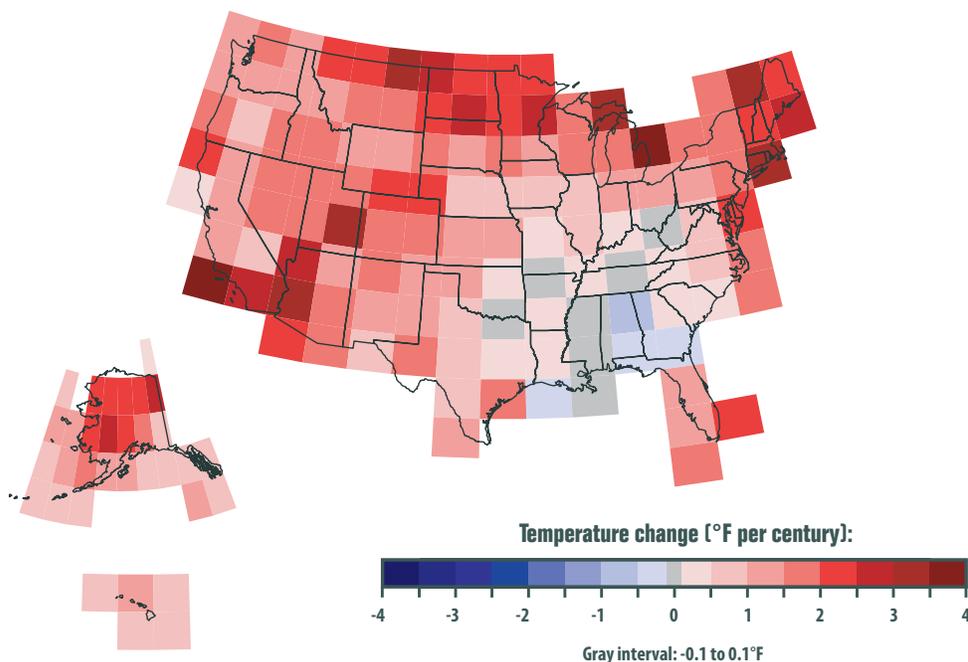
Temperature

Key Points

- Since 1901, temperatures have risen across the lower 48 states at an average rate of 0.13°F per decade (1.3°F per century) (see Figure 1). Average temperatures have risen more quickly since the late 1970s (0.35 to 0.51°F per decade). Seven of the top 10 warmest years on record for the lower 48 states have occurred since 1990, and the last 10 five-year periods have been the 10 warmest five-year periods on record.
- Global average surface temperatures have risen at an average rate of 0.13°F per decade since 1901 (see Figure 2), similar to the rate of warming within the lower 48 states. Since the late 1970s, however, the United States has warmed at nearly twice the global rate. Worldwide, 2000–2009 was the warmest decade on record.
- Some parts of the United States have experienced more warming than others (see Figure 3). The North, the West, and Alaska have seen temperatures increase the most, while some parts of the South have experienced little change. However, not all of these regional trends are statistically meaningful.

Figure 3. Rate of Temperature Change in the United States, 1901–2008

This figure shows how average air temperatures have changed in different parts of the United States since the early 20th century (since 1901 for the lower 48 states, 1905 for Hawaii, and 1918 for Alaska).



Data source: NOAA, 2009⁴

Indicator Limitations

Data from the early 20th century are somewhat less precise because there were fewer stations collecting measurements at the time. However, the overall trends are still reliable. Measurement instruments and methods (for example, the time of day measurements are taken) have also changed over time, and some stations have moved. Where possible, the data have been adjusted to account for these kinds of changes.

Data Sources

The data for this indicator were provided by the National Oceanic and Atmospheric Administration's National Climatic Data Center, which maintains a large collection of climate data online at: www.ncdc.noaa.gov/oa/ncdc.html. Surface temperature anomalies were calculated based on monthly values from a network of long-term monitoring stations. Satellite data were analyzed by two independent groups, resulting in the slightly different "UAH" and "RSS" trend lines.



Heat Waves

This indicator tracks the frequency of extreme heat events in the United States.

Background

A heat wave is a prolonged period of abnormally hot weather. With an overall warming of the Earth's climate, heat waves are expected to become more frequent, longer, and more intense in places where they already occur.⁵ Increased frequency and severity of heat waves can lead to more illness and death, particularly among older adults, the young, and other vulnerable groups (see the Heat-Related Deaths indicator on p. 58). Excessive heat also can kill or injure crops and livestock, and can lead to power outages as heavy demands for air conditioning strain the power grid.

About the Indicator

While there is no universal definition of a heat wave, this indicator defines a heat wave as a four-day period with an average temperature that would only be expected to occur once every 10 years, based on the historical record.

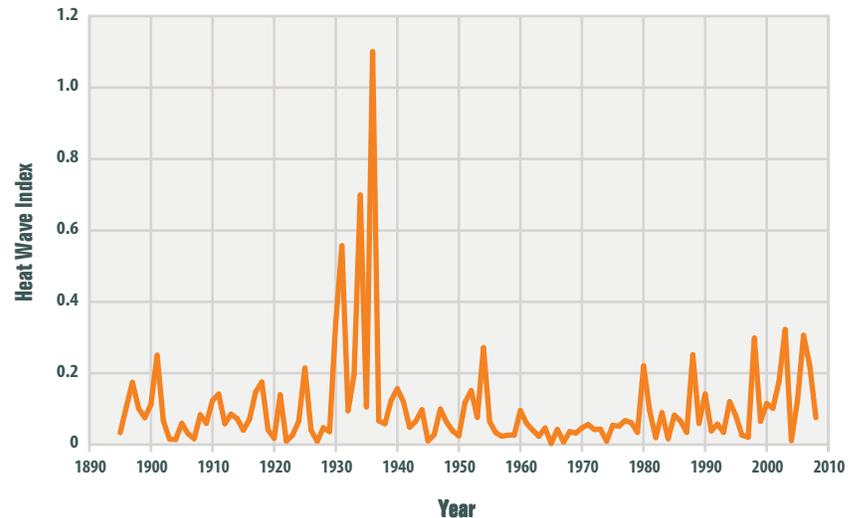
This indicator reviews trends in the U.S. Annual Heat Wave Index between 1895 and 2008. This index tracks the frequency of heat waves across the lower 48 states, but not the intensity of these episodes. The index uses daily maximum temperature data from the National Oceanic and Atmospheric Administration, which keeps records from weather stations throughout the nation. Approximately 300 to 400 stations reported data from 1895 to 1910; over the last 100 years, the number of stations has risen to 700 or more.

The index value for a given year could mean several different things. For example, an index value of 0.2 in any given year could mean that 20 percent of the recording stations experienced one heat wave; 10 percent of stations experienced two heat waves; or some other combination of stations and episodes resulted in this value.

(Continued on page 25)

Figure 1. U.S. Annual Heat Wave Index, 1895–2008

This figure shows the annual values of the U.S. Heat Wave Index from 1895 to 2008. These data cover the lower 48 states.



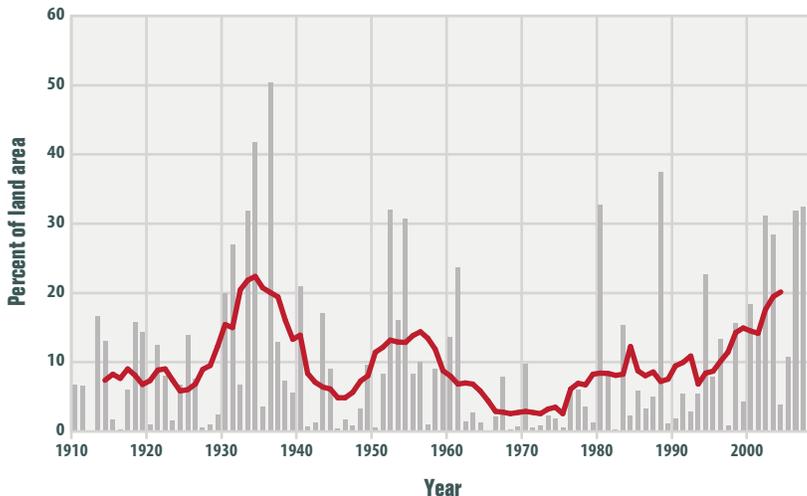
Data source: CCSP, 2009⁶

Key Points

- Heat waves occurred with high frequency in the 1930s, and these remain the most severe heat waves in the U.S. historical record (see Figure 1). Many years of intense drought (the “Dust Bowl”) contributed to these heat waves by depleting soil moisture and reducing the moderating effects of evaporation.⁷
- There is no clear trend over the entire period tracked by the index. Although it is hard to see in Figure 1 (because of the extreme events of the 1930s), heat wave frequency decreased in the 1960s and 1970s but has risen since then (see Figure 1).
- Like the heat wave index, the percentage of the United States affected by heat waves has also risen steadily since the 1970s (see Figures 2 and 3). The recent period of increasing heat is distinguished by a rise in extremely high nighttime temperatures.

Figure 2. Areas of the Lower 48 States With Hot Daily High Temperatures, 1910–2008

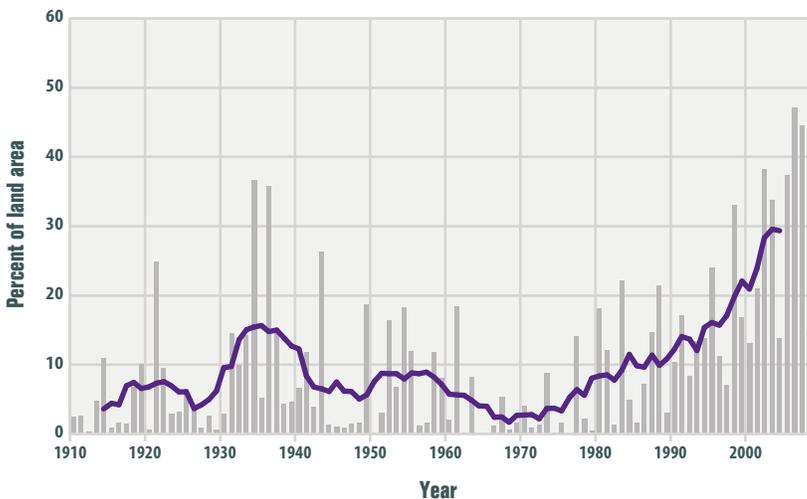
This chart shows the percentage of the land area of the lower 48 states with summer daily high temperatures well above normal. The bars represent individual years, while the line is a smoothed nine-year moving average.



Data source: CCSP,2009⁹

Figure 3. Areas of the Lower 48 States With Hot Daily Low Temperatures, 1910–2008

This chart shows the percentage of the land area of the lower 48 states with summer daily low temperatures well above normal. The bars represent individual years, while the line is a smoothed nine-year moving average.



Data source: CCSP,2009⁹

For additional perspective, this indicator also looks at heat waves in terms of size (percent of area affected) and the difference between trends in daytime high temperatures and trends in nighttime low temperatures.

Indicator Limitations

Temperature data are less certain for the early part of the record because fewer stations were operating at that time. In addition, measurement instruments and procedures have changed over time, and some stations have moved. The data have been adjusted to account for some biases, however, and these uncertainties are not sufficient to change the fundamental trends shown in the figures.

This indicator does not consider humidity, which can have additional health impacts when combined with heat.

Data Sources

The data for this indicator are based on measurements from the National Oceanic and Atmospheric Administration's National Weather Service Cooperative Observer Network. These weather station data are available online at: www.nws.noaa.gov/os/coop/what-is-coop.html.

Drought

This indicator measures drought conditions of U.S. lands.

Background

There are many definitions and types of drought. Meteorologists generally define drought as a prolonged period of dry weather caused by a lack of precipitation, which results in a serious water shortage for some activity, group, or ecological system. Drought can also be thought of as an imbalance between precipitation and evaporation.

As average temperatures rise because of climate change, the Earth's water cycle is expected to speed up, increasing evaporation. Increased evaporation will make more water available in the air for precipitation, but contribute to drying over some land areas. As a result, storm-affected areas are likely to experience increased precipitation (see the U.S. and Global Precipitation indicator on p. 28) and increased risk of flooding (see the Heavy Precipitation indicator on p. 30), while areas located far from storm tracks are likely to experience less precipitation and increased risk of drought. Since the 1970s, drought-affected areas have increased on a global scale—more likely than not as a result of climate change caused by human activities.¹⁰

Drought conditions can affect agriculture, water supplies, energy production, and many other aspects of society. The impacts vary depending on the type, location, intensity, and duration of the drought. For example, effects on agriculture can range from slowed plant growth to severe crop losses, while water supply impacts can range from lowered reservoir levels to major water shortages. Lower stream flow and ground water levels can also harm plants and animals, and dried-out vegetation increases the risk of wildfires.

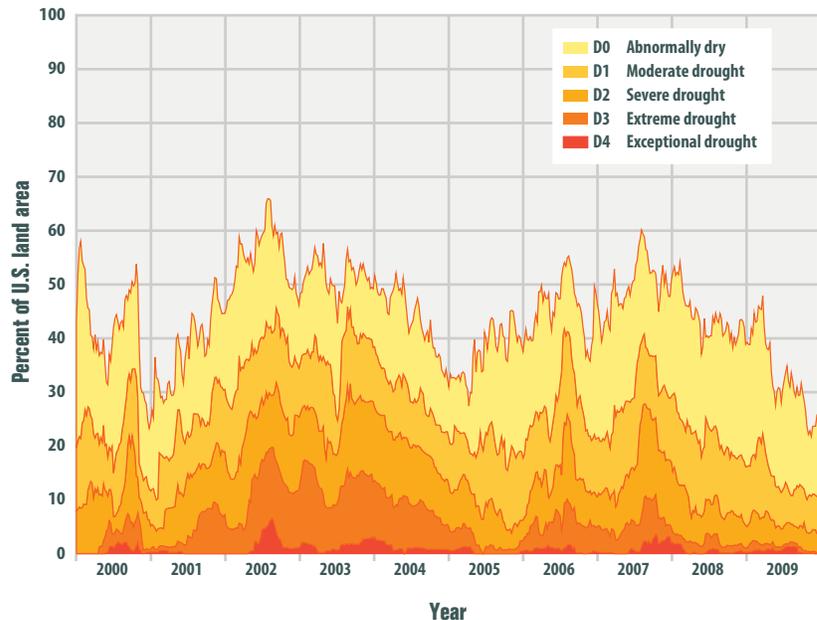
About the Indicator

During the 20th century, many indices were created to measure drought severity by looking at trends in precipitation, soil moisture, stream flow, vegetation health, and other variables.¹¹ This indicator is based on the U.S. Drought Monitor, which integrates several of these indices.

(Continued on page 27)

Figure 1. U.S. Lands Under Drought Conditions, 2000–2009

This chart shows the percentage of U.S. lands classified under drought conditions from 2000 through 2009. The data cover all 50 states plus Puerto Rico.



Data source: National Drought Mitigation Center, 2010¹²

Key Points

- Because data from the U.S. Drought Monitor are only available for the most recent decade, there is no clear long-term trend in this indicator. With continued data collection, future versions of this indicator should be able to paint a more complete picture of long-term trends in drought.
- Over the period from 2000 through 2009, roughly 30 to 60 percent of the U.S. land area experienced drought conditions at any given time (see Figure 1). The years 2002, 2003, and 2007 were relatively high drought years, while 2001, 2005, and 2009 were relatively low drought years.
- “Abnormally dry area” (D0)—the mildest drought event—was the most commonly occurring level of drought in the United States between 2000 and 2009.
- As of early 2010, moderate to severe drought is affecting parts of several western states, along with a small portion of the Upper Midwest.¹³

Categories of Drought Severity

Category	Description	Possible Impacts
D0	Abnormally dry	Going into drought: short-term dryness slowing planting or growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered.
D1	Moderate drought	Some damage to crops or pastures; streams, reservoirs, or wells low; some water shortages developing or imminent; voluntary water use restrictions requested.
D2	Severe drought	Crop or pasture losses likely; water shortages common; water restrictions imposed.
D3	Extreme drought	Major crop/pasture losses; widespread water shortages or restrictions.
D4	Exceptional drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells, creating water emergencies.

Experts update the U.S. Drought Monitor weekly and produce maps that illustrate current conditions as well as short- and long-term trends. Major participants include the National Oceanic and Atmospheric Administration, the U.S. Department of Agriculture, and the National Drought Mitigation Center.

For a map of current drought conditions, visit the Drought Monitor Web site at: www.drought.unl.edu/dm/monitor.html.

The Drought Monitor also considers additional factors such as snow water content, ground water levels, reservoir storage, pasture/range conditions, and other impacts.

The Drought Monitor uses codes from D0 to D4 (see table at left) to classify drought severity. This indicator measures the percent of U.S. land under each of these drought categories from 2000 through 2009. The indicator covers all 50 states and Puerto Rico.

Indicator Limitations

Because of the relative newness of the U.S. Drought Monitor, it cannot be used to assess long-term trends. Other indicators are available that do show historical trends, but they have other weaknesses and cannot be compared across geographic regions or across time.¹⁴

The drought classification scheme used for this indicator is produced by combining data from several different sources. These data are combined to reflect the collective judgment of experts and in some cases are adjusted to reconcile conflicting trends shown by different data sources over different time periods.

The indicator gives a broad overview of drought conditions in the United States. It is not intended to replace local or state information that might describe conditions more precisely for a particular region.

Data Sources

Data for this indicator were provided by the U.S. Drought Monitor. Historical data in table form are available at: www.drought.unl.edu/dm/DM_tables.htm?archive. Maps and current drought information can be found on the main Drought Monitor site at: www.drought.unl.edu/dm/monitor.html.





U.S. and Global

This indicator describes trends in average precipitation for the United States and the world.

Background

Precipitation can have wide-ranging effects on human life and ecosystems. Rainfall, snowfall, and the timing of snow-melt can all affect the amount of water available for drinking and irrigation, and can also determine what types of animals and plants (including crops) can survive in a particular place. Changes in precipitation can disrupt a wide range of natural processes, particularly if these changes occur abruptly and plant and animal species do not have time to adapt.

As average temperatures at the Earth's surface rise (see the U.S. and Global Temperature indicator on p. 22), more evaporation and cloud formation occurs, which, in turn, increases overall precipitation. Therefore, a warming climate is expected to increase precipitation in many areas. However, just as precipitation patterns vary across the world, so will the effects of climate change. By shifting the wind patterns and ocean currents that drive the world's climate system, climate change will also cause some areas to experience decreased precipitation.

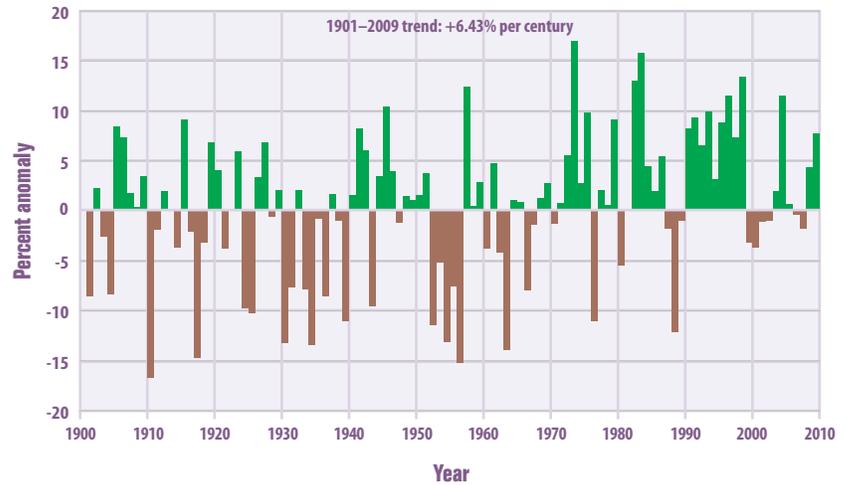
About the Indicator

This indicator examines U.S. and global precipitation patterns from 1901 to the present, based on rainfall and snowfall measurements from land-based stations worldwide. Data were provided by the National Oceanic and Atmospheric Administration, which keeps historical records from weather stations around the world.

This indicator shows annual anomalies, or differences, compared with the average precipitation from 1901 to 2000. These anomalies are presented in terms of percent change compared with the baseline.

Figure 1. Precipitation in the Lower 48 States, 1901–2009

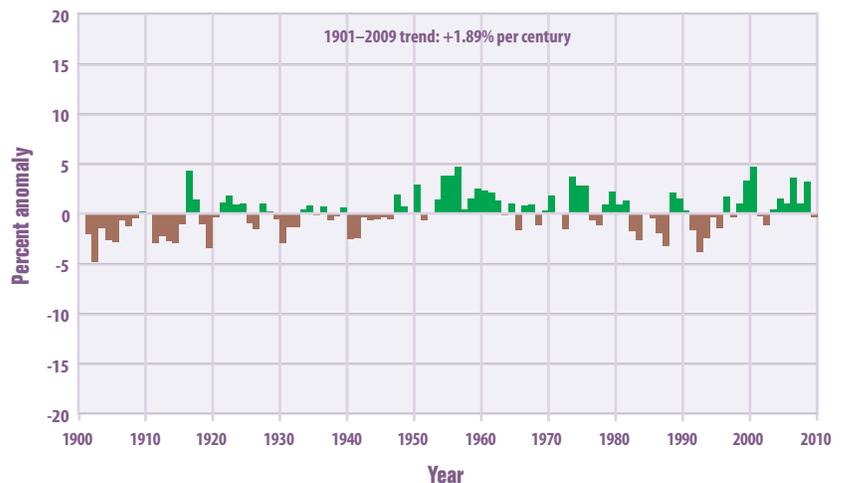
This figure shows how the amount of precipitation in the lower 48 states has changed since 1901. This graph uses the 1901 to 2000 average as a baseline for depicting change. Choosing a different baseline period would not change the shape of the trend.



Data source: NOAA, 2010¹⁵

Figure 2. Precipitation Worldwide, 1901–2009

This figure shows how the amount of precipitation globally has changed since 1901. This graph uses the 1901 to 2000 average as a baseline for depicting change. Choosing a different baseline period would not change the shape of the trend.



Data source: NOAA, 2010¹⁶

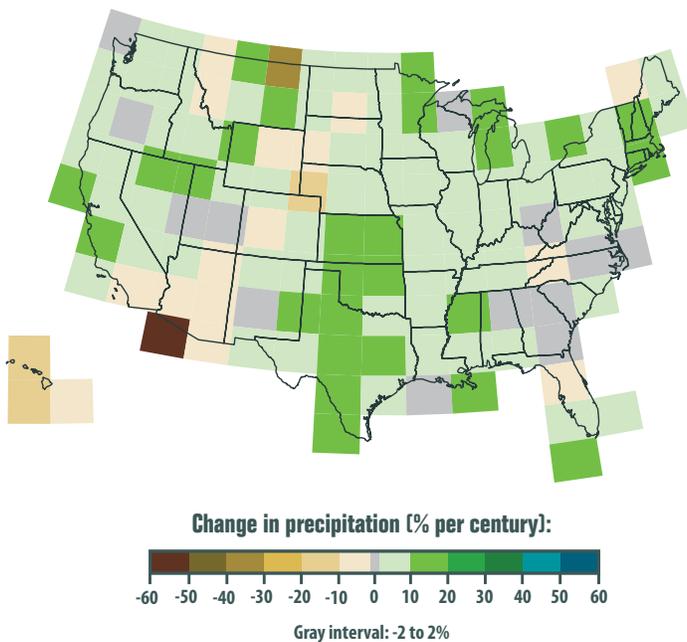
Precipitation

Key Points

- Average precipitation has increased in the United States and worldwide (see Figures 1 and 2). Since 1901, global precipitation has increased at an average rate of 1.9 percent per century, while precipitation in the lower 48 states has increased at a rate of 6.4 percent per century.
- Some parts of the United States have experienced greater increases in precipitation than others. A few areas such as Hawaii and parts of the Southwest have seen a decrease (see Figure 3).

Figure 3. Rate of Precipitation Change in the United States, 1901–2008

This figure shows how the amount of precipitation has changed in different parts of the United States since the early 20th century (since 1901 for the lower 48 states; since 1905 for Hawaii). Alaska is not shown because of limited data coverage.



Data source: NOAA, 2009¹⁷

Indicator Limitations

Data from the early 20th century are somewhat less precise because there were fewer stations collecting measurements at the time. However, the overall trends are still reliable. Measurement instruments and methods have also changed over time, and some stations have moved. Where possible, the data have been adjusted to account for these kinds of changes.

Data Sources

The data for this indicator were provided by the National Oceanic and Atmospheric Administration's National Climatic Data Center, which maintains a large collection of climate data online at: www.ncdc.noaa.gov/oa/ncdc.html. Global, U.S., and regional precipitation anomalies were calculated based on monthly values from a network of long-term monitoring stations.





Heavy Precipitation

This indicator tracks the frequency of heavy precipitation events in the United States.

Background

Heavy precipitation refers to instances during which the amount of precipitation experienced in a location substantially exceeds what is normal. What constitutes a period of heavy precipitation varies according to the location and the season.

Climate change can affect the intensity and frequency of precipitation. Warmer oceans increase the amount of water that evaporates into the air, and warmer air can hold more moisture than cooler air. When this moisture-laden air moves over land, it can produce more intense precipitation—for example, heavier rain and snow storms.¹⁸ The potential impacts of heavy precipitation include crop damage, soil erosion, and an increase in flood risk due to heavy rains. In addition, runoff from precipitation can hurt water quality as pollutants deposited on land wash into water bodies.

Heavy precipitation does not necessarily mean the total amount of precipitation at a location has increased—just that precipitation is occurring in more intense events. However, changes in the intensity of precipitation can also lead to changes in overall precipitation totals.

About the Indicator

Heavy precipitation events can be measured by tracking their frequency, by examining their return period (the chance that the event will be equaled or exceeded in a given year), or by directly measuring the amount of precipitation in a certain period.

One way to track heavy precipitation is by calculating what percentage of a particular location's total precipitation in a given year has come in the form of extreme one-day events—or, in other words, what percentage of precipitation is arriving in short, intense bursts. Figure 1 of this indicator looks at the prevalence of extreme single-day precipitation events over time.

(Continued on page 31)

Figure 1. Extreme One-Day Precipitation Events in the Lower 48 States, 1910–2008

This figure shows the percentage of the land area of the lower 48 states where a much greater than normal portion of total annual precipitation has come from extreme single-day precipitation events. The bars represent individual years, while the line is a smoothed nine-year moving average.

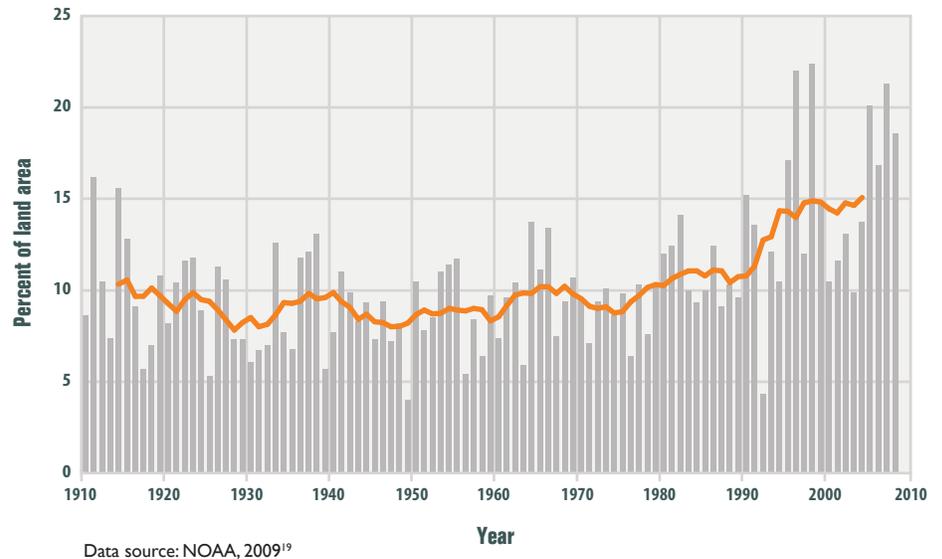
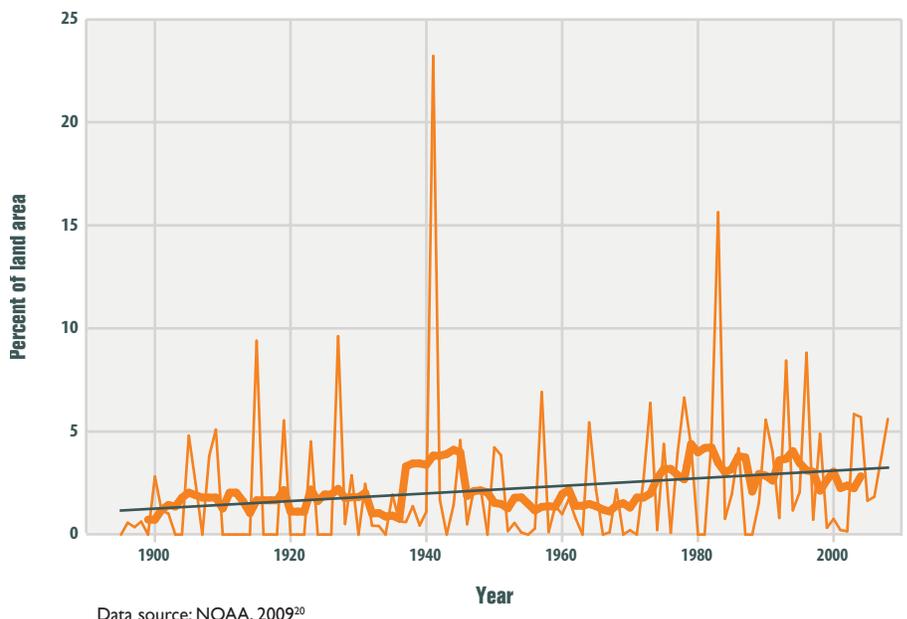


Figure 2. Abnormally High Annual Precipitation in the Lower 48 States, 1895–2008

This figure shows the percentage of the land area of the lower 48 states that experienced much greater than normal precipitation in any given year, which means it scored 2.0 or above on the annual Standardized Precipitation Index (SPI). The thicker orange line shows a nine-year moving average that smooths out some of the year-to-year fluctuations, while the straight black line is the trend line that fits the data best.



Key Points

- In recent years, a larger percentage of precipitation has come in the form of intense single-day events. Eight of the top 10 years for extreme one-day precipitation events have occurred since 1990 (see Figure 1).
- The prevalence of extreme single-day precipitation events remained fairly steady between 1910 and the 1980s, but has risen substantially since then. Over the entire period from 1910 to 2008, the prevalence of extreme single-day precipitation events increased at a rate of about half a percentage point per decade (5 percentage points per century) (see Figure 1).
- The percentage of land area experiencing much greater than normal yearly precipitation totals increased between 1895 and 2008. However, there has been much year-to-year variability. In some years there were no abnormally wet areas, while a few others had abnormally high precipitation totals over 10 percent or more of the lower 48 states' land area (see Figure 2).
- Figures 1 and 2 are both consistent with a variety of other studies that have found an increase in heavy precipitation over timeframes ranging from single days to 90-day periods to whole years.²¹ For more information on trends in overall precipitation levels, see the U.S. and Global Precipitation indicator on p. 28.

For added insight, this indicator also tracks the occurrence of abnormally high total yearly precipitation. It does so by looking at the Standardized Precipitation Index (SPI), which compares actual yearly precipitation totals with the range of precipitation totals that one would typically expect at a specific location, based on historical data. If a location experiences less precipitation than normal during a particular period, it will receive a negative SPI score, while a period with more precipitation than normal will receive a positive score. The more precipitation (compared with normal), the higher the SPI score. The SPI is a useful way to look at precipitation totals because it allows comparison of different locations and different seasons on a standard scale. Figure 2 shows what percentage of the total area of the lower 48 states had an annual SPI score of 2.0 or above (well above normal) in any given year.

Both parts of this indicator are based on data from a large national network of weather stations compiled by the National Oceanic and Atmospheric Administration.

Indicator Limitations

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.

Data Sources

The data used for this indicator were provided by the National Oceanic and Atmospheric Administration's National Climatic Data Center. Figure 1 is based on Step #4 of the National Oceanic and Atmospheric Administration's U.S. Climate Extremes Index; for data and a description of the index, see: www.ncdc.noaa.gov/extremes/cei.html. Figure 2 is based on the U.S. SPI, which is shown in a variety of maps available online at: www.ncdc.noaa.gov/oa/climate/research/prelim/drought/spi.html. The data and metadata used to construct these maps are available from the National Oceanic and Atmospheric Administration at: <ftp://ftp.ncdc.noaa.gov/pub/data/cirs>.



Tropical Cyclone

This indicator examines the intensity of hurricanes and other tropical storms in the Atlantic Ocean, Caribbean, and Gulf of Mexico.

Background

Hurricanes, tropical storms, and other intense rotating storms fall into a general category called cyclones. There are two main types of cyclones: tropical and extratropical. Tropical cyclones get their energy from warm tropical oceans, while extratropical cyclones form outside the tropics, getting their energy from the jet stream and from temperature differences between the north and the south, often involving cold fronts and warm fronts.

This indicator focuses on tropical cyclones in the Atlantic Ocean, Caribbean, and Gulf of Mexico. Tropical cyclones are most common during the “hurricane season,” which runs from June through November. The effects of tropical cyclones are numerous and well known. At sea, storms disrupt and endanger shipping traffic. When cyclones encounter land, their intense rains and high winds can cause property damage, loss of life, soil erosion, and flooding. The associated storm surge—the large volume of ocean water pushed ashore by the cyclone’s strong winds—can also cause severe flooding and destruction.

Climate change is expected to affect tropical cyclone intensity by increasing sea surface temperatures, a key factor that influences cyclone formation and behavior. According to the U.S. Global Change Research Program, it is very likely that increased levels of greenhouse gases have contributed to an increase in sea surface temperatures in areas where hurricanes form, suggesting a human contribution to hurricane activity over the last 50 years.²² The U.S. Global Change Research Program and the Intergovernmental Panel on Climate Change project that tropical cyclones will become more intense, with higher wind speeds and heavier rains.²³ However, observations of past cyclone activity and projections of future activity have uncertainties because of changes in monitoring technology, longer-term regional climate patterns, and the limitations of climate models.

About the Indicator

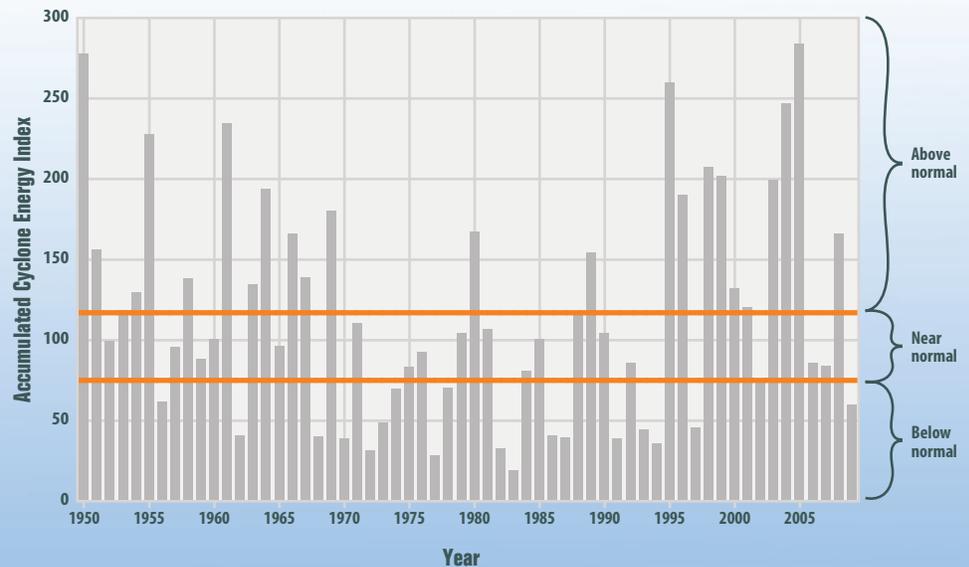
This indicator uses two related indices: the Accumulated Cyclone Energy (ACE) Index and the Power Dissipation Index (PDI).

The National Oceanic and Atmospheric Administration uses the ACE Index to measure the strength of individual tropical storms as

(Continued on page 33)

Figure 1. North Atlantic Cyclone Intensity According to the Accumulated Cyclone Energy Index, 1950–2009

This figure shows total annual Accumulated Cyclone Energy (ACE) Index values from 1950 through 2009. The National Oceanic and Atmospheric Administration has defined “near normal,” “above normal,” and “below normal” ranges based on the distribution of ACE Index values over the 50 years from 1951 to 2000.



Data source: NOAA, 2010²⁴



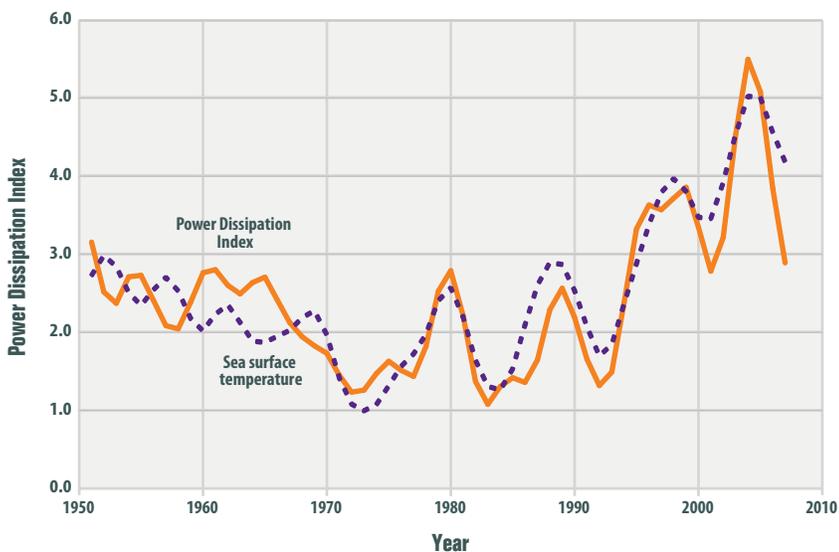
Intensity

Key Points

- When examining the entire ACE Index data series from 1950 to 2009, no clear trends in cyclone intensity are apparent (see Figure 1). However, intensity has risen noticeably over the past 20 years, and six of the 10 most active years have occurred since the mid-1990s. Comparable levels of activity were also seen during the previous high-activity era which spanned the 1950s and 1960s.
- The PDI (see Figure 2) shows a similar trend: fluctuating cyclone intensity for most of the mid- to late 20th century, followed by a noticeable increase since 1995. These trends are closely related to variations in sea surface temperature in the tropical Atlantic (see Figure 2), leading the U.S. Global Change Research Program to conclude that hurricane activity has “increased substantially since the 1950s and ’60s in association with warmer Atlantic sea surface temperatures.”²⁵

Figure 2. North Atlantic Cyclone Intensity According to the Power Dissipation Index, 1949–2009

This figure presents annual values of the Power Dissipation Index (PDI). North Atlantic sea surface temperature trends are provided for reference. Note that sea surface temperature uses different units, but the numbers have been adjusted here to show how the trends are similar. The lines have been smoothed using a five-year weighted average.



Data source: Emanuel, 2010²⁶

well as the total cyclone activity over the course of a hurricane season. An individual storm's ACE Index value is a number based on the storm's maximum wind speed measured at six-hour intervals over the entire time when the cyclone is classified as at least a tropical storm (that is, a storm with a wind speed of at least 39 miles per hour). Therefore, the ACE Index value accounts for both cyclone strength and duration.

The National Oceanic and Atmospheric Administration calculates the ACE Index value for an entire hurricane season by adding the ACE Index values for all named storms in a season, including subtropical storms, tropical storms, and hurricanes. For this indicator, the ACE Index has been converted to a numerical scale where 100 equals the median value (the midpoint) over a base period from 1951 to 2000. The National Oceanic and Atmospheric Administration has set specific thresholds (see Figure 1) to define whether the ACE Index for a given year is close to normal, significantly above normal, or significantly below.

For additional perspective, this indicator also shows trends in the PDI. Like the ACE Index, the PDI is based on measurements of wind speed, but it uses a different calculation method that places more emphasis on storm intensity. This indicator shows the annual PDI value, which represents the sum of PDI values for all named storms during the year.

Indicator Limitations

Over time, data collection methods have changed as technology has improved. For example, wind speed collection methods have evolved substantially over the past 60 years. How these changes in data gathering technologies might affect data consistency over the life of the indicator is not fully understood.

Data Sources

The ACE Index data (Figure 1) came from the National Oceanic and Atmospheric Administration's Climate Prediction Center, and are available online at: www.cpc.noaa.gov/products/outlooks/background_information.shtml. Values for the PDI have been calculated by Kerry Emanuel at the Massachusetts Institute of Technology. Both indices are based on wind speed measurements compiled by the National Oceanic and Atmospheric Administration.