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Weather and Climate Change: What's the Difference?

Weather is day-to-day temperature, precipitation, and other conditions.

Climate is weather observed over multidecadal periods for a defined location. For example, the National Oceanic and Atmospheric Administration (NOAA) measures a *climate normal* over specific 30-year periods for locations in the United States.

Climate variability is how weather may vary for multiple weeks or years from the long-term average.

Climate change occurs when the long-term climate shifts, without an apparent return to previous normals.

With much discussion of climate change in Congress, in the news, and among constituents, some commonly used words may be misunderstood or misused. Below are explanations of several key terms: *weather*, *climate*, *climate variability*, and *climate change,* as well as some associated concepts.

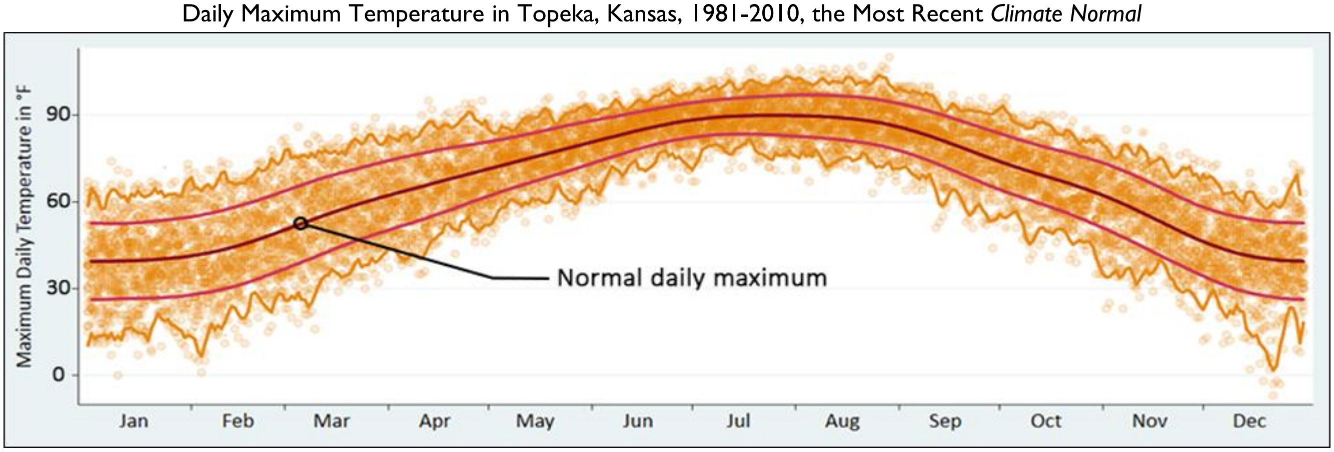
Weather is the state of the atmosphere at a specific place and time, described by such conditions as temperature, precipitation, humidity, cloudiness, and wind speed. Weather can include conditions of the Earth's water and land surfaces as well, with such variables as wave height and snow cover. Weather conditions can vary rapidly or last up to a few days in the mid-latitudes. NOAA compiles observations from weather stations around the United States, in the oceans, from international sources, and from other federal agencies. NOAA analyzes historical weather data and provides multiday forecasts or seasonal outlooks.

Climate is defined by the long-term statistics of weather compiled for a specified place (**Figure 1**), including the globe. For example, climate would include the maximum hourly precipitation in July in a particular county over 30 years or the global mean surface temperature from 1981 to 2010. The availability of long-term data varies by location, making climate analysis for some locations challenging.

NOAA's National Centers for Environmental Information defines U.S. *climate normals* as "three-decade averages of climatological variables including temperature and precipitation" for defined locations. The most recent climate normal for a defined location uses weather observations for 1991-2020. People use climate normals for a wide array of purposes, such as placing daily weather into a historical context or determining technical specifications for the resilience of buildings and infrastructure against extreme weather.

Figure 1. Illustration of How Weather Makes Up the Long-Term Climate, Using Temperature

Daily Maximum Temperature in Topeka, Kansas, 1981-2010, the Most Recent *Climate Normal*



Source: CRS, using data from NOAA, National Climate Data Center, Climate Data Online. Extracted February 26, 2020.

Notes: The highest temperature on any given day and place is its *daily maximum temperature*, which is one aspect of weather. In this figure, each yellow dot represents the daily maximum temperature in Topeka, Kansas, per day in the most recent 30-year *climate normal* from 1981 to 2010. Overall, the statistics of this figure show aspects of Topeka's recent climate. The darkest line, in the center, is the *normal* daily maximum temperature in NOAA's *climate normal*. The smooth pink lines above and below it represent one (statistical) standard deviation from the average (about 18 percentage points above and below). The two yellows lines, above and below, represent the 5th and 95th percentiles, computed by CRS to show extreme daily maximum temperatures. (CRS used rolling three-day averages of these values to smooth the lines and better show instances of extreme weather—those dots above the 95th percentile or below the 5th.) About 90% of the time, the daily maximum temperature could be expected to fall between the 5th and 95th percentile lines. CRS selected Topeka because it is roughly in the center of the continental United States.

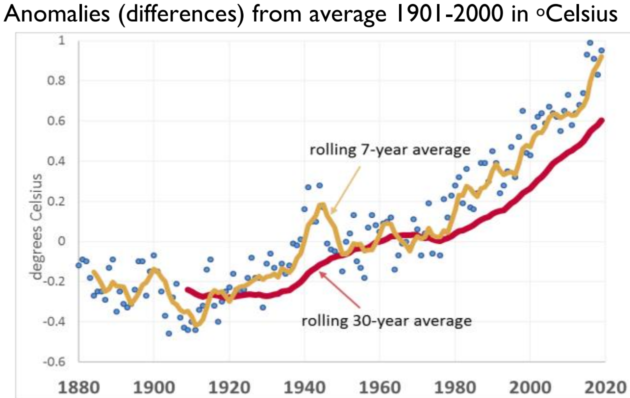
Climate variability can include several different concepts. Generally, it means the differences from the long-term averages (or other statistics) of climate-related variables, such as precipitation, over longer time or wider areas than individual weather events. Climate variability may describe how a season is above or below the *climate normal* average for, say, temperature or snowfall. Climate variability may also describe longer, multiyear patterns that are not average, such as when certain large-scale weather patterns occur. An example is the so-called El Niño/La Niña (ENSO) cycle, with cycles of warm and cool periods in the Pacific Ocean and the atmosphere. ENSO phases typically last from nine to 12 months and on average occur every two to seven years. With only climate variability, scientists would expect the climate to reflect historically average conditions.

When the climate continues to change over longer times, climatologists discern *climate change*. In effect, this means that what was "normal" has shifted. See **Figure 2**.

Climate change may be discerned when the statistics of the climate (e.g., the climate normal) continue to shift over multiple decades. Distinguishing climate change from climate variability can be challenging. Detecting climate change requires multiple decades of consistently collected measurements. The greater the climate change relative to the variability, the more rapidly scientific detection can occur. Observers have pointed to this as one reason that scientists did not reach consensus until the 1990s that the Earth's climate had changed over the 20th century. *Global warming* is one aspect of climate change; it is a sustained increase of global average temperature, usually measured at the surface of the Earth, though it may also be measured at specific altitudes in the atmosphere.

Figure 2.Illustration of Climate Variability and Change in Global Mean Surface Temperatures, 1880-2019

Anomalies (differences) from average 1901-2000 in °Celsius



Source: CRS, using data from NOAA, Climate at a Glance.

Notes: The blue dots represent each year's annual average temperature and, as a set, illustrate interannual variability of temperature. The yellow line shows climate variability as a rolling seven-year average of annual temperatures. The red line depicts climate change as increasing annual temperature, averaged over rolling 30-year periods.

Attributing Climate Variability and Climate Change to Different "Forcings"

A number of factors drive climate variability and climate change. Some factors are internal to the climate system, and some, such as solar variability or human-related greenhouse gas emissions, are external *forcings*. Each factor has its own rhythm and pattern, temporally ranging from less than a year to tens of thousands of years. Geographically, some forcings have stronger regional or hemispheric effect, while others are global. The temporal and geographical characteristics of each is like a fingerprint on the climate system. Using such "fingerprints," with sufficient observations and powerful computing systems, the 2017 U.S. National Climate Assessment (NCA4) concluded:

> It is extremely likely [>95%] that human influence has been the dominant cause of the observed warming since the mid-20th century. For the warming over the last century, there is no convincing alternative explanation supported by the extent of the observational evidence.

For more information about scientific assessments of climate change, see CRS Report R45086, *Evolving Assessments of Human and Natural Contributions to Climate Change*, by Jane A. Leggett.

Extreme Weather and Climate Change

Some extreme weather can lead to emergencies or disasters. Not all extreme weather events can be attributed to climate change. Nonetheless, climate models project that some events that would be extreme in the current climate—such as daily maximum temperatures higher than 92ºF in July in Topeka (**Figure 1**)—would occur more and more frequently as the Earth's climate warms with continued greenhouse gas emissions. Extremely cold days are expected to become less frequent with global warming.

According to the 2017 NCA4, since the mid-20th century "[s]ome extremes have already become more frequent, intense, or of longer duration, and many extremes are expected to continue to increase or worsen." As examples, "what in the past have been considered to be extreme precipitation events are becoming more frequent" on most continents, and "[t]he annual minimum and maximum sea ice extent have decreased over the last 35 years." However, "[w]hether global trends in high-intensity tropical cyclones are already observable is a topic of active debate."

So while not all extreme weather experienced today can be attributed to climate change, climate change may make some of today's extreme events more likely (especially those related to high temperatures, hydrological drought, or heavy precipitation). Scientists use complex attribution studies, such as "fingerprinting," to draw such conclusions.

Global Change Is Broader Than Climate Change

Another concept, broader than climate change, is that of *global change*. The Global Change Research Act of 1990 (P.L. 101-606) defined it as "changes in the global environment (including alterations in climate, land productivity, oceans or other water resources, atmospheric chemistry, and ecological systems) that may alter the capacity of the Earth to sustain life."

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