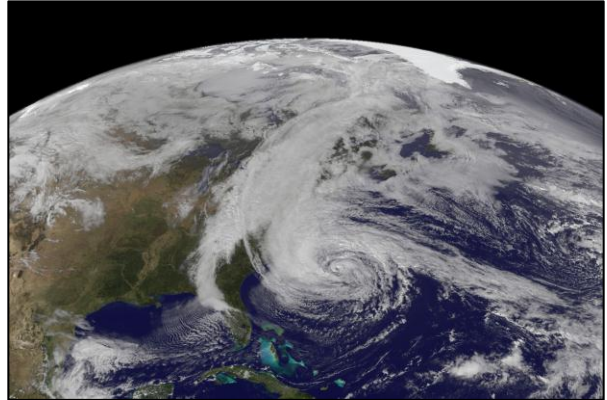


Weather and Climate

Module Overview

Before the end of June 2011, the National Oceanic and Atmospheric Administration (NOAA) officially declared the year as being among the most extreme weather-event years in recorded U.S. history (Morello & ClimateWire, 2011). During the first six months of 2011, there were eight weather-related disasters resulting in total damages of over \$32 billion. Whenever these events like Hurricane Katrina (which devastated the Gulf Coast in 2005) or the extreme drought and massive wildfires (which scorched Texas in 2011) occur, people naturally wonder whether and to what extent global climate change may be influencing them.



GOES View of Hurricane Sandy. Image Credit: [NASA](#)

Even though it is impossible to directly link global climate change to a particular event, many of these extreme events are consistent with expected changes from a warming climate. According to the World Meteorological Organization, “Scientists are still studying the links between these events and climate change.” This evidence is beginning to show a pattern consistent with scientists’ predictions of consequences resulting from climate change.

Why are scientists so cautious about confirming a link between extreme weather events and climate change? To help you answer this question, you will first need to understand the difference between weather and climate.

This module examines the fundamentals of weather and climate and why scientists are cautious about confirming a link between the two. You will learn the differences between weather and climate, how climate is classified, and how scientists define and identify weather extremes.

When you complete this module, you should be able to

- Differentiate between weather, and climate.
- Characterize the five general types of climate, as defined by Koppen’s Climate classification system.
- Explain the relationship between global warming and climate change.
- Compare methods meteorologists use for forecasting weather to those used by climate scientists for predicting climate trends.
- Analyze temperature data to identify recent heat waves at various locations on Earth.
- Identify extreme weather events using the National Climatic Data Center (NCDC) website.

Weather Versus Climate

Are Weather and Climate the Same?

WEATHER the state of the atmosphere at some place and time

People often confuse weather and climate; they are not identical. According to the American Meteorological Society (AMS), **weather** is defined as the state of the atmosphere at some place and time, usually expressed in terms of temperature, air pressure, humidity, wind speed and direction, precipitation, and cloudiness. **Meteorologists** study the atmosphere, processes that cause weather, and the life cycle of weather systems.

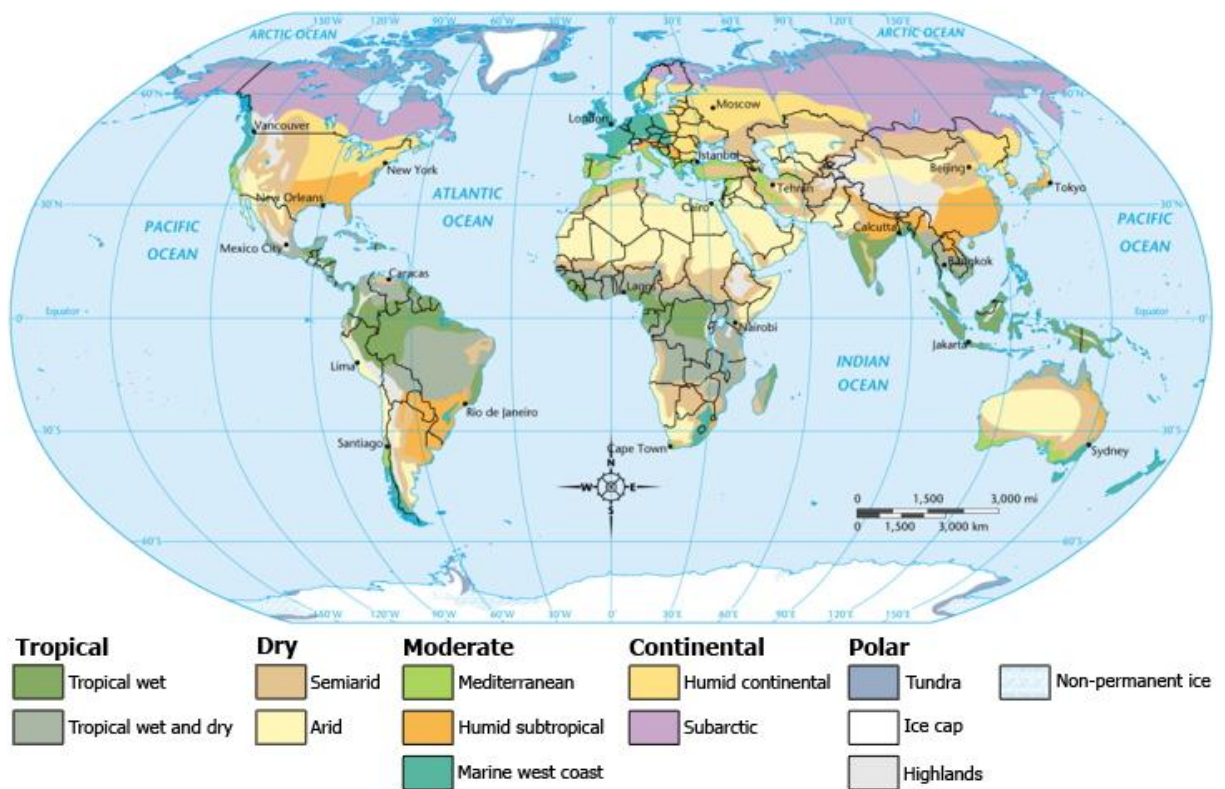
Climate is defined in terms of the average (mean) of weather elements (such as temperature and precipitation) over a specified period of time. (The World Meteorological Organization defines the typical time period of time as 30 years.) Climate also encompasses weather extremes for a particular place.

CLIMATE the average of weather elements over a specified period of time

Scientists have developed a variety of ways for classifying climate. In the early 20th century, a German scientist named Wladimir Köppen developed one of the most widely used classification systems. The Köppen system categorizes climate into five main types, which can be further divided into subcategories. Table 2.1 below shows the five main climate type and characteristics of each type.

Table 2.1 Summary of Köppen's Climate Classification System

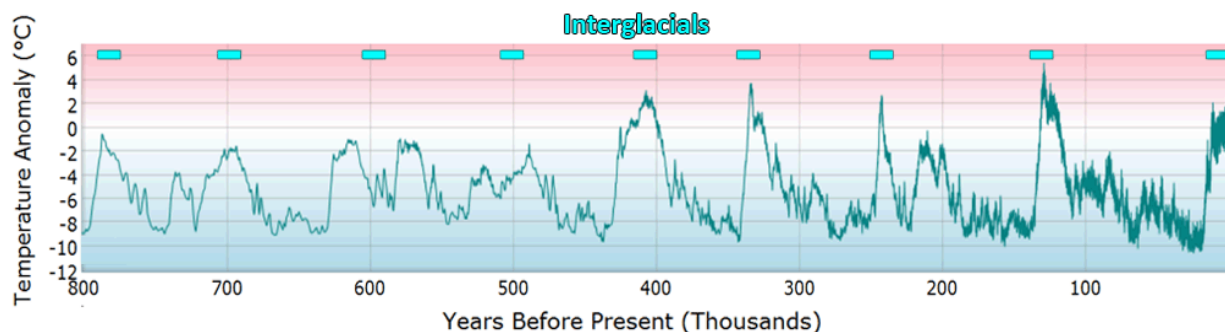
Type of Climate	Characteristics
Tropical	Humid and average temperature above 18°C (64°F)
Dry	Evaporation exceeding precipitation with constant water deficiency throughout the year
Moderate	Humid and warm or hot summers and mild winters with average temperatures between -3°C (27°F) and 18°C (64°F)
Continental	Humid and warm summers with the average temperature of warmest month exceeding 10°C (50°F) cold winters with average temperature of coldest month below -3°C (27°F)
Polar	Extremely cold winters and average temperature of the warmest summer month below 10°C (50°F)



Map of Global Climate Classifications. Image Credit: [Wikipedia](https://en.wikipedia.org/wiki/World_climate_map)

The planet's climate has actually changed many times over Earth's long geologic history. For example, over the past million years, Earth has experienced several glacial periods interspersed with interglacial (warmer) periods. The relatively constant and favorable interglacial period of climate experienced over the past 8,000 years has made human civilization's advancement possible.

Temperature Anomalies Over the Past 800,000 Years (European Project for Ice Coring in Antarctica [EPICA] Ice Core Data)



CLIMATE CHANGE

a significant and sustained change from one climatic condition to another

Climate change refers to a significant and sustained (over decades or longer) change from one climatic condition to another. The term “**global warming**” refers to a specific kind of climate change in which Earth’s average temperature is increasing. Of growing concern is what is known as **abrupt climate change**. According to the National Oceanic and Atmospheric Administration

(NOAA), abrupt climate change is a relatively new area of scientific research whose formal definition is still being developed, but it refers to a sudden, rapid change from one climate state to another (over a period of years rather than centuries or millennia).

GLOBAL WARMING

specific kind of climate change in which Earth’s average temperature is increasing

What Is Abrupt Climate Change?

The United States Climate Change Science Program defines abrupt climate change as “a change in the climate (for example, in temperature or precipitation) that takes place over a few decades or less, persists for at least a few decades, and causes substantial disruptions in human and natural systems.” Abrupt climate change may affect the entire globe or just a region.

Forecasting Weather Versus Climate



Image Credit: [Peter Brown](#), Rocky Mountain Tree-Ring Research

Meteorologists focus primarily on real-time (current) data to predict local or regional atmospheric conditions for the hours, days, or weeks ahead. Thus, weather prediction tends to be more local and relates to conditions in the immediate future from days to weeks.

Climate scientists, on the other hand, look at atmospheric conditions in terms of averages and trends (patterns) that have occurred over many decades, centuries, and millennia. Weather is variable, but can be averaged over time to indicate climate trends. Therefore, climate scientists can use weather data plus **proxy data** to help them identify previous trends and improve their predictions of future trends.

What Are Proxy Data?

Proxy data include biological, cryological (which refers to frozen water), geological, and historical records that scientists use to deduce Earth’s atmospheric conditions in the distant past. By examining evidence such as the tree rings of old-growth trees and ice core samples taken from glaciers, scientists can figure out what Earth’s temperature, greenhouse gas composition, and precipitation levels were like over the course of its geologic history.

Meteorologists and climate scientists use similar tools. Weather balloons, satellites, specially designed airplanes, and radar and other ground-based data collection instruments (to measure wind speed, precipitation, air temperature, humidity levels, etc.) are all good examples. These methods and tools have enabled humans to collect reliable atmospheric data on a consistent basis since the mid 1800s. They have grown increasingly more precise and sophisticated over time, to such an extent that meteorologists can now consistently provide reasonably accurate near-term (1 week or less) weather forecasts.



Image Credit: [NASA](#)

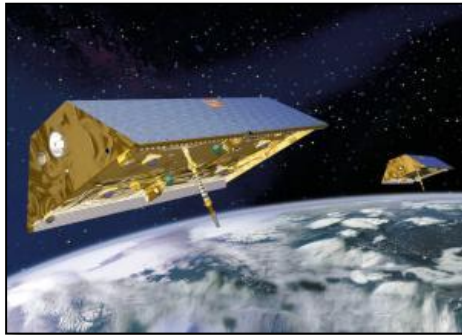


Image Credit: [NASA](#)

Climate monitoring requires data covering all areas of the planet over a much longer time period. Sophisticated Earth-observing satellites equipped with remote-sensing equipment circle the globe. With each pass, they can record sea surface and other temperatures, measure atmospheric gases and rainfall amounts, take visible and infrared photos of Earth's surface, and calculate Earth's outgoing infrared and reflected solar radiation.

Increasing Resolution of Global Climate Models

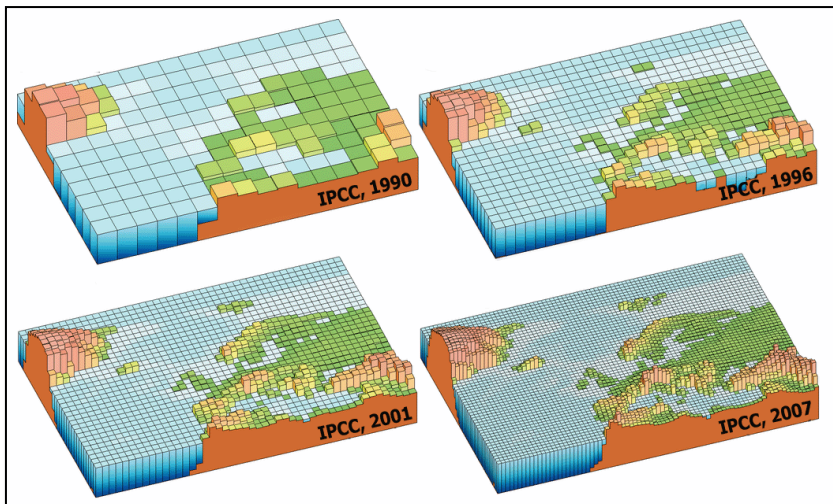


Image Credit: IPCC

Climate scientists also use increasingly higher resolution computer models, known as global climate models, to simulate the physical processes of the atmosphere and oceans and make predictions about future climate scenarios.

Extreme Weather Events

How "Extreme" Is Extreme?

All weather events that cause loss of life, disrupt normal human activities, and result in property damage appear extreme. It is a question of perspective: How do today's severe weather events compare to severe weather events in the recent and distant past?

Several variables (land-use practices, population density, and flood-control projects) can complicate making direct comparisons between past and present events. For example, since 1986 the global human population has grown by approximately 2 billion. Simply said, there are more people than ever living in formerly unpopulated or sparsely populated areas. So comparing death tolls, between recent and past events may not be the most meaningful indicator of a particular weather event's intensity.



Image Credits: Microsoft Clip Art (2) and SFWMD.

Nonetheless, the growing body of meteorological data indicates an increase in the number of extreme weather events occurring here in the United States since 1980, and the number of extreme events also appears to be rising worldwide.

Billion Dollar Weather/Climate Disasters 1980 - 2011

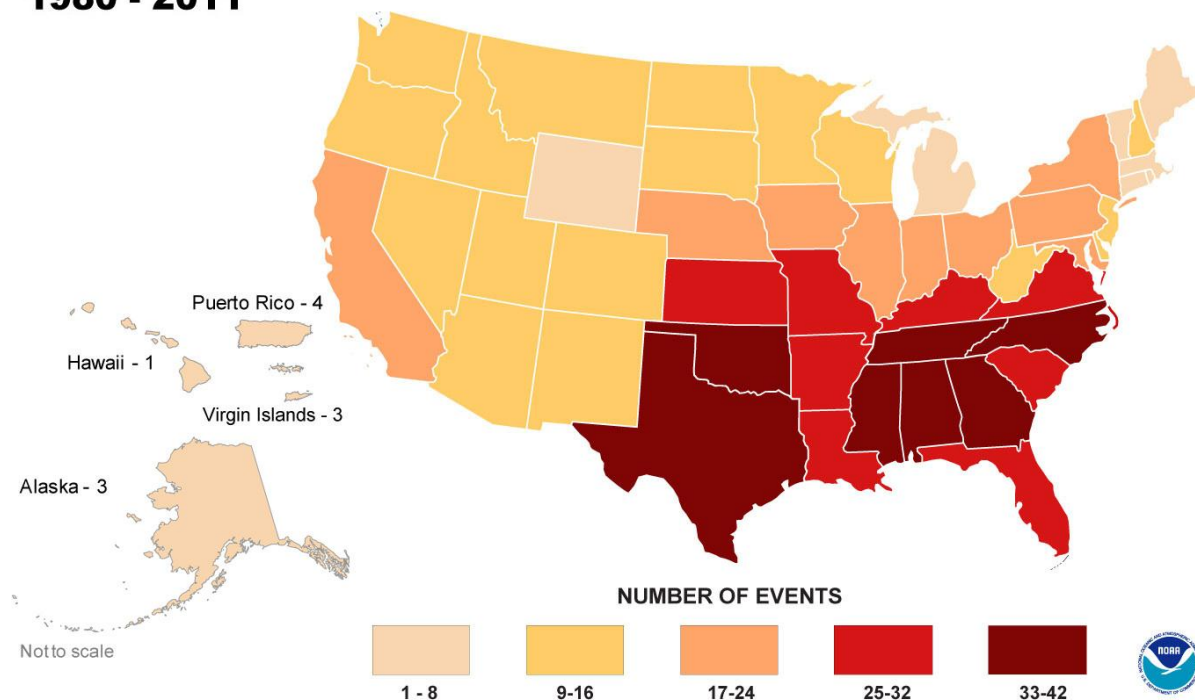


Image Credit: [NOAA](http://noaa.gov)

Below are just a few examples from the last several years:

2009–2010 Eastern United States “Snowmageddon”

According to meteorologist Dr. Jeff Masters, a “bizarre upside-down” wintertime Arctic circulation in the atmosphere was the “most extreme configuration in 145 years of record keeping.” A high-pressure center with clockwise winds replaced the normal low-pressure center with a counter-clockwise airflow. As a result, frigid Arctic air flooded the eastern United States and dumped over 2 feet of snow from Philadelphia to D.C. while warm air moved into Canada and caused “the warmest and driest winter on record.” There was so little snow on the ground for the

Vancouver winter Olympics that Canada was forced to bring in snow by truck for the event.

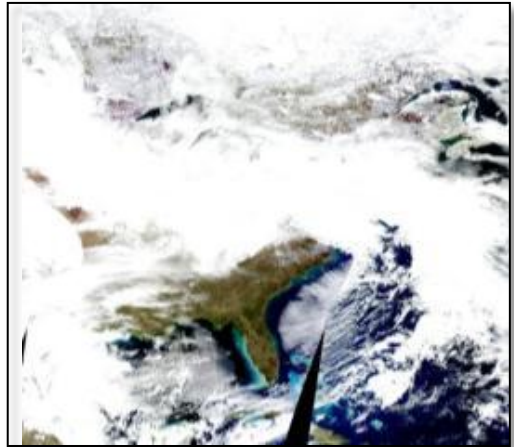


Image Credit: [NASA](#)



Image Credit: Microsoft Clip Art

2010 Russian Heat Wave and Fires

“Russia’s meteorological service says the 50-day heat wave in Central Russia was the worst weather-caused natural disaster in the northern hemisphere in 2010. On average, the year was the hottest since at least 1891, when records were first kept” (RT.com/TV-Novosti, 2011). According to the Center for Research on the Epidemiology of Disasters (CRED’s) EM-DAT Website, over 55,000 people died in the 2010 Russian heat wave, which was compounded by raging forest fires near Moscow, the capital city.

2010 Northern Pakistan Floods

The Russian drought and fires were accompanied by the floods in Pakistan, which were the worst in at least 80 years. A NASA research study has found “that the same large-scale meteorological event — an abnormal Rossby wave [part of the jet stream] — sparked extreme heat and persistent wildfires in Russia as well as unusual downstream wind patterns that shifted rainfall in the Indian monsoon region and fueled heavy flooding in Pakistan” (*Science Daily*, 2011).

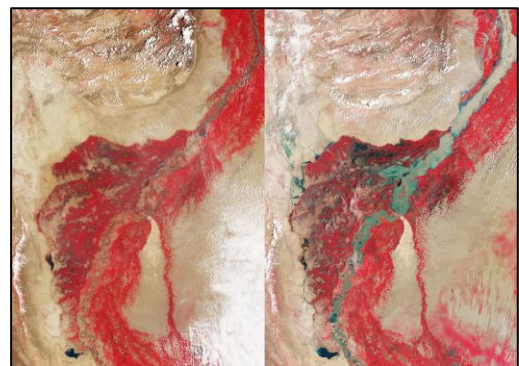


Image Credit: [NASA](#)

CRED reports that the July 2010 death toll in the Pakistan floods was lower than for the major flood in 1950. However, in terms of the number of people affected (20,359,496) and the damage (\$9,500,000, in U.S. dollars), the flood of 2010 was the worst in Pakistan’s history.



Image Credit: [NASA](#)

2010 South Atlantic Rare Tropical Storm

The U.S. Naval Research Laboratory began tracking a rare South Atlantic subtropical cyclone designated 90Q on March 9, 2010. On March 10, the storm intensified, and it was upgraded to a tropical storm. On March 13, it was given the name Anita. Including Anita, there have been just a handful of documented tropical storms in the South Atlantic. And although Anita's formation was very unusual, in 2004 Hurricane Catarina was the "first documented hurricane to ever occur in the South Atlantic basin" (Braun, 2008). Tropical and subtropical storms rarely form in the South Atlantic basin due to a combination of strong wind shear air currents and cool sea temperatures. Between 1957 and 2007, there were just 92 documented subtropical storms in the South Atlantic.

2010–2011 Texas's Worst Drought and Fire Season in Recorded History

Between the fall of 2010 (the beginning of the wildfire season) and September 1, 2011, Texas had 16,368 fires, with nearly 3.5 million acres (14,163.99 square kilometers) having burned. These fires were sparked by what Texas State Climatologist John Nielsen-Gammon described as the worst drought in Texas over a 12-month period in the state's history. According to the National Climate Data Center, July 2011 was the hottest month ever recorded (since records began being kept back in 1895). The Texas Plant and Soil Lab blog (2011) reported that crops had failed, ranchers were selling off their "skin-and-bones" cattle herds, and 1,400 homes burned in the Bastrop fires alone. It went on to describe the situation as "events of Biblical proportions."



Image Credit: [NOAA](#)



Image Credit: Microsoft Clip Art

What Is the Significance of Weather Extremes?

The variability of these events — for example, excessive precipitation (rain and snow) or heat waves, drought, and wildfires — is so great, that scientists need a long record of observations and data to establish definitive links between severe events and climate change. By definition, extreme weather events are rare, which means that oftentimes there are very limited data available to use for comparison.

However, the IPCC's 2012 report, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, indicates that scientists have enough confidence in the data collected since 1950 to definitively link extreme temperatures to global climate change.

"It is *very likely* that there has been an overall decrease in the number of cold days and nights³, and an overall increase in the number of warm days and nights³, on the global scale, i.e., for most land areas with sufficient data. ... It is *virtually certain* that increases in the frequency and magnitude of warm daily temperature extremes and decreases in cold extremes will occur in the 21st century on the global scale." (Source: IPCC, 2012 report, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, pp. 13, 11)

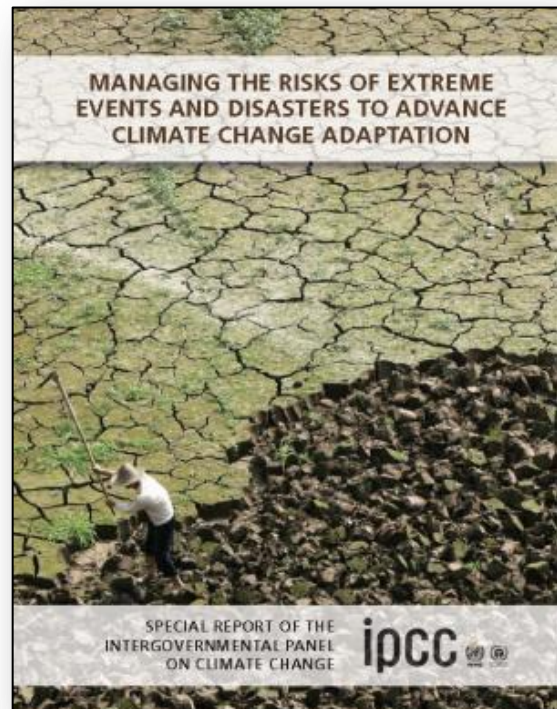


Image Credit: [IPCC](#)



Image Credit: [Microsoft Clip Art](#)

IPCC scientists also note "statistically significant trends in the number of heavy precipitation events in some regions," but there is less confidence in whether the data confirm there is an overall global increase in these events (IPCC, 2012). Scientific evidence of a link between climate change and specific, extremely large, violent hurricanes and tornadoes is also much less certain.

The increasing number of extreme weather events is consistent with what climate scientists have long predicted. They result in significant loss of life, destruction of public infrastructure and private property, economic hardship, and social disruption. Additionally, unusually high nighttime temperatures (in the absence of wildfires or other extreme events) can reduce crop yields, and prolonged drought can trigger crop failures — both of which increase the problem of worldwide food shortages and hunger.

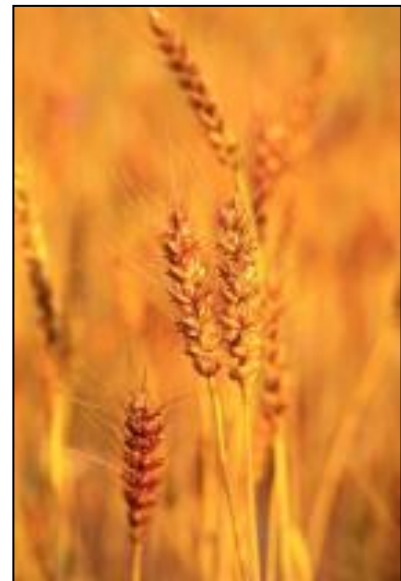


Image Credit: [Microsoft Clip Art](#)

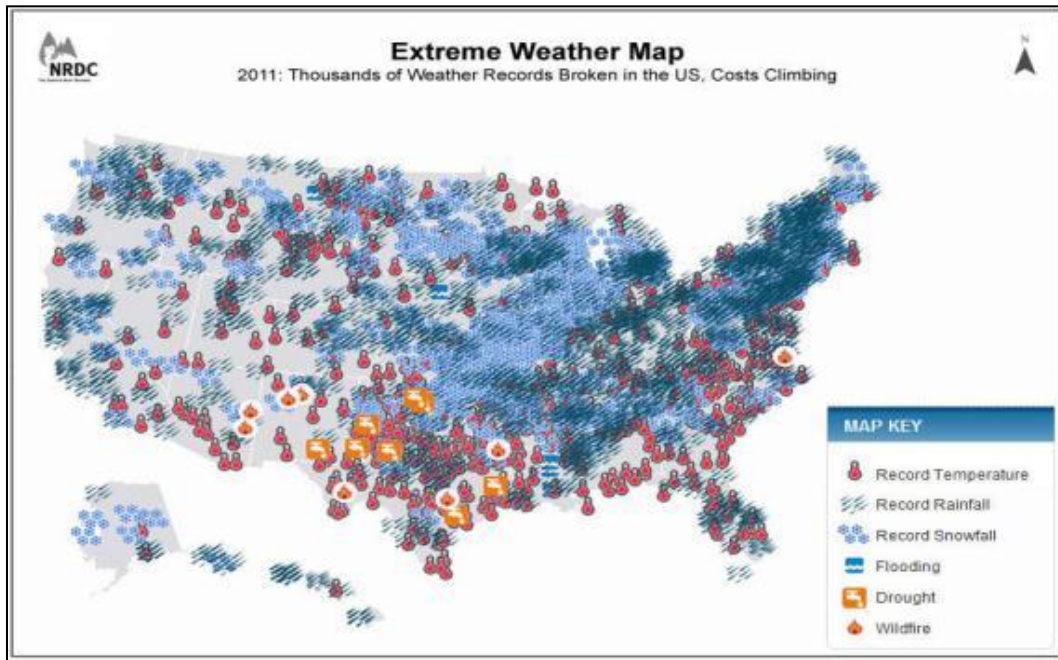


Image credit: [NRDC](#)

Multiple natural disasters occurring within a short timeframe (as we have recently experienced here in the United States) place added strain on fragile electrical grids and other aging systems and increase the cost for national, state, and local governments. And the huge economic damages that result from extreme weather threaten the stability of our insurance system.

**To learn more about extreme weather,
proceed to the Investigation *Are Extreme Weather Events Increasing?***

Weather and Climate - Review

In this module, you have learned that weather refers to current atmospheric conditions occurring at a particular place. Climate, by contrast, refers to weather trends and patterns occurring globally or regionally over decades, centuries, and even millennia. Extreme weather events, by definition, are rare and intense. You have learned that although scientists are still unable to conclusively link specific extreme weather events to global climate change, these events are predicted consequences of long-term changes in Earth's climate.