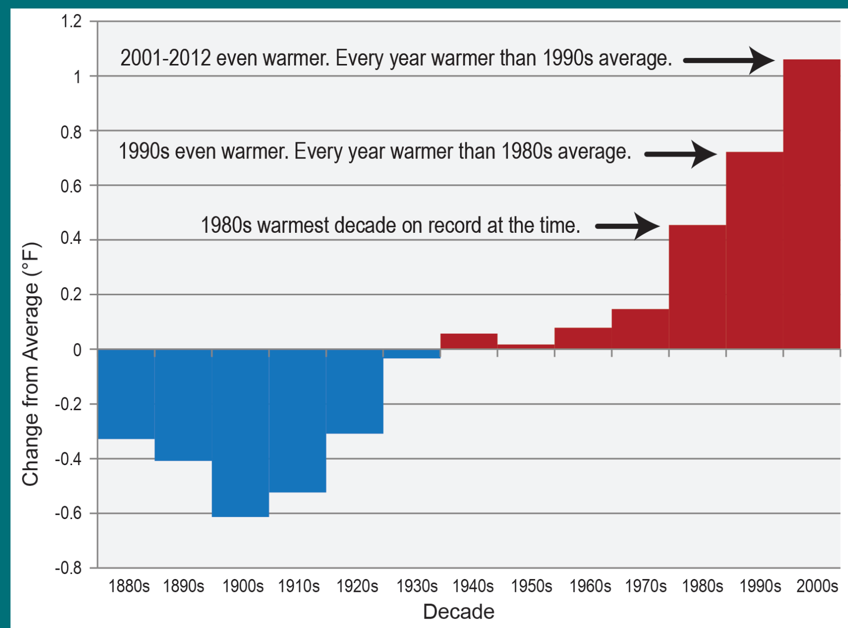
FINDING 1 OUR CHANGING CLIMATE

Global climate is changing and this is apparent across a wide range of observations.

Evidence for changes in Earth's climate can be found from the top of the atmosphere to the depths of the oceans. Researchers from around the world have compiled this evidence using satellites, weather balloons, thermometers at surface stations, and many other types of observing systems that monitor the Earth's weather and climate. The sum total of this evidence tells an unambiguous story: the planet is warming.

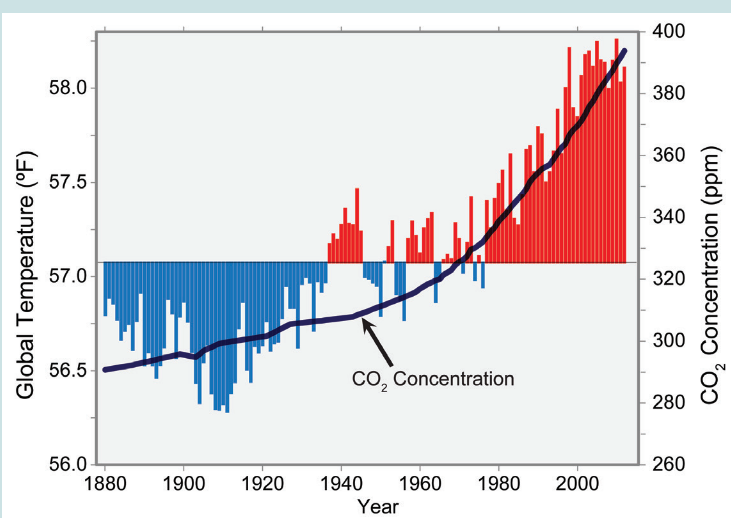
Temperatures at Earth's surface, in the troposphere (the active weather layer extending up to about 5 to 10 miles above the ground), and in the oceans have all increased over recent decades. The largest increases in temperature are occurring closer to the poles, especially in the Arctic. This warming has triggered many other changes to the Earth's climate. Snow and ice cover have decreased in most areas. Atmospheric water vapor is increasing in the lower atmosphere because a warmer atmosphere can hold more water. Sea level is increasing because water expands as it warms and because melting ice on land adds water to the oceans. Changes in other climate-relevant indicators such as growing season length have been observed in many areas. Worldwide, the observed changes in average conditions have been accompanied by increasing trends in extremes of heat and heavy precipitation events, and decreases in extreme cold. It is the sum total of these indicators that leads to the conclusion that warming of our planet is unequivocal.

Temperature Change by Decade



The last five decades have seen a progressive rise in the Earth's average surface temperature. Bars show the difference between each decade's average temperature and the overall average for 1901-2000. (Figure source: NOAA NCDC).

Global Temperature and Carbon Dioxide

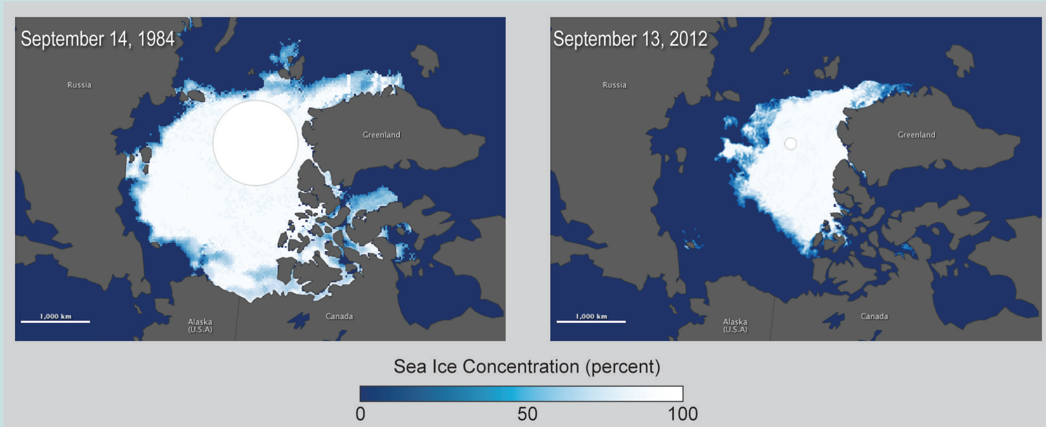


Global annual average temperature (as measured over both land and oceans) has increased by more than 1.5°F (0.8°C) since 1880 (through 2012). Red bars show temperatures above the long-term average, and blue bars indicate temperatures below the long-term average. The black line shows atmospheric carbon dioxide (CO_2) concentration in parts per million (ppm). While there is a clear long-term global warming trend, some years do not show a temperature increase relative to the previous year, and some years show greater changes than others. These year-to-year fluctuations in temperature are due to natural processes, such as the effects of El Niños, La Niñas, and volcanic eruptions. (Figure source: updated from Karl et al. 2009[1]).

FAQ

Sea ice in the Arctic has decreased dramatically since the satellite record began in 1978. Minimum Arctic sea ice extent (which occurs in early to mid-September) has decreased by more than 40%.[2] This decline is unprecedented in the historical record, and the reduction of ice volume and thickness is even greater. Ice thickness decreased by more than 50% from 1958-1976 to 2003-2008.[3] The percentage of the March ice cover made up of thicker ice (ice that has survived a summer melt season) decreased from 75% in the mid-1980s to 45% in 2011.[4]

Arctic Sea Ice Decline

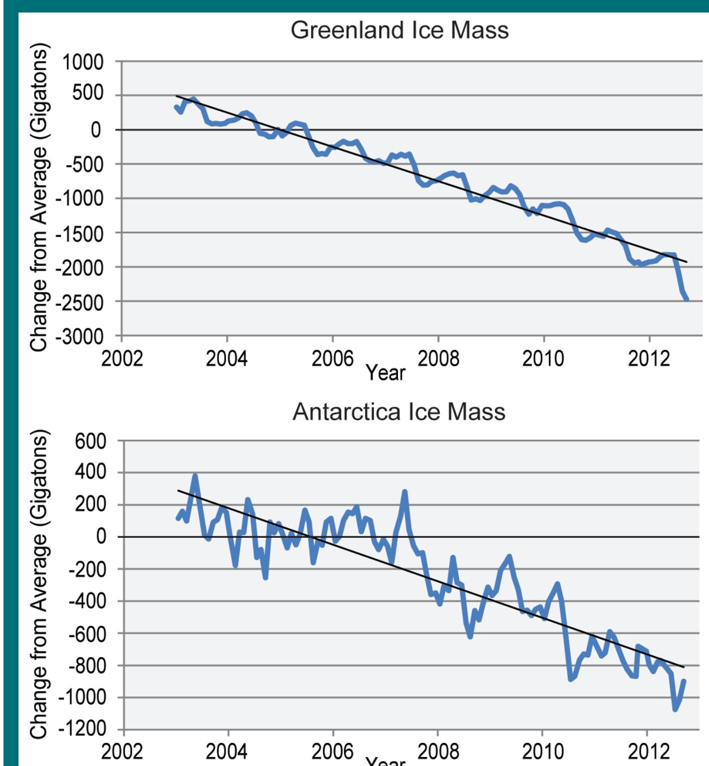


The retreat of sea ice has occurred faster than climate models had predicted. Image on left shows Arctic minimum sea ice extent in 1984, which was about 2.59 million square miles, the average minimum extent for 1979-2000. Image on right shows that the extent of sea ice had dropped to 1.32 million square miles at the end of summer 2012. The dramatic loss of Arctic sea ice increases warming and has many other impacts on the region. Marine mammals including polar bears and many seal species depend on sea ice for nearly all aspects of their existence. Alaska Native coastal communities rely on sea ice for many reasons, including its role as a buffer against coastal erosion from storms and as a platform for hunting. (Figure source: NASA Earth Observatory 2012[8]).

Ice loss increases Arctic warming by replacing white, reflective ice with dark water that absorbs more energy from the sun. More open water can also increase snowfall over northern land areas[5] and increase the north-south meanders of the jet stream, consistent with the occurrence of unusually cold and snowy winters at mid-latitudes in several recent years.[5,6] Significant uncertainties remain in interpreting the effect of Arctic ice changes on mid-latitude weather patterns.[7]

In addition to the rapid decline of Arctic sea ice, rising temperatures are reducing the volume and surface extent of ice on land and lakes. Snow cover on land has also decreased over the past several decades, especially in late spring.

Ice Loss from the Two Polar Ice Sheets



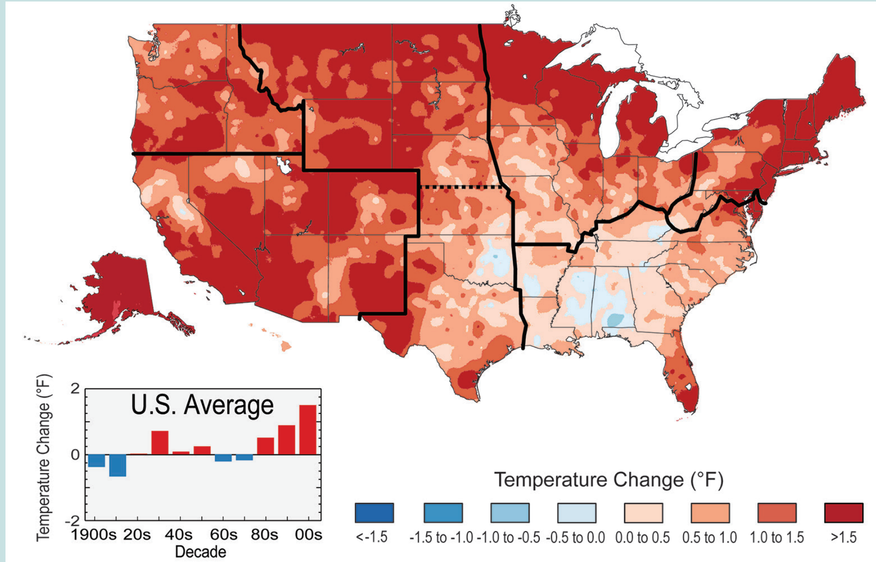
Satellite measurements show that both Greenland and Antarctica are losing ice as the atmosphere and oceans warm. Melting of the polar ice sheets and glaciers on land add water to the oceans and raise sea level. How fast these two polar ice sheets melt will largely determine how quickly sea level rises. (Figure source: adapted from Wouters et al. 2013[9]).

The ice sheets on Greenland and Antarctica are losing mass, adding to global sea level rise.

Climate in the United States is changing.

U.S. average temperature has increased by 1.3°F to 1.9°F since record keeping began in 1895; most of this increase has occurred since about 1970. The most recent decade was the nation's warmest on record. Because human-induced warming is superimposed on a naturally varying climate, the temperature rise has not been, and will not be, uniform or smooth across the country or over time.

Observed U.S. Temperature Change



The colors on the map show temperature changes over the past 22 years (1991-2012) compared to the 1901-1960 average for the contiguous U.S., and to the 1951-1980 average for Alaska and Hawai'i. The bars on the graph show the average temperature changes for the U.S. by decade for 1901-2012 (relative to the 1901-1960 average). The far right bar (2000s decade) includes 2011 and 2012. The period from 2001 to 2012 was warmer than any previous decade in every region. (Figure source: NOAA NCDC / CICS-NC).

While surface air temperature is the most widely cited measure of climate change, other aspects of climate that are affected by temperature are often more directly relevant to both human society and the natural environment. Examples include shorter duration of ice on lakes and rivers, reduced glacier extent, earlier melting of snowpack, reduced lake levels due to increased evaporation, lengthening of the growing season, changes in plant hardiness zones, increased humidity, rising ocean temperatures, rising sea level, and changes in some types of extreme weather.

Taken as a whole, these changes provide compelling evidence that increasing temperatures are affecting both ecosystems and human society.

A longer growing season provides a longer period for plant growth and productivity and can slow the increase in atmospheric CO_2 concentrations through increased CO_2 uptake by living things and their environment.[10] The longer growing season can increase the growth of beneficial plants (such as crops and forests) as well as undesirable ones (such as ragweed).[11] In some cases where moisture is limited, the greater evaporation and loss of moisture through plant transpiration (release of water from plant leaves) associated with a longer growing season can mean less productivity because of increased drying[12] and earlier and longer fire seasons.

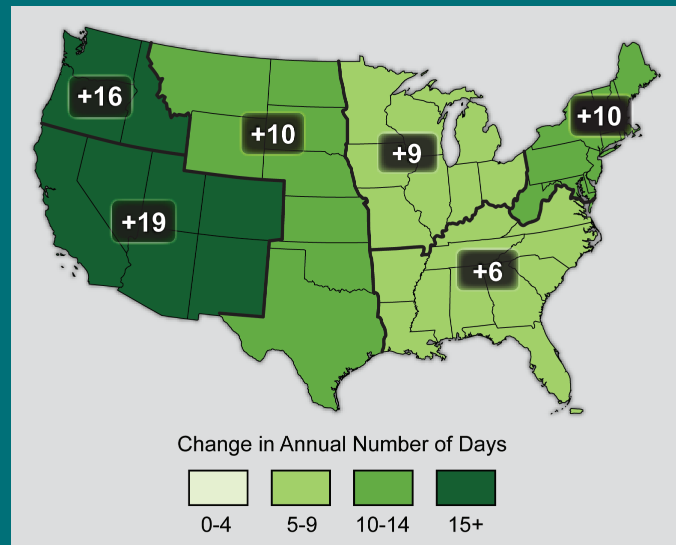
On the left is a photograph of Muir Glacier in Alaska taken on August 13, 1941; on the right, a photograph taken from the same vantage point on August 31, 2004. Total glacial mass has declined sharply around the globe, adding to sea level rise. (Left photo by glaciologist William O. Field; right photo by geologist Bruce F. Molnia of the United States Geological Survey.)

Increased frost-free season length, especially in already hot and moisture-stressed regions like the Southwest, can lead to further heat stress on plants and increased water demands for crops. Higher temperatures and fewer frost-free days during winter can lead to early bud burst or bloom of some perennial plants, resulting in frost damage when cold conditions occur in late spring. In addition, with higher winter temperatures, some agricultural pests can persist year-round, and new pests and diseases may become established.[13]

The lengthening of the frost-free season has been somewhat greater in the western U.S. than the eastern U.S.,[1] increasing by 2 to 3 weeks in the Northwest and Southwest, 1 to 2 weeks in the Midwest, Great Plains, and Northeast, and slightly less than 1 week in the Southeast. These differences mirror the overall trend of more warming in the north and west and less warming in the Southeast.

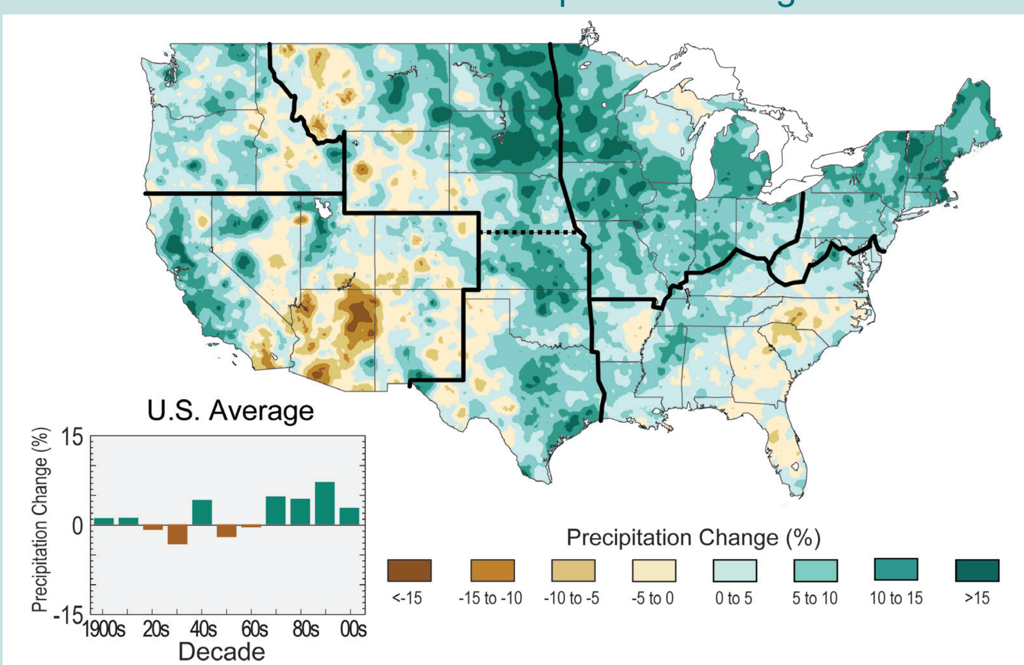
Average annual precipitation over the U.S. has increased in recent decades, although there are important regional differences. For example, precipitation since 1991 (relative to 1901-1960) increased the most in the Northeast (8%), Midwest (9%), and southern Great Plains (8%), while much of the Southeast and Southwest had a mix of areas of increases and decreases.

Observed Increases in Frost-Free Season



The frost-free season length, defined as the period between the last occurrence of 32°F in the spring and the first occurrence of 32°F in the fall, has increased in each U.S. region during 1991-2012 relative to 1901-1960. Increases in frost-free season length correspond to similar increases in growing season length. (Figure source: NOAA NCDC / CICS-NC).

Observed U.S. Precipitation Change



The colors on the map show annual total precipitation changes for 1991-2012 compared to the 1901-1960 average, and show wetter conditions in most areas. The bars on the graph show average precipitation differences by decade for 1901-2012 (relative to the 1901-1960 average). The far right bar is for 2001-2012. (Figure source: NOAA NCDC / CICS-NC).

The global warming of the past 50 years is primarily due to human activities, predominantly the burning of fossil fuels.

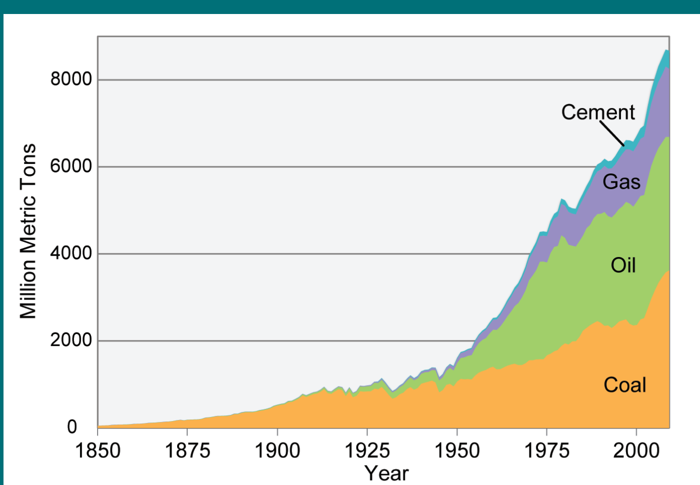
Climate has changed naturally throughout Earth's history. However, natural factors cannot explain the recent observed warming.

In the past, climate change was driven exclusively by natural factors: explosive volcanic eruptions that injected reflective particles into the upper atmosphere, changes in energy from the sun, periodic variations in the Earth's orbit, natural cycles that transfer heat between the ocean and the atmosphere, and slowly changing natural variations in heat-trapping gases in the atmosphere.

All of these natural factors, and their interactions with each other, have altered global average temperature over periods ranging from months to thousands of years. For example, past glacial periods were initiated by shifts in the Earth's orbit, and then amplified by resulting decreases in atmospheric levels of carbon dioxide and subsequently by greater reflection of the sun's energy by ice and snow as the Earth's climate system responded to a cooler climate.

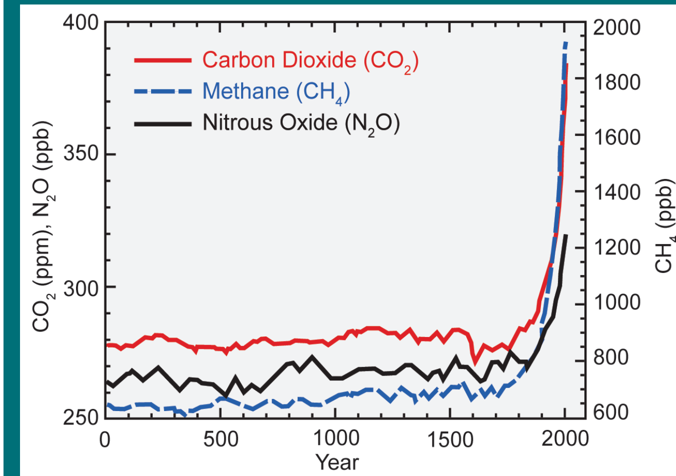
Natural factors are still affecting the planet's climate today. The difference is that, since the beginning of the Industrial Revolution, humans have been increasingly affecting global climate, to the point where we are now the primary cause of recent and projected future change.

Carbon Emissions in the Industrial Age



Carbon emissions from burning coal, oil, and gas and producing cement, in units of million metric tons of carbon. These emissions account for about 80% of the total emissions of carbon from human activities, with land-use changes (like cutting down forests) accounting for the other 20% in recent decades. (Data from Boden et al. 2012[15]).

2000 Years of Heat-Trapping Gas Levels



Increases in concentrations of these gases since 1750 are due to human activities in the industrial era. Concentrations are parts per million (ppm) or parts per billion (ppb), indicating the number of molecules of the greenhouse gas per million or billion molecules of air. (Figure source: Forster et al. 2007[14]).

The majority of the warming at the global scale over the past 50 years can only be explained by the effects of human influences, especially the emissions from burning fossil fuels (coal, oil, and natural gas) and from deforestation.

The emissions from human influences affecting climate include heat-trapping gases such as carbon dioxide (CO_2), methane, and nitrous oxide, and particles such as black carbon (soot), which has a warming influence, and sulfates, which have an overall cooling influence. In addition to human-induced global climate change, local climate can also be affected by other human factors (such as crop irrigation) and natural variability.

Carbon dioxide has been building up in the atmosphere since the beginning of the industrial era in the mid-1700s, primarily due to burning coal, oil, and gas, and secondarily due to clearing of forests. Atmospheric levels have increased by about 40% relative to pre-industrial levels.

Methane levels in the atmosphere have increased due to human activities including agriculture (with livestock producing methane in their digestive tracts and rice farming producing it via bacteria that live in the flooded fields); mining coal, extraction and transport of natural gas, and other fossil fuel-related activities;

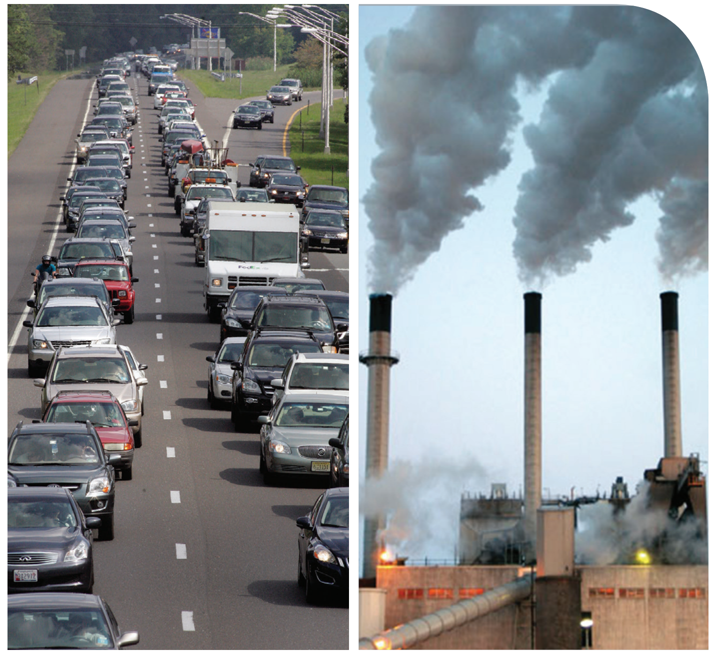
and waste disposal including sewage and decomposing garbage in landfills. Since pre-industrial times, methane levels have increased by 250%.

Other heat-trapping gases produced by human activities include nitrous oxide, halocarbons, and ozone. Nitrous oxide levels are increasing, primarily as a result of fertilizer use and fossil fuel burning. The concentration of nitrous oxide has increased by about 20% relative to pre-industrial times.

The conclusion that human influences are the primary driver of recent climate change is based on multiple lines of independent evidence. The first line of evidence is our fundamental understanding of how certain gases trap heat, how the climate system responds to increases in these gases, and how other human and natural factors influence climate. The second line of evidence is from reconstructions of past climates using evidence such as tree rings, ice cores, and corals. These show that global surface temperatures over the last several decades are clearly unusual, with the last decade (2000-2009) warmer than any time in at least the last 1,300 years and perhaps much longer.

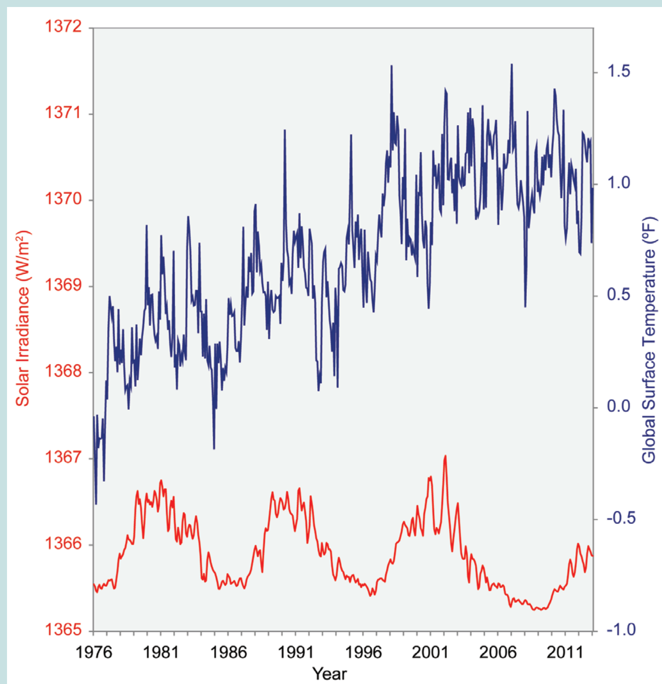
The third line of evidence comes from using climate models to simulate the climate of the past century, separating the human and natural factors that influence climate. When the human factors are removed, these models show that solar and volcanic activity would have tended to slightly cool the earth, and other natural variations are too small to explain the amount of warming. Only when the human influences are included do the models reproduce the warming observed over the past 50 years.

Another line of evidence involves so-called "fingerprint" studies that are able to attribute observed climate changes to particular causes. For example, the fact that the stratosphere (the layer above the troposphere) is cooling while the Earth's surface and lower atmosphere are warming is a fingerprint that the warming is due to increases in heat-trapping gases. In contrast, if the observed warming had been due to increases in solar output, Earth's atmosphere would have warmed throughout its entire extent, including the stratosphere. In addition to such temperature analyses, scientific attribution of observed changes to human influence extends to many other aspects of climate, such as changing patterns in precipitation, increasing humidity, changes in pressure, and increasing ocean heat content.



Oil used for transportation and coal used for electricity generation are the largest contributors to the rise in carbon dioxide that is the primary driver of recent climate change.

Measurements of Surface Temperature and Sun's Energy



The full record of satellite measurements of the sun's energy received at the top of the Earth's atmosphere is shown in red, following its natural 11-year cycle of small ups and downs, without any net increase. Over the same period, global temperature relative to 1961-1990 average (shown in blue) has risen markedly. This is a clear indication that changes in the sun are not responsible for the observed warming over recent decades. (Figure source: NOAA NCDC / CICS-NC).