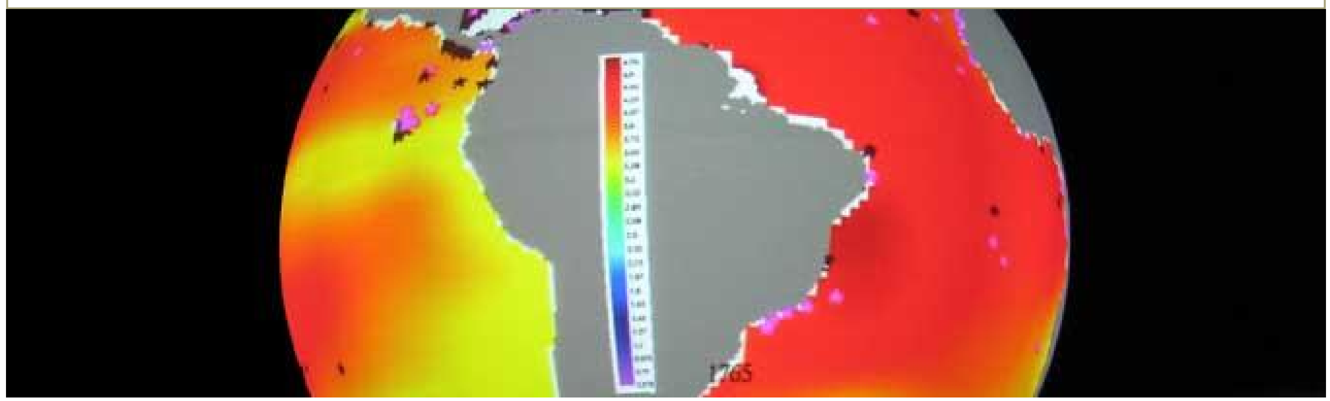
THE BASICS



The Basics

The Center for Climate and Energy Solutions is a source of reliable information about the causes and potential consequences of climate change. Here we provide an overview of fundamental facts and data and answers to frequently asked questions.

The Earth is warming

The world is undoubtedly warming. The Earth's average surface temperature has increased by about 1.4°F (0.8°C) since the late 1800s. Since the 1970s, each decade has been warmer than the previous decade.

The 10 warmest years on record (since 1880) have all occurred since 1998, and all but one have happened since 2000. See a list of global average annual temperatures here.

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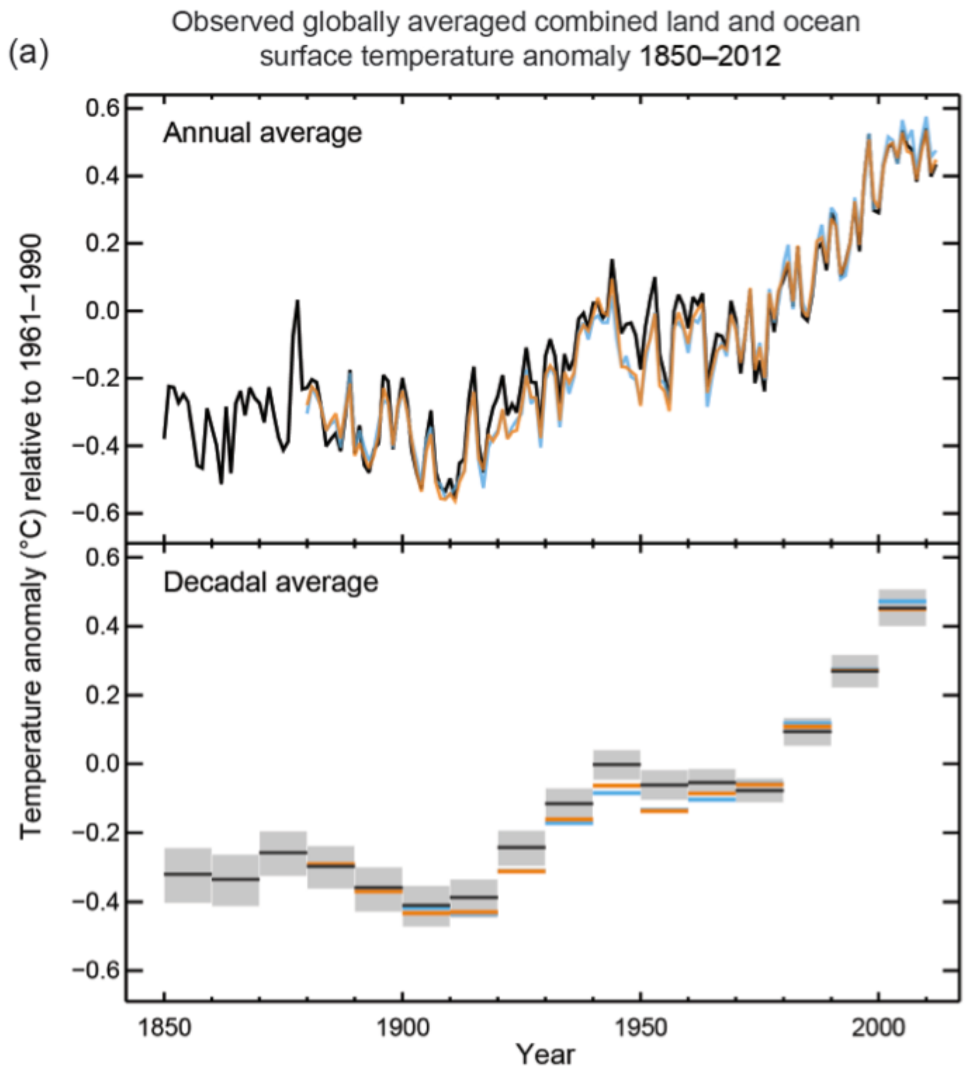
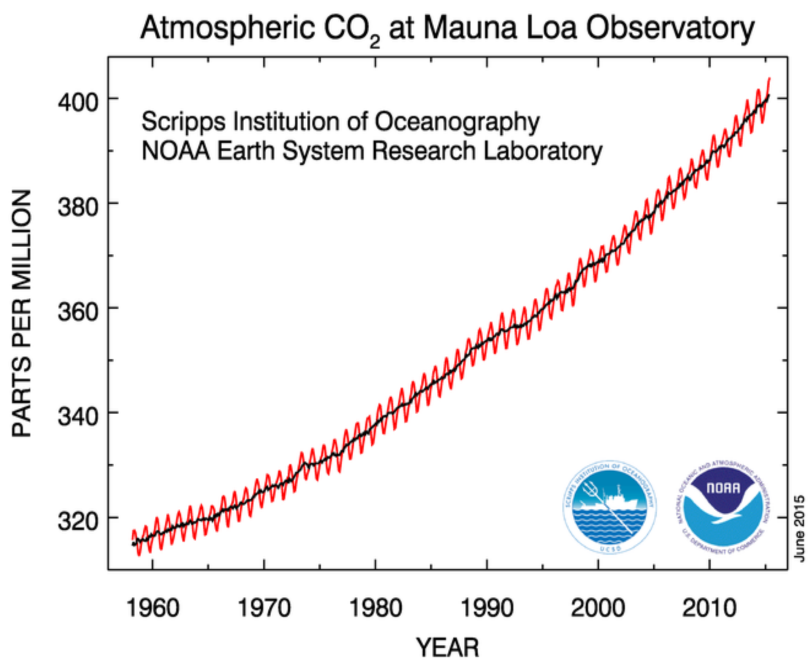


Observed global mean temperature anomalies, combined for the land and ocean, from 1850 to 2012 from three data sets. Top panel: annual mean values. Bottom panel: decadal mean values including the estimate of uncertainty for one dataset (black). Anomalies are relative to the mean of 1961-1990. Source: Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) Working Group 1, Figure SPM.1.

Human-caused emissions are responsible

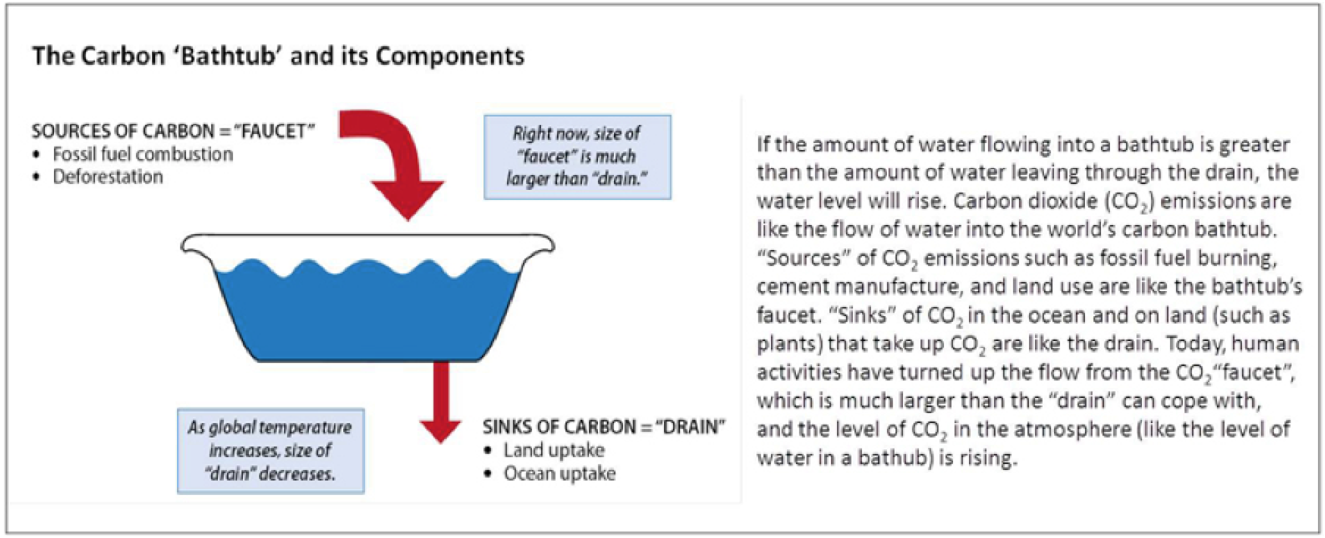
The warming of the Earth is largely the result of emissions of carbon dioxide and other greenhouse gases from human activities. These activities include burning fossil fuels and changes in land use, such as agriculture and deforestation.

As a result, greenhouse gases are accumulating in our atmosphere. Carbon dioxide concentrations in the atmosphere since pre-industrial times have increased from 280 parts per million to nearly 400 parts per million.



Atmospheric carbon dioxide from 1958-2014. The red curve shows the monthly average. The black curve has been adjusted to take the seasonal changes in CO_2 concentration into account. Source: Dr. Pieter Tans, NOAA/ESRL (http://www.esrl.noaa.gov/gmd/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography (scrippsco2.ucsd.edu/).

The reason for the accumulation is simple: Human activities are putting more carbon dioxide than the planet’s vegetation and ocean can remove. A useful analogy is that of a bathtub, where the flow of water out of the faucet exceeds the flow through the drain, as illustrated in the U.S. Environmental Protection Agency’s (EPA) background materials on the causes of climate change.



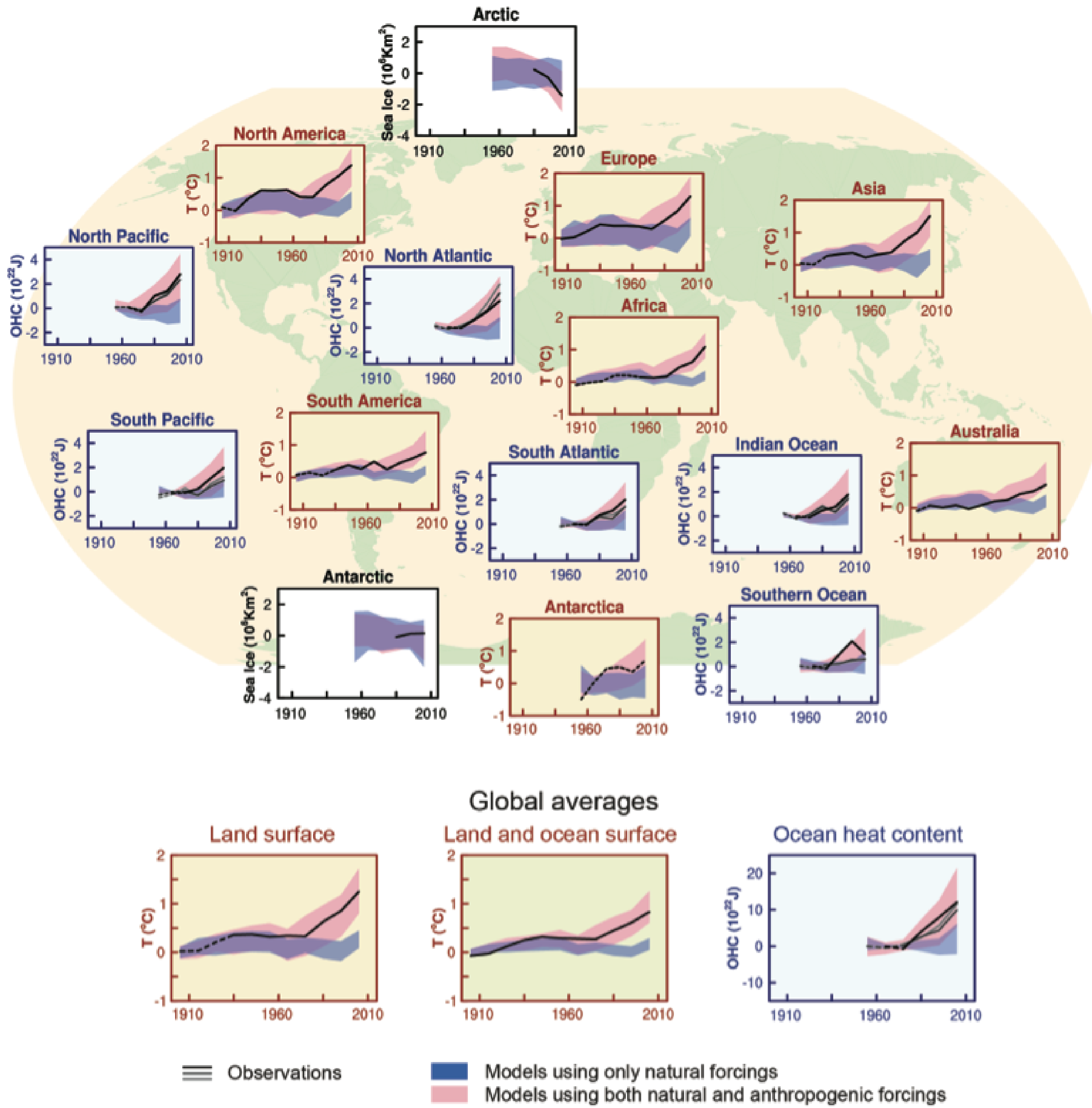
At the rate we are putting carbon dioxide into the atmosphere, it accumulates faster than it can be drained out. Source: EPA: Causes of Climate Change, based on the National Research Council publication Warming World, Impacts by Degree.

The warming we've observed has been driven, in large part, by the accumulation of greenhouse gases in the atmosphere.

The Fifth Assessment Report (AR5) from the IPCC summarizes: *It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century… It is extremely likely that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together.*
IPCC AR5, Working Group 1, Summary for Policy Makers, p.17

Other factors capable of changing the climate, like volcanic eruptions and changes in the sun's intensity, cannot by themselves explain the changes we've observed in the Earth's climate. The figure below shows the outcomes of different computer simulations of climate (see caption for details).Only the simulations that included human influences exhibited warming similar to the observed temperatures around the globe during the last century.

Comparison of observed and simulated indicators of climate change



Observed (black lines) and simulated (shading) surface temperatures, ocean heat content, and sea ice extent. The blue shading represents simulations without humans' influence on climate, and do not match the globally-average observations or those over most continents. The pink shading represents simulations where greenhouse gas emissions and other human influences have been taken into account – these simulations do a much better job at

tracking temperatures and ocean heat content globally and regionally. Source: IPCC AR5 Working Group 1 report, Figure SPM.6.

Impacts will be severe if the trend continues

The amount of warming that occurs by the end of this century depends on our choices now. If we don't make much progress in curbing emissions, temperatures for the planet could rise between 4.7°F to 8.6°F (2.6°C to 4.8°C) by the end of the century, compared to the average temperature around the end of the 20th century (1986-2005). Warming in the United States is expected to be higher than the global average. Warming averaged across the country could be between 5°F to 10°F, assuming that emissions rates continue.

Although we have the opportunity to avoid some of this warming, we are still likely to face a number of impacts arising from climate change in the coming decades. In fact, we are already observing some of these impacts now.

- **Sea level rise** – Sea level has risen about 8 inches in the last 100 years, making coastal storms more damaging and accelerating erosion. Globally, future sea level rise is likely to range from 1 to 4 feet, and could be even higher if glaciers in Greenland or Antarctica melt especially quickly.
- **Polar ice** – Arctic sea ice during the summer has been shrinking, and sometime in the 21st century, perhaps within the next few decades, the Arctic will likely be ice-free in the summer. The ice sheets in Greenland and Antarctica have also been melting more rapidly in recent years, which could increase the rate of global sea level rise.
- **More heavy downpours** – More rain is coming in heavy precipitation events in many parts of the world, including the United States. This may contribute to stronger or more frequent floods.
- **More heat waves** – Heat waves have become more frequent and intense, threatening human health, stressing water resources, and increasing energy demands.
- **Threats to ecosystems** – Many plants and animals will be forced to shift their habitats to higher elevations or higher latitudes as warming makes it more difficult to thrive in their current locations.
- **Increased agricultural pests** – With milder winters, many pests and pathogens that affect plants and livestock have been able to migrate to new areas, posing problems to farmers and ranchers.
- **Ocean acidification** – Increased carbon dioxide in the atmosphere has caused the oceans to become more acidic. Further acidification could dissolve the shells of many organisms at the bottom of the food chain, threatening to disrupt the ocean ecosystem.

These impacts pose challenges to infrastructure, businesses, and communities, particularly in countries already struggling to meet the basic food, water, shelter, and security needs of their citizens.

In addition, rapid warming can increase the risk of climate "surprises" or "tipping points." Examples of these tipping points include the injection of methane into the atmosphere from thawing permafrost that could further accelerate warming, or the loss important ecosystems, such as large areas of the boreal or Amazon forests, that occurs as temperatures warm and precipitation patterns change. Although we don't know when some of these tipping points might be crossed, continued warming would raise the chances that they could occur.,

We must both reduce emissions and build resilience

We now have two jobs ahead of us.

The first is mitigation – using policy, technology and other actions to reduce the greenhouse gas emissions responsible for climate change. We need to transition to a lower-carbon economy. Steps along this path will include improving energy efficiency; increasing the use of low- and zero-carbon energy sources such as wind, solar, and nuclear power; and developing carbon capture and storage technologies.

The second is bolstering our resilience to climate impacts– making sure that businesses and communities can withstand the changes in the climate that we can't avoid.

Frequently Asked Questions:

What's the difference between "global warming" and "climate change"?

"Global warming" refers to the increase of the Earth's average surface temperature due to a build-up of greenhouse gases in the atmosphere. "Climate change" is a broader term that refers to weather trends observed over relatively long periods of time (many decades or longer). Climate change can include many variables (temperature, precipitation, wind direction, wind speed) and different geographic scales (over a continent, within an ocean, for the Northern Hemisphere, for the planet).

Is climate change a natural or human-caused phenomenon?

Human activities that release carbon dioxide and other greenhouse gases into the atmosphere are largely responsible for recent climate change. The pattern of warming that we have observed, in which warming has occurred in the lower portions of the atmosphere (the troposphere) and cooling has occurred at higher levels (the stratosphere), is consistent with how greenhouse gases work – and inconsistent with other factors that can affect the global temperature over many decades, like changes in the sun's energy. Although natural forces affect the climate (like volcanic eruptions and variations in the sun's energy), they alone cannot account for the warming that has occurred.

How do we know that human activity is causing greenhouse gas concentrations in the atmosphere to rise?

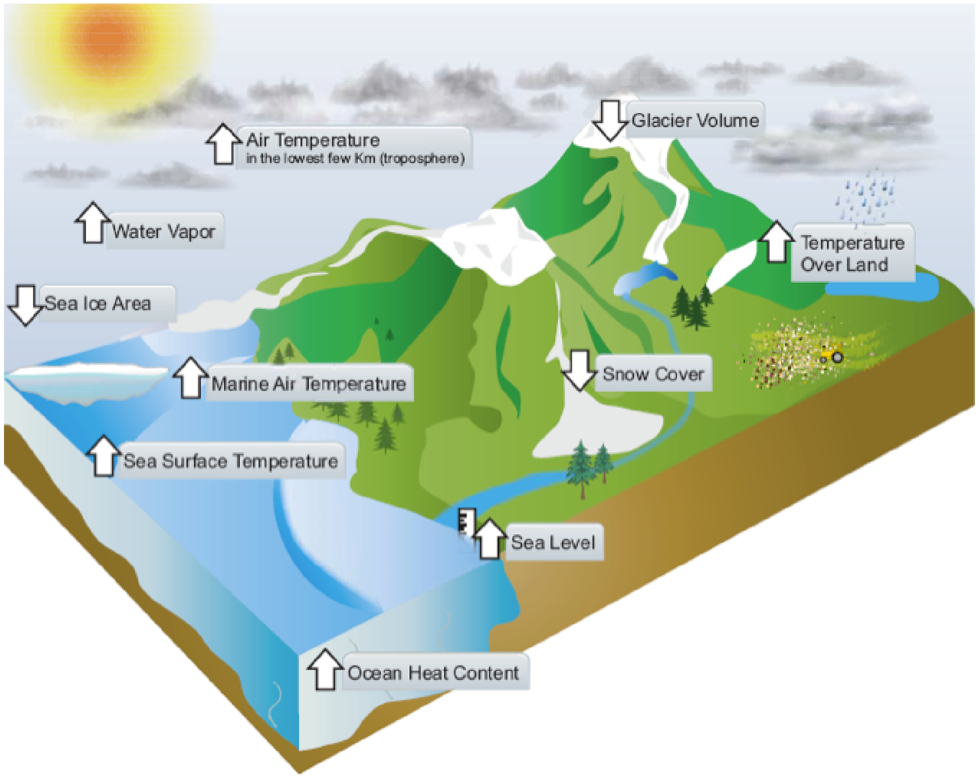
Several pieces of evidence make it clear that greenhouse gas concentrations in the atmosphere are increasing because of human activities:

- Ice cores from Greenland and Antarctica tell us that carbon dioxide and other greenhouse gas concentrations were relatively stable for thousands of years, but began to rise around 200 years ago, about the time that humans began to engage in very large-scale agriculture and industry. Concentrations for these gases are now higher than at any time for which we have ice core records, which stretch back 800,000 years.
- Some greenhouse gases, such as industrial halocarbons, are only made by humans. Their accumulation in the atmosphere can only be explained by human activity
- Scientists and economists have developed estimates of human sources of greenhouse gases. These estimates show that emissions have been increasing, consistent with the increases that are observed in the atmosphere.
- Carbon comes in different isotopes (carbon-12, carbon-13, and carbon-14; the numbers indicate the atomic weight). Carbon dioxide from fossil fuels has a certain isotopic "signature" that differs from other sources of CO_2. Scientists measure the different isotopes to confirm that the increase in carbon dioxide in the atmosphere is predominantly from fossil fuel combustion.

This evidence leaves no doubt that greenhouse gas concentrations are increasing because of human activities.

Has the climate already begun to change, and how do we know?

This illustration shows components of the climate system that would be expected to change in a warming world, and the changes they show that are consistent with warming (arrow direction denotes the sign of the change).



Source: IPCC AR5, Working Group 1, FAQ 2.1. Figure 1.

In addition to direct measurements of air temperature, we have a number of other changes (see figure) that are consistent with a warming planet. The evidence for these changes has grown stronger over the years.

> The National Climate Assessment summarizes the state of our knowledge:
>
> *Evidence for climate change abounds, from the top of the atmosphere to the depths of the oceans. Scientists and engineers from around the world have meticulously collected this evidence, using satellites and networks of weather balloons, thermometers, buoys, and other observing systems. Evidence of climate change is also visible in the observed and measured changes in location and behavior of species and functioning of ecosystems. Taken together, this evidence tells an unambiguous story: the planet is warming, and over the last half century, this warming has been driven primarily by human activity.*
> *National Climate Assessment, p.7*

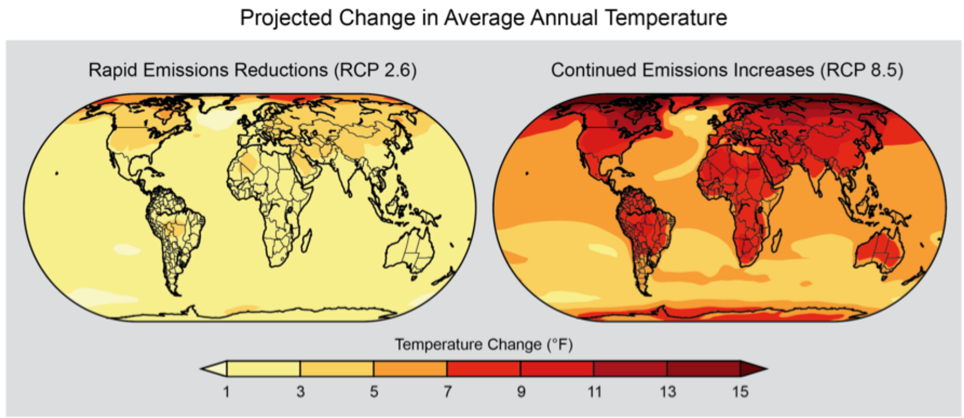
How do you explain seasonal cold weather if the climate is warming?

Climate change involves changes in long-term statistics of weather, but it does not mean an end to cold weather or to winter. Instead, it means that, averaged over many decades, cold winters and mild summers will become less frequent, and mild winters and hot summers will be more frequent. In fact, both of these trends have been observed over the past 50 years in the United States and globally. It is also important to remember that a cold winter for one location doesn't mean a cold winter everywhere. The U.S. Midwest and East Coast experienced a relatively cold winter in 2013-2014, but California had one of its warmest winters ever recorded.

How much warmer will we get?

Projections for average global temperature increase this century range from about 2°F to around 11°F compared to temperatures in the late 1900s. However, at the higher latitudes, many locations are likely to warm by more than the global average (see figure).

The large range among projections stems mostly from different pathways in future energy use and greenhouse gas emissions. To keep warming to the lower end of the range, significant cuts in emission would need to be implemented immediately. In recent decades, the planet's greenhouse gas emissions trajectory has been much more similar to the high end of the warming projections.



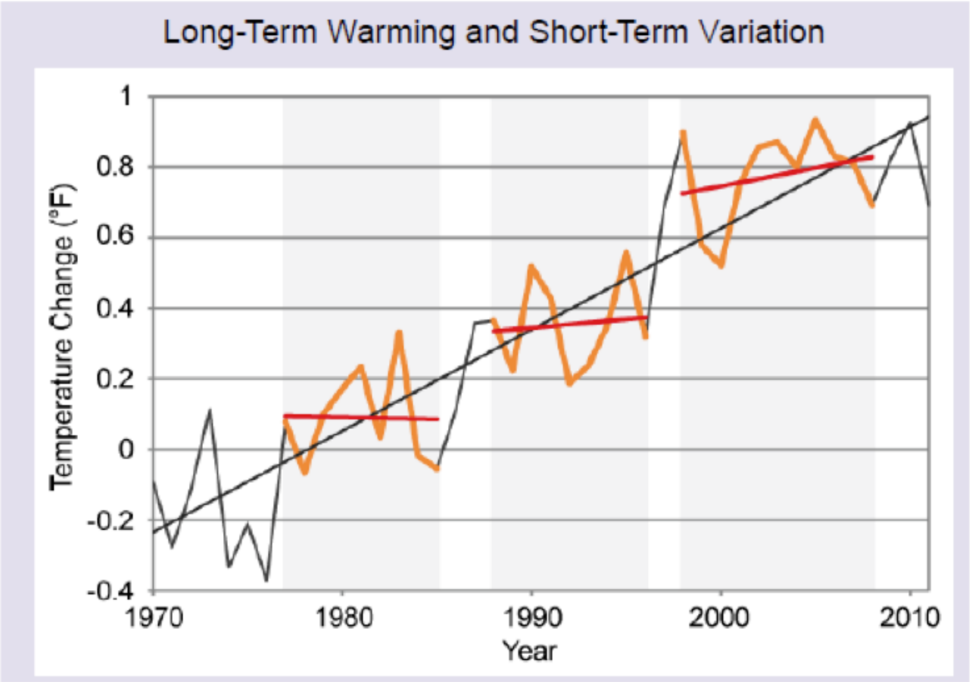
Projected changes in average annual temperature over the period 2071-2099 (compared to the period 1970-1999). The map on the left corresponds to a future where greenhouse gas emissions are substantially reduced immediately and net CO_2 emissions become negative near the end the 21^{st} century. The map on the right corresponds to a future in which greenhouse gas emissions continue to grow. Source: National Climate Assessment Figure 2.5.

Has there been a "pause" in global warming?

During the last 15 years or so, global mean surface temperatures have not warmed as rapidly as they had during previous decades. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) concludes that this is probably due to a combination of factors, including a redistribution of heat in the ocean, volcanic eruptions, and the recent minimum in the 11-year solar cycle.

> *"…trends based on short records are very sensitive to the beginning and end dates and do not in general reflect long-term climate trends."*
> *IPCC AR5, Working Group 1, Summary for Policy Makers, p.5*

Looking at the past temperature record or computer simulations of future climate shows that periods of less warming (or even slight cooling) can occur within longer periods of warming. In other words, the recent apparent "slowdown" in warming does not change the "big picture" of our understanding of climate change, or our expectation for future warming.



Short-term periods of cooling or limited warming can be embedded in longer-term warming trends. The recent "slowdown" of warming is not inconsistent with an expectation of future warming. Source: National Climate Assessment, Appendix 3, Figure 15.

Won't some parts of the world benefit from warmer weather?

There are some benefits that come with warming and increased carbon dioxide:

- Energy demands for heating usually decrease
- Carbon dioxide can accelerate growth from some types of crops
- Growing seasons get longer, which may increase agricultural production
- Illness and mortality related to cold declines

However, most studies show that damages caused by climate change far outweigh these benefits. Work supporting the Risky Business report shows that in almost all regions of the United States, warming will create more problems than benefits.

According to the National Climate Assessment and the IPCC Working Group 2 Report: Impacts, Adaptation, and Vulnerability, potential harm to individuals, communities, and businesses, include threats to:

- **Coasts** – In the near-term, sea level rise is likely to increase storm surge, making hurricanes and other severe storms more destructive. It may also contaminate groundwater supplies with saltwater. In the longer term, many coastal communities may become inundated, forcing choices about investing in shoreline protection and/or moving farther inland. This could be more troublesome for people who live in small island nations, where higher ground may be limited or resettlement in new countries may be necessary.
- **Water resources** – Water may become less available because of changes in precipitation patterns, loss of

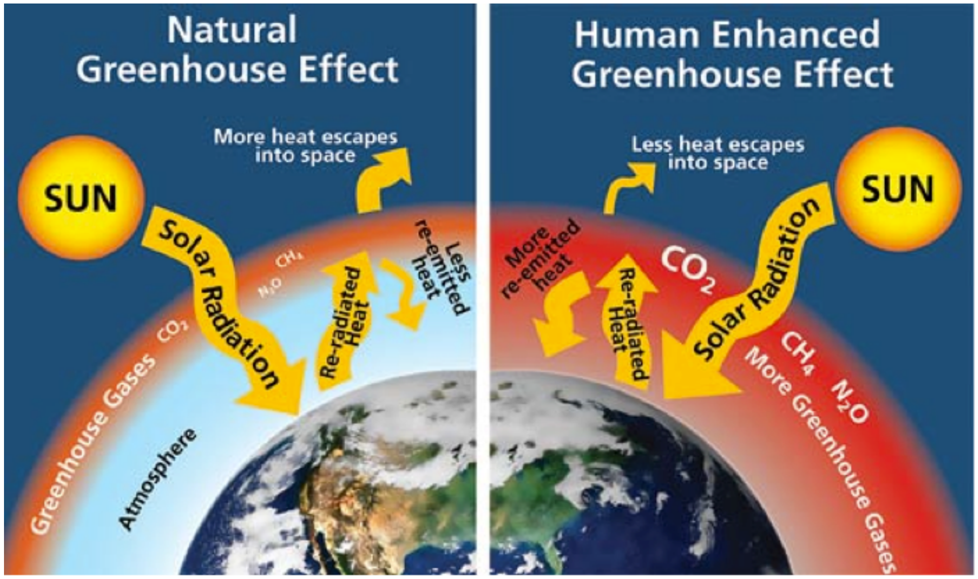
snowpack, and earlier snowmelt. Warmer temperatures can drive up water demands for agriculture, energy, and human consumption. Flooding from heavier rainfall events can also potentially overcome wastewater treatment systems and spread agricultural runoff into water bodies. This can cause threats to the economy and human health, especially in areas with growing populations or limited reservoirs and water treatment plants.

- **Health** – Warmer temperatures can increase the risks of heat-related illness and even death. Warmer temperatures can also help expand the ranges of diseases carried by insects or ticks, bringing them to regions where they were previously not a threat. Warmer temperatures can increase smog, reducing air quality and causing health issues for the young, elderly, or those with respiratory problems.
- **Security** – Climate change can affect access to basic needs (food, water, energy, shelter), especially in developing countries. Impacts on these critical resources can trigger or exacerbate migration, conflict, and political instability, which have security implications for the United States. In addition, loss of Arctic sea ice presents new operational issues for the U.S. Navy and for the security of our Arctic border.

What is the greenhouse effect? How does it work?

The greenhouse effect is a naturally occurring process in the Earth's atmosphere that warms the planet. In the absence of a greenhouse effect, the average temperature at the Earth's surface would be approximately 60°F colder.

Visible light from the sun passes through the atmosphere and is absorbed by the Earth's surface, heating it up. That energy is then emitted back to the atmosphere as heat. Greenhouse gases in the atmosphere can absorb this energy, preventing it from escaping into space. This raises the temperature of the atmosphere and ultimately, the Earth’s surface. You can think of greenhouse gases as a blanket - and human-induced increases in greenhouse gas concentrations make this blanket thicker, warming the planet.



Source: National Park Service

What are the most important greenhouse gases?

We have a complete discussion of the main greenhouse gases and their sources here.

The EPA also provides a wealth of information about greenhouse gas emissions and sources.

Are scientists in agreement about the reality and cause of climate change?

Yes. Polls of climate scientists show there is not an active "debate" within the field. For example, this poll shows that 97 percent of scientists who specifically study climate systems agree that recent warming is real and is almost certainly caused by human activities.

There are plenty of important research questions debated by scientists. How fast will the ice sheets melt? How are changes in the jet stream related to climate change? But scientists agree on the fact that the planet is warming, and that human activities are an important driver.

How reliable are climate projections?

Resources on climate projections and climate models can be found at the National Research Council. They also have a helpful interactive graphic.

Current computer models can faithfully simulate many of the important aspects of the global climate system, such as how global average temperature changes over many decades, the march of the seasons on large spatial scales; and how the climate responds to large-scale forcing, like a large volcanic eruption. So we can be confident that they correctly represent some of the "big picture" features of climate. However, simulations of climate at more regional and local scales, such as a country or state, can still be uncertain. Models also often have difficulty simulating year-to-year changes in the climate system, so a model run in 2014 is unlikely to precisely predict the global temperature in 2015 or 2016.

It is also important to note that projections for this century should not be viewed as predictions. Rather, they represent a range of possible futures, consistent with different concentrations of greenhouse gases in the atmosphere. If we emit a particular level of greenhouse gases in the coming decades, the projection provides us a glimpse of how different our climate might be.

How much do greenhouse gas emissions have to be reduced to stop climate change?

While greenhouse gases continue to accumulate in the atmosphere, the climate will warm. And even if we were able to "stabilize" the concentrations of greenhouse gases in the atmosphere, the planet will continue to warm for many decades, as time lags within the climate system are relatively long.

It can be most useful to think about climate change through a risk management lens – the more greenhouse gases that we emit, the greater the risks for dangerous impacts to occur. Through this lens, reducing emissions helps lower our risks, and the greater the reductions, the greater the risk avoided.

Other C2ES Resources

Brief: Myths vs. Realities of Climate Change

Kids Corner

Extreme Weather and Climate Change

Publications

Climate Change 101 Series

Additional Resources:

IPCC Fifth Assessment Working Group 2 Report FAQs

National Climate Assessment Appendix 4

National Research Council/Royal Society – Climate Change: Evidence and Causes

Skeptical Science

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