NOAA Climate.gov Frequently Asked Questions (FAQ) on Global Warming

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SECTION 1: CHANGES

+ What is global warming, and how is it different from climate change and climate variability?

"Global warming" refers to an increase in Earth's annually averaged air temperature near the surface. Thermometer readings are collected from many thousands of weather stations around the world—over land and ocean—and then used to produce a global average temperature for each year. The resulting series of annual averages of global temperature from 1880 to 2012 show that Earth has warmed by 1.5°F (0.85°C)[1] Most of that warming has occurred since 1976.

"Climate change" is a broadly inclusive term that refers to a *long-term* (decades to centuries) change in any of a number of environmental conditions for a given place and time—such as temperature, rainfall, humidity, cloudiness, wind and air circulation patterns, etc.

"Climate variability" refers to *short-term* (weeks to decades) changes in some of these same environmental conditions for a given place and time. Climate variability is often the result of natural oscillations in Earth's climate system — such as the El Niño-Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), the Pacific-North American Teleconnection Pattern, etc. These oscillations and other similar phenomena can influence weather and climate patterns around the globe.

+ Is the globe still warming today?

Yes. Earth has warmed by 1.5°F (0.85°C) since 1880 and most of that warming has occurred since 1976.[1] Each of the last three decades has been warmer than the one prior—the 1990s were warmer than the 1980s and the 2000s were the warmest decade on record.[1,2] Such a dramatic rise in temperature in three consecutive decades is a clear indicator that the globe is warming.

However, the most definitive warming has been happening in the ocean, which has absorbed more than 80% of the additional energy in the climate system.[2,3] Measurements show that while the rate of *air temperature* warming slowed in the early part of the 21st century, the *ocean* continued to warm at an unusually rapid rate.

+ If the globe is still warming, then why are some locations not warming while others have experienced cooling?

The 1.5°F (0.85°C) warming is a change in the ***annual average*** temperature of the whole world.[1] This warming is not uniform over the entire globe; nor are temperature increases expected to occur continuously. Differences in exposure to sunlight, cloud cover, atmospheric circulation patterns, aerosol concentrations, atmospheric humidity, land surface cover, etc., vary from place to place. These differences influence whether and how much a location is warming or cooling.

+ Can historical temperature data records be trusted? Haven't they been skewed by non-

climate factors like instrument changes and "urban heat islands"?

Our global historical temperature records can be trusted to represent changes in Earth's temperature over long time periods. Different scientific and technical teams in the United States and other countries have assessed weather stations' historical temperature data and concluded that the data are of high quality and are well suited for studies of global temperature changes from 1880 to 2012.[4,5,6,7]

If ignored, non-climate factors can skew individual stations' data records by sometimes introducing an "artificial" cooling trend and sometimes introducing an "artificial" warming trend.[8] Important examples are changes in the type of measuring instrument used in the record and the effect of buildings and pavement in the vicinity of temperature measuring stations (i.e., the "urban heat island effect"). But these and other known problems have not been ignored; rather, steps have been taken to remove or minimize non-climate impacts on the long-term records. These steps are well documented and have been undertaken in a transparent way.[9] The non-climate artifacts have been identified and removed from station data records in cases where there is high confidence that it can be accomplished without harming the data quality. In cases where there is reason to believe that station data contain significant errors that cannot be corrected, those data are removed from national and global averages.

Although the possibility of unknown or uncorrected errors in the land surface temperature data cannot be completely excluded, many other lines of evidence confirm that our world has warmed over multiple decades:

- Sea surface temperatures have increased.[2]
- Air temperatures aloft are increasing, according to weather balloons and satellites.[2]
- Birds are migrating earlier and their migration patterns are changing.[10]
- Plants are blooming earlier in the spring.[10]
- Fish species are migrating northward and toward cooler, deeper waters.[10]
- Overall, glaciers are melting and spring snow cover is declining in the Northern Hemisphere.[2]
- Greenland's ice sheet—which holds about 8% of Earth's fresh water—is melting at an accelerating rate.[2]
- Mean global sea level is rising.[2]
- Summertime Arctic sea ice is declining rapidly in both thickness and extent.[11]

+ A global warming of 1.5°F (0.85°C) seems small, given that some locations experience temperature swings of 30°F or more in a single day. Why is this change in global temperature a concern?

It's important to recognize that weather and climate are related but they are different things. Daily temperature swings of tens of degrees at a given location are common weather-driven events. But when measurements of the daily high and low temperatures in many thousands of locations all over the world—on land and ocean—are examined for an entire year and then averaged together, the Earth's ***annual average*** temperatures from year to year are found to be ***very*** stable when the climate isn't changing. In a geological context, a 1.5°F (0.85°C) warming over a span of 100 years is an unusually large temperature change in a relatively short span of time and indicates that the climate is changing.This warming is important because it increases the probabilities of extreme weather and climate events.[12]

If global warming were to stop now, its most potentially serious problems would be prevented. However, global warming is expected to continue at an increasing rate. In several decades our world is likely to become warmer than it's been for over a million years, with unpredictable consequences. It's also important to recognize that Earth is not warming uniformly, nor is it expected to. Middle and high latitudes in general change more than the tropics, and land surface temperatures change more than ocean temperatures. Over the long term, land masses at the latitude of the United States are expected to warm much more than the global average.

SECTION 2: CAUSES

+ Are humans causing or contributing to global warming?

Yes, human activities have increased the abundance of heat-trapping gases in the atmosphere, which a large majority of climate scientists agree is the main reason for the 1.5°F (0.85°C) rise in average global temperature since 1880.[13,14] Carbon dioxide is the heat-trapping gas primarily responsible for the rise but methane, nitrous oxide, ozone, and various other very long-lived heat-trapping gases also contribute. Carbon dioxide is of greatest concern because its rate of increase is exerting a larger overall warming influence than all of those other gases combined, and because carbon dioxide levels in the atmosphere will remain elevated for centuries unless we implement a way to remove carbon dioxide from the atmosphere effectively and economically. Most carbon dioxide from human activities is released from burning coal and other fossil fuels. Other human activities, including deforestation, biomass burning, and cement production also produce carbon dioxide.

+ How strong is the scientific evidence that Earth is warming and that humans are the main cause?

There is overwhelming scientific evidence that Earth is warming and a preponderance of scientific evidence that human activities are the main cause. Thousands of weather stations worldwide—over land and ocean—have been recording daily high and low temperatures for many decades and, in some locations, for more than a century. When different scientific and technical teams in different U.S. agencies (e.g., NOAA and NASA) and in other countries (e.g., the U.K.'s Hadley Centre) average these data together, essentially the same results are found: Earth's average surface temperature has risen by about 1.5°F (0.85°C) since 1880.[15]

The primary cause is that, over the last 200 years, human activities have added about 500 billion metric tons of carbon dioxide to the atmosphere, increasing the abundance of this heat-trapping gas by about 40 percent. Today, humans add about 70 million metric tons of carbon dioxide to the atmosphere ***every day***. The amount of carbon dioxide in the atmosphere has increased from about 278 parts per million (ppm) in 1800 to about 398 ppm today.[19] Today's carbon dioxide levels are unusually high; much higher than at any other time in the last 800,000 years. The warming influence of heat-trapping gases was recognized in the mid-1800s.[14]

Additionally, many other lines of evidence confirm that our world has warmed over multiple decades:

- Sea surface temperatures have increased.[2]
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+ Do humans also exert a cooling influence on Earth's climate?

Yes, human activities exert a cooling influence on Earth in several ways. Overall, this cooling influence is smaller than the warming influence of the heat-trapping gases humans put into the air.[14]

Particulate pollution (aerosols) is humanity's greatest cooling influence.[14] Plumes of aerosols are produced by: power plants and large-scale industrial processes; smoke and gases from biomass burning; windblown dust from deforested areas, dried wetlands, and crop fields; and exhaust from ships, cars, trucks, buses, and trains. Most aerosol particles scatter the sun's rays back to space, thereby directly exerting a cooling influence by reducing the amount of sunlight reaching the surface. Aerosols also have an *indirect* cooling influence by producing brighter white (more reflective) and longer-lived clouds that reduce the amount of sunlight reaching the surface. Aerosols' indirect cooling influence via clouds contributes twice as much cooling as their direct cooling influence outside of clouds. But to keep aerosols' cooling influence in proper perspective, their cooling influence is only about one-third as large as the current warming effect of human-produced heat-trapping gases.[32]

Whereas aerosols linger in the atmosphere from days to a few weeks, heat-trapping gases that humans release to the atmosphere linger from decades to centuries. Plus, when it was recognized that human particle pollution causes other undesired harmful side effects—such as acid rain and human respiratory diseases and deaths—the United States and other nations adopted regulations to reduce emissions of some aerosols.

Another measurable way in which humans exert a cooling influence is by changing land cover over large areas in ways that increase the land's reflectance, thereby reducing the amount of sunlight absorbed. By comparison, the cooling influence of humanity's land cover changes only offsets about 5% of the warming caused by human-emitted heat-trapping gases.[32]

+ Couldn't the sun be the cause of the recent global warming?

No, there has been no significant net change in the sun's energy output from the late 1970s to the present, which is the period of the most rapid warming.[16] If the sun had intensified its energy output then *all* layers of Earth's atmosphere would warm. But such warming hasn't been observed. Rather, warming has occurred in the lower atmosphere (troposphere) and *cooling* in the upper atmosphere (stratosphere)—which is exactly what would be expected if the warming was due to an increase in heat-trapping gases near the surface. This evidence from temperature records is regarded as a "smoking gun" linking today's global warming to the increase in heat-trapping gases in the lower atmosphere.

+ Didn't the globe stop warming after 1998, a period when human activities emitted more carbon dioxide than in any other period in human history? And, if so, doesn't this mean climate is not as sensitive to carbon dioxide as previously thought?

No, the globe did not stop warming after 1998. While 1998 was one of the ten warmest years on record, the other nine warmest years have all occurred after 1998.[2]

It's important to remember that, even during global warming periods, every year won't be warmer than the year before, and there may even be several years in a row of cooler average temperatures. That's why it's more reliable to look at changes between 5-year and 10-year blocks of time over a span of *decades* before drawing conclusions about climate sensitivity.

It's true that humans have released more carbon dioxide into the atmosphere from 1998 to 2012 than in any other 15-year period in history, and it's true there was a slowdown in the *rate* of global warming during that time. Most of the excess heat (>80%) from global warming has been going into the ocean.[17] The point is *global warming didn't stop over the last decade*; most of the warming happened in the ocean rather than in the lower atmosphere.

Scientists are always reassessing their estimates of climate sensitivity based on observed changes in temperature and ocean heat content. It's too early to conclude that the climate system isn't as sensitive to carbon dioxide as scientists thought, though that possibility is being actively researched. Stay tuned…!

+ What role does the ocean play in global warming?

The ocean helps to reduce both the causes and effects of global warming. The ocean absorbs about 30% of all human-produced carbon dioxide, thereby keeping large amounts of this heat-trapping gas out of the atmosphere.[14] The ocean also absorbs more than 80% of all excess heat in the Earth's system, where excess heat is the difference between the sun's total incoming energy and the total energy leaving Earth's system.[17,18] Ocean absorption of excess heat is currently helping to slow the rate of global warming.

Carbon dioxide is absorbed in the ocean at a rate that depends on temperature. Under natural conditions the ocean serves as a carbon dioxide *source* during warming periods and a carbon dioxide *sink* during cooling periods. The warmer the ocean grows, the more it will become a source of carbon dioxide, thereby contributing to global warming.

Also, the ocean serves as a massive source of water vapor. As Earth's temperature rises, the rate of evaporation increases too. Since water vapor is also a heat-trapping gas, changes in the amount of water vapor in the atmosphere serve to amplify temperature changes caused by other factors such as carbon dioxide.

+ Doesn't carbon dioxide in the atmosphere come from natural sources?

There are natural sources of carbon dioxide, such as decomposing biomass, venting volcanoes, naturally occurring wildfires, human and animal respiration, etc. Over geological time spans before the industrial revolution, these natural sources of carbon dioxide were in balance with natural "sinks"—such as the ocean, phytoplankton, and plants on land that absorb carbon dioxide. The only new process on Earth that has been identified that can account for the significant tipping of Earth's carbon balance is humans burning ever increasing amounts of fossil fuels together with other large-scale activities like deforestation, biomass burning, and cement production.[14] Since the industrial revolution, human activities have increased the abundance of carbon dioxide in the lower atmosphere by about 40%.[19]

+ Don't volcanoes emit more carbon dioxide than humans?

No, human activities emit about 135 times more carbon dioxide than volcanoes do in a typical year.[21] Volcanoes emit between 0.2 and 0.3 billion tons of carbon dioxide per year whereas human activities emit about 29 billion tons of carbon dioxide per year.[21]

+ What is the 'greenhouse effect'?

While it's not a perfect analogy, some say the atmosphere works like a greenhouse. The sun's rays (shortwave energy) enter a greenhouse through its glass ceiling and walls to warm the interior. The glass makes it hard for the heat (longwave energy) to escape, and heat builds up inside the greenhouse until the heat can escape fast enough.

Certain naturally occurring gases in Earth's atmosphere have a similar warming effect on the surface. This warming is referred to as the "greenhouse effect," and the gases that trap heat are called "greenhouse gases." The most important greenhouse gases in Earth's atmosphere are water vapor, carbon dioxide, methane, and ozone. Earth's surface must warm to an average of about 59°F (with present-day concentrations) until enough energy can be emitted by greenhouse gases and escape to space to balance the energy being absorbed from the Sun.

Though these important greenhouse gases occur naturally in the atmosphere in varying concentrations, human activities are directly and indirectly increasing their abundance. In addition, other greenhouse gases not normally found in nature are being added to the atmosphere. The net result is to intensify Earth's greenhouse effect, causing Earth's surface to warm.

+ Hasn't Earth warmed and cooled naturally throughout history?

Yes, Earth has warmed and cooled naturally throughout its history. For example, increases or decreases in the Sun's brightness would have caused short-term warming and cooling. Also, major volcanic eruptions can cause short-term cooling. For example, in 1991, Mt. Pinatubo erupted with such force it injected sulfate gases and particles into the stratosphere, above where rain clouds form. There, these reflective aerosol particles lingered for almost a year and spread around the globe. Pinatubo's volcanic particle plume scattered and reflected so much sunlight back to space that it actually caused Earth to cool by about 0.9°F (0.5°C) that year.

Additionally, Earth has experienced longer term cold periods ("ice ages") and warm periods ("interglacials") on 100,000-year cycles for at least the last million years. Going from an ice age to an interglacial and back again, Earth's average temperature changed anywhere from 7°F to 12.5°F (4-7°C). These fluctuations in global average temperature happened because gradual, ongoing changes in Earth's orbital mechanics changed our planet's tilt relative to the sun. The gradual shift in Earth's tilt changed where and how much sunlight fell on the Northern Hemisphere. Thus, there was a slight increase in the amount of sunlight shining where most of our planet's landmass is located, which was just enough to nudge our world in a warming direction. As Earth began to transition from an ice age to an interglacial, other factors (known as "climate feedbacks") in the climate system came into play and added to the warming.[20] For example:

- the large ice sheets on North America, Europe, and Asia shrank, which changed the land cover from a mostly bright white reflector to a dark green or brown absorber of solar energy and added to the warming[20];
- global cloudiness may have declined, which would have allowed more sunlight to reach the surface and add to the warming[20];
- as the land and oceans warmed, they released more carbon dioxide and methane (heat-trapping gases) which added to the warming[20]; and
- lightning-triggered wildfires probably grew more frequent, and burned over larger areas, thereby accelerating the conversion of forest biomass into carbon dioxide and methane gas, which added to the warming.[20]

As Earth's orbital mechanics tilted the Northern Hemisphere away from the sun, these processes slowed or reversed, leading to ice ages. These processes explain why Earth has warmed and cooled on roughly 100,000-year cycles for at least the last 1 million years.[20]

+ Why is the current global warming trend any different than previous warming periods in Earth's history?

Today's global warming is different from previous warming periods in two key ways: the ***reason*** and the ***rate***. Today, the reason Earth is warming is mainly due to the increase in heat-trapping gases that humans are adding to the atmosphere. And our world is warming at a ***much faster rate*** today than it did in the interglacial warm periods over the last million years. The transition from the last ice age to the current interglacial period is estimated to have spanned 5,000 years.[14] Humans could witness the same magnitude of global warming within a span of about 110 years. In other words, if our world warms by as much as 7°F (4.1°C) from 1990 to 2100, as some climate models project could happen, then that warming rate is about 45 times faster than the warming Earth experienced when it emerged from the last ice age.[22]

+ Isn't there a lot of debate and disagreement among climate scientists about the causes and effects of global warming?

No. By a large majority, climate scientists agree that average global temperature today is warmer than in pre-industrial times, and that human activity is a significant contributing factor.[23,24,25]

The United States' foremost scientific agencies and organizations have recognized global warming as a human-caused problem that should be addressed. The U.S. Global Change Research Program has published a series of scientific reports documenting the causes and impacts of global climate change. NOAA, NASA, the National Science Foundation, the National Research Council, and the Environmental Protection Agency have all published reports and fact sheets stating that Earth is warming mainly due to the increase in human-produced heat-trapping gases.

The American Meteorological Society (AMS) issued this position statement: "Warming of the climate system now is unequivocal, according to many different kinds of evidence. … many of the observed changes noted above are beyond what can be explained by the natural variability of the climate. It is clear from extensive scientific evidence that the dominant cause of the rapid change in climate of the past half century is human-induced increases in the amount of atmospheric greenhouse gases,..." (Adopted Aug. 20, 2012)

The American Geophysical Union (AGU) issued this position statement: "Human-induced climate change requires urgent action. Humanity is the major influence on the global climate observed over the last 50 years. Rapid societal responses can significantly lessen negative outcomes." (Published Aug. 2013)

In 2009, the American Association for the Advancement of Science (AAAS) reaffirmed the position of its Board of Directors and the leaders of 18 respected organizations, who concluded based on multiple lines of scientific evidence that global climate change caused by human activities is now underway, and it is a growing threat to society.

SECTION 3: IMPACTS

+ What harm will global warming cause?

Harmful climate-related impacts are being observed in the United States and around the world.[13,14] The combination of warming temperatures and melting ice sheets and glaciers is causing global sea level to rise, which presents a growing threat to vital coastal ecosystems and millions of people around the world who live in coastal regions. This threat includes both the gradual upward creep of sea level and periodic, catastrophic ocean surges associated with land-falling cyclones.

An overall shift toward more extreme and longer-lasting heat waves has been observed.[12] The year 2012 saw thousands of temperature records broken all over the United States, and it was by far the U.S.'s warmest year on record. But it's not just the daily high temperatures that are a concern. The average daily *low* temperatures have been rising at an even faster rate than the average daily highs. Doctors and farmers alike have observed that heat stress occurs in people, livestock, and crops when the temperature doesn't cool down enough overnight. As a result, productivity in people, plants, and animals declines which, in turn, hurts our quality of life and economy.

A warmer atmosphere has a greater capacity to hold water vapor. Consequently, climate models project that global warming will tend to cause wet regions to get wetter and dry regions to get drier. In the east and northeastern United States, an increase has been observed in very heavy downpours of rain leading to flash flooding, loss of life, and damages to property and infrastructure. Climate models suggest floods and water quality problems are likely to be amplified by climate change in most "wet" regions.[13] According to the IPCC (SREX Report), "there is medium confidence (based on physical reasoning) that projected increases in heavy rainfall would contribute to increases in local flooding in some catchments or regions."

At the same time, "dry" regions are getting drier. Large areas in the west and southwest U.S. have experienced abnormally dry to exceptional drought conditions that stress water resources and present challenges to farmers, ranchers, water resource managers, and energy utilities.[13] These water deficits appear to be part of a long-term trend toward drier conditions in the west and southwest. Internationally, more intense and longer lasting droughts over wider areas could cause global food shortages and political unrest, contributing to mass starvation and armed conflicts.[12]

+ Is global warming a threat to humans? If so, how?

Yes, health care providers and insurers alike recognize that global warming is a threat to humans. The major public health organizations of the world have said that climate change is a critical public health problem. According to the U.S. National Institute of Environmental Health Sciences, climate change makes many existing diseases and conditions worse, and it helps pests and pathogens spread into new regions. The most vulnerable people—children, the elderly, the poor, and those with health conditions—are at increased risk for climate-related health effects.[26]

Global warming is also a threat to the economy and national security in many developing nations. Because societies and their built environments have developed under a climate that has fluctuated within a relatively small range of conditions, most impacts of a rapidly changing climate will present challenges—particularly as extreme weather and climate conditions become more extreme, more frequent, and longer lasting. In developing nations, populations are much more vulnerable to weather and climate extremes and are less able to adapt. Any climate-related impacts on scarce natural resources, food, and water are more likely to trigger humanitarian crises or armed conflicts that can destabilize nations, or whole regions.[12]

In the United States, the most rapidly growing population is in the Mountain West. That region is projected to experience more frequent and more severe wildfires with less water availability, particularly during the high-demand period of summer. Because of high demand for irrigating agriculture, overuse of rivers and streams is common in the arid West, particularly along the Front Range of the Rocky Mountains in Colorado, in Southern California, and in the Central Valley of California. Rapid population and economic growth in these arid and semi-arid regions has dramatically increased people's vulnerability to water shortages.[13]

+ Is global warming a threat to land and marine ecosystems?

Yes, global warming is impacting species and habitats across America and around the world. According to the U.S.'s *National Fish, Wildlife, and Plants Climate Adaptation Strategy,* warmer temperatures, rising sea levels, and other climate-related changes are stressing countless species of plants, animals, and fish.[10] Adaptable species with wide geographic ranges—such as white-tailed deer and feral hogs—are likely to continue to thrive. But those species that depend on particular habitats—such as the southwestern willow flycatcher (bird) and coldwater fishes—are vulnerable.[10]

Here are some specific examples (selected from among many that are available)[10]:

- Warmer temperatures and droughts are expected to put some of the 750 million acres of forests in the United States under greater stress, cause decreased productivity, and increase risk of fire.
- Millions of acres of lodgepole pine and other conifer trees across the West have been killed by an epidemic outbreak of mountain pine beetles. Warmer temperatures have enabled more beetles to survive the winter and earlier arrivals of spring have allowed the insect to reproduce more generations per year while expanding their range.
- Roughly 285 million acres of grasslands in the U.S. stretch from Canada to the Gulf Coast, and include tallgrass prairie, cattle pastures, and prairie pothole wetlands that serve as breeding grounds for ducks. Warmer, drier conditions expected from climate change will likely dry up wetlands, speed the invasion of non-native grasses and pests, contribute to more fires, and reduce the quality of forage for livestock and wildlife.
- Many of the nation's lakes, rivers, and streams are expected to warm. Coldwater fish like trout and salmon will be adversely affected, while warmer water species like bass will expand their range. Falling water levels, especially in the Great Lakes, will lead to shoreline habitat loss, affecting nursery grounds and nesting areas.
- Many commercial and recreational fish stocks along the East Coast have shifted their distributions northward from 25 to 200 miles over the past 40 years as ocean temperatures have increased.
- As the ocean absorbs much of the additional carbon dioxide humans put into the atmosphere, its waters grow more acidic. In 2007-08, two major West Coast oyster hatcheries found that their oyster larvae were dying due to the higher acidity of the seawater being pumped into their facilities.
- Small increases in ocean temperature severely stress corals and cause them to expel the symbiotic algae that nourish them and give them their vibrant colors. This process, known as "coral bleaching," changes their color to a dull white and leaves this vibrant ecosystem dead or dying.

+ Are there positive benefits from global warming?

Yes, there will probably be some short-term and long-term positive benefits from global warming. For example, the flip side of increased mortality from heat waves may be decreased mortality from cold waves.

In the short term, farmers in some regions may benefit from the earlier onset of spring and from a longer warm season that is suitable for growing crops. Also, studies show that, up to a certain point, crops and other plants grow better in the presence of higher carbon dioxide levels and seem to be more drought-tolerant.[13] But this benefit is a two-edged sword: weeds, many invasive plant species, and insect pests will also thrive in a warmer world. Water availability will be impacted in drier agricultural areas that need irrigation. At some point, the positive benefits to crops of increased carbon dioxide may be overwhelmed by the negative impacts of heat stress and drought.

In the long term, shipping commerce will benefit from the opening of the Northwest Passage for longer periods of the year due to the loss of Arctic sea ice. However, in the long run, if a "business as usual" approach to emitting heat-trapping gases is maintained at the present rate, or faster, then the negative costs and impacts of global warming are very likely to far outweigh the positive benefits over the course of this century, with increased potential for catastrophic impacts from more extreme events.[12] In part, this is because any substantial change, whether warmer or colder, would challenge the societal infrastructure that has developed under the current climate.

+ What is an "extreme event"? Is there evidence that global warming has caused or contributed to any particular extreme event?

An *extreme event* is a time and place in which weather, climate, or environmental conditions — such as temperature, precipitation, drought, or flooding — rank above a threshold value near the upper or lower ends of the range of historical measurements.[29] Though the threshold is arbitrary, some scientists define extreme events as those that occur in the highest or lowest 5% or 10% of historical measurements.[30]

Human-caused climate change is not the sole cause of any single extreme event. However, changes in the intensity or frequency of extremes may be influenced by human-caused climate change.[27, 28] Heat waves will tend to be a bit hotter—both the daily high and daily low temperatures. And, because a warmer atmosphere holds more water vapor, precipitation events will tend to be heavier (as measured by total rainfall or snowfall). These are just two examples of how extreme events are becoming more extreme.

Establishing causes of a specific extreme event can be difficult and requires case-specific methods. Scientists can assess whether a specific event (e.g., the 2012 U.S. drought, or the storm surge from Superstorm Sandy) has become more or less likely, or stronger or weaker, as a consequence of human-caused climate change. In nineteen recent analyses of twelve extreme events in 2012, scientists found that some events had direct ties to climate change, while others did not.[31] For more details, see Climate.gov's Q&A with Thomas Peterson, lead editor of the report.

+ How can Earth's climate be accurately predicted years or decades in the future when weather cannot be accurately predicted more than 2 weeks from now? What's the difference between weather and climate?

Weather and climate occur on different scales of time and space, and depend on different aspects of Earth's environment. Weather describes atmospheric conditions *at a particular time and place.* Climate is the *overall statistical characteristics* of weather and environmental conditions, such as long-term averages and ranges of variability, for a given place and season.

Weather forecasters look at initial conditions and then make short-term *deterministic* predictions about future ***events*** (from minutes to days, to less than 2 weeks). Due to the fluid and chaotic nature of the atmosphere, it is impossible to make accurate deterministic predictions about weather events more than 2 weeks in the future. Climate forecasters look at the state of the key controlling parameters of the climate system and then make long-term *probabilistic* predictions about future ***conditions*** (from more than 2 weeks to years, to decades). People do this all the time with high reliability. For example, while you don't know what the weather will be a like on a given day in Washington, D.C., in the year 2020, you can be confident that temperatures will be warmer in the summer than in the winter.

Another way to understand the differences between deterministic and probabilistic predictions is to consider how other types of experts use them. For example, a doctor may have a hard time *determining* exactly when a particular overweight, middle-aged person who smokes cigarettes is going to die. But a life insurance agent can easily make a *probabilistic prediction* of the person's life expectancy based on the average life spans of millions of overweight, middle-aged people who smoked.

SECTION 4: CHOICES

+ Can we slow or even reverse global warming?

In principle, we can slow the rate of global warming by slowing the emission rates of heat-trapping gases—mainly carbon dioxide—and black carbon aerosol to the atmosphere. Some continued warming is inevitable. Stabilizing global temperature at its current level would be very difficult because it would require cutting the emission of heat-trapping gases all the way to zero. If and when zero emissions becomes possible, temperatures won't start to recover until heat-trapping gases are actually removed from the atmosphere. Such removal happens naturally on time scales ranging from less than a year (e.g., black carbon aerosol) to centuries (e.g., carbon dioxide). Additionally, technical means exist to remove some heat-trapping gases (including carbon dioxide) from the atmosphere.

Ultimately, global warming could be reversed by returning the abundance of heat-trapping gases in the atmosphere to pre-industrial levels (circa 1750). The challenge in slowing or reducing global warming is finding a way to make these changes on a global scale that is technically, economically, socially, and politically viable. Reducing our emission of carbon dioxide has the added benefit of slowing the rate at which humans are making the ocean's water more acidic, which is a threat to shell-forming organisms and the marine food chain.

In response to a request from the U.S. Congress, the U.S. National Academy of Sciences published a series of peer-reviewed reports, titled *America's Climate Choices*, to provide authoritative analyses to inform and guide responses to climate change across the nation. Relevant to this question, the NAS report titled *Limiting the Magnitude of Future Climate Change* explains policies that could be adopted to slow or even reverse global warming. The report says, "Meeting internationally discussed targets for limiting atmospheric greenhouse gas concentrations and associated increases in global average temperatures will require a major departure from business as usual in how the world uses and produces energy."

Alternative methods to slow or reduce global warming have been proposed that are, collectively, known as "climate engineering" or "geo-engineering." Some geo-engineering proposals involve cooling Earth's surface by injecting reflective particles into the upper atmosphere to scatter and reflect sunlight back to space. Other proposals involve seeding the oceans with iron to stimulate large-scale phytoplankton blooms, thereby drawing down carbon dioxide out of the atmosphere through photosynthesis. Such methods could work, in principle, but many climate scientists oppose undertaking geo-engineering until we have a much better understanding of the possible side effects. Additionally, there are unresolved legal and ethical issues surrounding geo-engineering.

Given these concerns, the American Meteorological Society published a position paper (readopted in January 2013) in which it said: "...research to date has not determined whether there are large-scale geo-engineering approaches that would produce significant benefits, or whether those benefits would substantially outweigh the detriments. Indeed, geo-engineering must be viewed with caution because manipulating the Earth system has considerable potential to trigger adverse and unpredictable consequences."

+ What can I do to help reduce global warming?

Because most human-produced heat-trapping gases come from burning fossil fuels, there is great potential for the collective actions of many individuals worldwide to reduce global warming by making changes in their daily and annual activities that produce heat-trapping gases and aerosols. Specifically, people can consider making the following choices in their personal lives:

- reduce household energy use through use of energy efficient appliances and heating and air conditioning systems;
- increase investments in renewable energy sources such as solar and wind power systems;
- avoid unnecessary household energy use through lighting and temperature control options as well as the use of power strips with switches enabling people to turn off always-on "vampire" appliances (i.e., computers and cable TV boxes); and
- limit travel distances in conventional automobiles and aircraft while choosing energy-efficient mass transportation options, such as trains and buses, where possible.

Making the best choices to reduce emissions requires accurate and quantitative information about how our different lifestyles cause emissions. Examples of direct emissions are energy use in households, automobiles, and air travel. Indirect emissions result from production and distribution of goods used in household and businesses. More guidance on courses of action can be found in the National Academy of Sciences' 2010 report, titled *Informing an Effective Response to Climate Change.*

As addressed in previous questions, stabilizing global temperature at its current level requires eliminating all emissions of heat-trapping gases or, equivalently, achieving a carbon-neutral society in which people remove as much carbon from the atmosphere as they emit. Achieving this goal will require substantial societal changes in energy technologies and infrastructure that go far beyond the collective actions of individuals and households to reduce emissions.

+ What can businesses and business leaders do about global warming?

Business leaders can evolve their business models to pursue "win-win" strategies that allow them to stay profitable while improving their energy efficiency, reducing their carbon emissions, and reducing their, and their customers', risks to climate-related impacts. Businesses can offer low-carbon-emitting products and services to customers who are seeking them. They can consider making low-carbon products and services the *default* where consumers have a range of choices. Also, businesses that make "climate-smart" choices in their offices and operations can let their customers know about it. These and other climate choices are summarized in two 2010 reports by the National Academy of Sciences, titled *Informing an Effective Response to Climate Change* and *Adapting to the Impacts of Climate Change*.

+ What can people do about the expected impacts caused by global warming?

With continued increases in heat-trapping gas emissions, particularly that of carbon dioxide, climate change projections include changes in average temperatures, precipitation patterns, drought occurrences, and the frequency of extreme events. These changes can be a threat to humans as noted above in answers to previous questions. The distribution of these changes around the globe will not be uniform so some areas will experience more changes than others. Societies, governments, and individuals can take steps to reduce risks and vulnerabilities to shifting climate and weather events in their homes, communities, and businesses. From infrastructure upgrades to better management of natural resources (like lands, coastal ecosystems, and freshwater reservoirs), to better preparedness and communications when extreme events do occur — people can make human structures and systems more resilient to projected climate-related impacts. Over time, these and other adaptation measures will save lives, money, and valuable resources.

Additional climate choices are summarized in two 2010 reports by the National Academy of Sciences, titled *Informing an Effective Response to Climate Change* and *Adapting to the Impacts of Climate Change*.

+ What is NOAA's climate mission?

NOAA is an agency that enriches life through science. From the surface of the sun to the bottom of the ocean, NOAA advances scientific understanding of Earth's environment, climate, and weather. We provide foundational climate science, data, and information services that Americans want and need to make informed decisions. Without NOAA's climate monitoring, research, and modeling capabilities we couldn't quantify where and how climate conditions have changed, nor could we predict where and how they're likely to change.

NOAA is working to improve the nation's resilience to changes in climate and weather. Specifically, NOAA is working to…

- help people prepare for drought and water resource challenges;
- protect and preserve coasts and coastal infrastructure;
- identify and manage risks to marine ecosystems and the valuable services they provide;
- reduce communities' and businesses' vulnerability to extreme weather; and
- help people to understand and evaluate options for mitigating and adapting to climate-related impacts.

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