



# Climate Change 101

Climate scientists are supplying a wealth of evidence about what is happening to the earth's climate and what it portends for our local environments, while other disciplines are identifying and developing effective interventions. Evidence-based public health practice requires that public health professionals apply evidence developed by epidemiologists, clinical researchers, and scientists across a broad range of other disciplines. You don't need to be a climate scientist to address the health risks of climate change or the health benefits of climate action. Our job is to draw on the science and apply it in public health practice.

97% of climate scientists agree that climate change is happening now and there is scientific consensus that is driven by human activity.<sup>1</sup>

## Climate Change: One symptom of planetary health

While climate change is the greatest health challenge of our time, it is one of many disruptions to what is known as planetary health. Planetary health asserts that the scale and nature of human activity, including population growth, is pushing the limits of all the planet's resources to the brink of habitability. Human exploitation and consumption of Earth's resources are causing fundamental changes in the planet's biophysical processes, which include climate change, but also widespread pollution of air, water, and soils; rapid biodiversity loss; altering of carbon, nitrogen, and phosphorus cycles; pervasive changes in land use and land cover; and scarcity of resources critical to sustaining life, such as water and arable land.

"Each of these interacts with the others in complex ways, altering the quality of the air we breathe, the water we have access to, and the food we can produce. Rapidly changing environmental conditions also alter our exposures to infectious diseases and natural hazards such as heat waves, droughts, floods, fires, and tropical storms. These... ultimately affect every dimension of our health and wellbeing, including nutritional outcomes, infectious disease, non-communicable disease, displacement and conflict, and mental health outcomes... We need to expand the realm of public health to include how we manage our planet's natural systems: the types of cities we construct, how we produce energy, how we feed ourselves, and how well we protect our marine and terrestrial biodiversity. In the context of planetary health, the boundaries between public health and nearly every other facet of human activity become more porous. In short, we need a new paradigm."

*Dr. Samuel Myers, November 2017<sup>4</sup>*

## 3.1 What Is Climate Change?

- **Weather** is the temperature, humidity, precipitation, cloudiness, and wind that we experience in the atmosphere at a given time in a specific location. Weather forecasts are generally accurate over days to weeks. Climate is the average weather over a long time period (30–50 years) in a region.
- **Climate variability** refers to natural variation in climate that occurs over months to decades. El Niño, which changes temperature, rain, and wind patterns in many regions over about 2–7 years, is an example of natural climate variability. **Climate change** is a systematic change in the long-term state of the climate over multiple decades or longer.<sup>2</sup>

Climate scientists use statistical tests to ascertain that observed changes in climate are not within the range of natural variability. The 2017 Fourth National Climate Assessment states that “there are no alternative explanations supported by the evidence that are either credible or that can contribute more than marginally to the observed patterns.”<sup>3</sup>

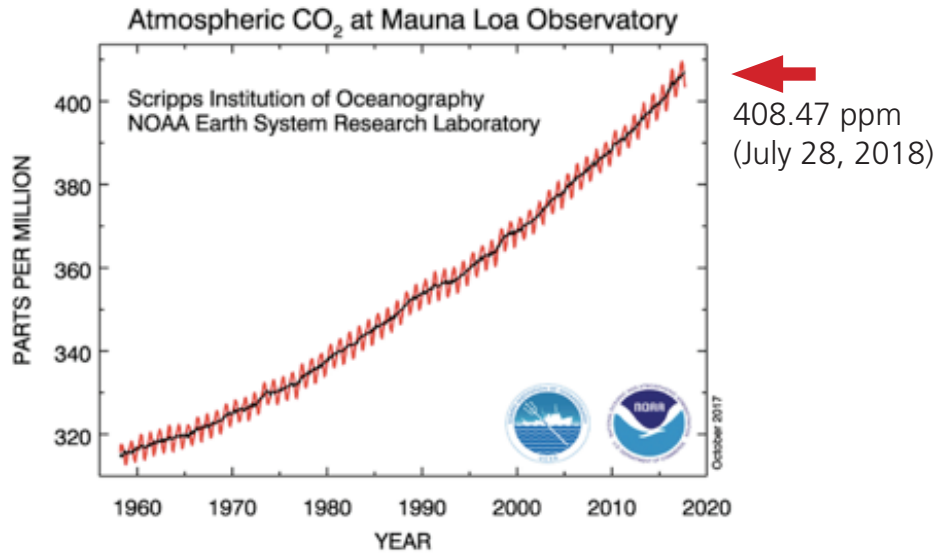
## 3.2 Greenhouse Gas Emissions Cause Climate Change<sup>5</sup>

Climate change is caused by a change in the earth’s energy balance. The earth is gaining energy as the atmosphere increasingly stores more of the sun’s energy than it radiates or reflects back into space.

Since the Industrial Revolution started over 200 years ago, human activities have added very large quantities of greenhouse gases (GHG), also called climate pollutants, into Earth’s atmosphere through the burning of fossil fuels (e.g., coal, oil, gas). These [GHG act like a greenhouse](#) to trap the sun’s energy and heat, rather than letting it reflect back into space.<sup>6</sup> Without these GHG the earth’s atmosphere would be too cold for life, but when the concentration of GHG is too high, too much heat is trapped, and the earth’s temperature rises outside the range of natural variability.

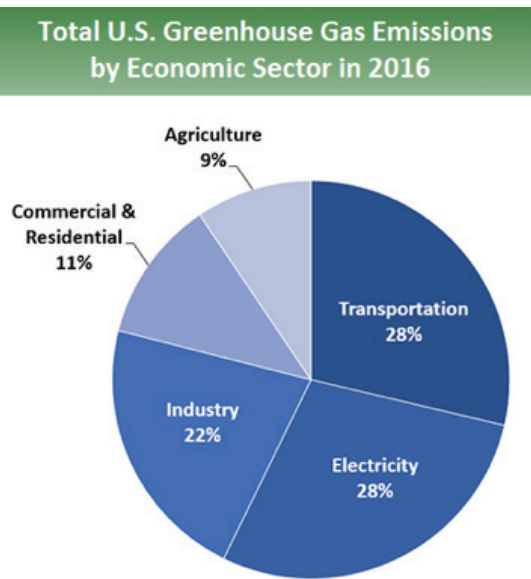
Carbon dioxide (CO<sub>2</sub>) is the primary GHG from human activities—accounting for 81.6% of all U.S. GHGE in 2016—and is responsible for the greatest amount of warming to date.<sup>7</sup> The main human activity that emits CO<sub>2</sub> is the combustion of fossil fuels (coal, natural gas, and oil) for electricity production, transportation and industrial processes that together account for more than 80% of the CO<sub>2</sub> released into the atmosphere.<sup>8</sup> Our planet has not experienced CO<sub>2</sub> levels as high as now since approximately 3.5 million years ago when Earth was about 2.3°C warmer and sea levels 33–65 feet higher (Figure 3.2.1).<sup>9</sup> CO<sub>2</sub> has a long half-life, so the “climate effects of CO<sub>2</sub> released into the atmosphere will persist for tens, if not hundreds, of thousands of years into the future.”<sup>10</sup>

**Figure 3.2.1:** Atmospheric CO<sub>2</sub> at Mauna Loa Observatory<sup>11</sup>



Other important GHG such as methane, nitrous oxide, black carbon, and various fluorinated gases are emitted in smaller quantities than CO<sub>2</sub>, but they trap more heat in the atmosphere than CO<sub>2</sub> traps.<sup>12</sup> The ability to trap heat is measured as Global Warming Potential (GWP). As the most common and abundant greenhouse gas, CO<sub>2</sub> has a GWP of 1; all other GHG warming potentials are compared to it. Fluorinated gases, for example, have GWPs thousands of times greater than CO<sub>2</sub>, meaning that pound-for-pound, these gases have a much stronger impact on climate change than CO<sub>2</sub>.<sup>13</sup> (See [Appendix 4](#) for a summary table of GHGE in the United States, their main sources, and their GWP and half-life in the atmosphere.) GHGE come from a variety of sources, but major sources include transportation, agriculture, and energy production (Figure 3.2.2).

**Figure 3.2.2:** Percentage of U.S. GHGE by Economic Sector, 2016<sup>14</sup>



## Short-Lived Climate Pollutants

Greenhouse gases with a high global warming potential but a short lifetime in the atmosphere are called “short-lived climate pollutants” (SLCP), or “super-pollutants”. Key SLCP include methane, black carbon, and some fluorinated gases. Because of the combination of a short half-life and high GWP, the climate change impacts of the SLCP are “front-loaded”—more of the impacts from SLCP occur sooner, while the full weight of impacts from CO<sub>2</sub> will be felt later. Methane, for example, comprises 10% of total U.S. GHGE and primarily comes from animal agriculture, food decomposition, and the extraction, distribution, and use of natural gas.<sup>15</sup>

Reducing emissions of short-lived climate pollutants may “buy time” while we make the transition away from carbon-polluting systems. Cutting global levels of SLCP significantly by 2030 will:<sup>16</sup>

- cut global warming in half, or 0.6°C, by 2050 and by 1.4°C by 2100;
- prevent 2.4 million premature deaths globally each year.

## The Carbon Budget and the Urgency of Climate Action

For many years, there was a scientific consensus that holding global average temperature increases of 2°C (3.6°F) above pre-industrial levels would be “safe,” meaning that although climate impacts would be significant, they would be manageable. However, far worse impacts of warming are occurring at a current average global temperature increase of 1.1°C (2°F) than had been anticipated. There is now great concern that if greenhouse gas emissions continue unabated, the Earth’s temperature will rise about 4°C (2.7°F) by the end of the century with potentially catastrophic consequences for life on earth. In 2015, nearly 200 nations agreed in the Paris Agreement that the risks of catastrophic climate change are significantly reduced if we can keep global temperatures from rising more than 1.5°C (2.7°F).

Because GHG persist in the atmosphere for many years, the magnitude of warming and other climate impacts is not determined by emissions in any one year or from any one source, but rather by the total GHG in the atmosphere produced cumulatively and globally over time.<sup>18</sup> Scientists can calculate how much warming will result from different cumulative amounts of GHG in the atmosphere.

The “carbon budget” is the amount of carbon dioxide that can be emitted and still have a reasonable chance of remaining below a particular rise in global temperature. To remain below a 1.5°C rise, total global emissions cannot exceed 240 billion tons of carbon from now forward. This is our current “carbon budget.”<sup>19</sup> Despite growing research into technological solutions to capture and remove CO<sub>2</sub> levels in the atmosphere, there is currently no known safe and effective way to remove emitted greenhouse gases from the atmosphere on a global scale. Reducing greenhouse gas emissions is thus the only known effective way to prevent using up our carbon budget. The longer we wait to reduce carbon pollution, the more drastic the action that will be required to remain within our carbon budget.

**Runaway climate change:** Climate scientists are concerned that some climate impacts may take on a life of their own, through positive feedback loops or surpassing of tipping points. For example, [collapse of the West Antarctic Ice Sheet](#) could lead to very rapid sea level rise, or melting of permafrost could lead to large releases of methane that would further increase warming through a positive feedback loop. Likewise, the whiteness of ice gives it high reflectivity, especially compared to the dark ocean water. As Arctic ice melts, less heat is reflected by ice, more is absorbed by the ocean, leading to further warming and rising of sea levels.<sup>17</sup>

### 3.3 Human Activities Cause Climate Change

While GHGE are the proximate cause of climate change, the production and release of these gases into the atmosphere is primarily the result of human activity, embedded in key systems such as energy, transportation, agriculture, and our consumption-driven economy. These systems are also key contributors to health outcomes and health inequities (See Sections [2—Health Equity](#) and [4—Health Impacts](#)). For example:

- Transportation systems determine how people and goods get from place to place, affecting physical activity, traffic injuries, air pollution, and GHGE. Fuel prices, pedestrian and bicycle infrastructure, and access to public transit influence driving behavior. Transportation systems impact access to jobs and services, and the loss of farmland and habitat.<sup>20</sup>
  - The transportation sector contributed 28% of all U.S. GHG emissions in 2016.<sup>21</sup>
  - Transportation is one of the fastest-growing sources of domestic GHGE and accounts for nearly half of the increase in total U.S. emissions since 1990.<sup>22</sup>
  - On-road vehicles were responsible for the vast majority (83%) of transportation-related GHGE; passenger cars and light-duty trucks contribute 60% of these emissions.<sup>23</sup>
- Agriculture and food systems determine the cost of and access to different kinds of food and nutrition; what crops are grown, and how; water usage, soil health and depletion; deforestation, and biodiversity loss. Industrialized animal production generates methane from livestock manure, antibiotic resistance from the overuse of antibiotics to increase animal growth, and water contamination from the excessive application of nitrogen fertilizers and pesticides. Corn and soy subsidies reduce meat prices and increase meat consumption.
  - Agriculture was responsible for 9% of total U.S. GHGE in 2016, 52% of methane emissions, and 84% of nitrous oxide release.<sup>24</sup>
  - When fertilizer use, refrigeration, transportation, and land use changes, such as deforestation and soil depletion, are taken into account, our food and agriculture systems account for about one third of global GHGE.<sup>25</sup>
- Energy systems provide for heating, lighting, and cooking, but the incomplete combustion of carbon also produces significant air pollution (e.g. from indoor cook stoves in poor countries, and from coal-fired power plants around the world). An estimated seven million deaths are associated with air pollution every year—one in eight of total global deaths.<sup>26</sup> Coal and uranium miners are at very high risk of occupational illness and injury, and mining often causes irreparable damage to water sources and natural habitats.<sup>27,28</sup>

- Electricity production contributes 28% of U.S. GHGE.<sup>29</sup>
- Electricity generated from renewables releases about 1/20th the GHGE of coal over the full life cycle.<sup>30</sup> Switching from fossil fuels to clean, renewable energy is a critical path to the reduction of greenhouse gas emissions.
- Economic systems distribute, allocate and determine access to wealth and resources, foster or alleviate wealth inequities, offer access to livelihoods and employment, and—in concert with social value systems—determine how much value we place on consumption of goods and/or non-marketable resources such as clean air, clean water, and open space.

## 3.4 Environmental Impacts of Climate Change

Climate change is causing five critical global environmental changes:<sup>31</sup>

- **Warming temperature of the earth’s surface and the oceans:** The earth has warmed at a rate of 0.13°C per decade since 1957, almost twice as fast as its rate of warming during the previous century.
- **Changes in the global ‘hydrologic’ (water) cycle:** Over the past century there have been distinct geographical changes in total annual precipitation, with some areas experiencing severe and long-term drought and others experiencing increased annual precipitation. The frequency and intensity of storms increases as the atmosphere warms and is able to hold more water vapor.
- **Declining glaciers and snowpack:** Across the globe, nearly all glaciers are decreasing in area, volume and mass. One billion people living in river watersheds fed by glaciers and snowmelt may be impacted by early spring runoff and flooding and diminished water flows in late summer.
- **Sea level rise:** Warmer water expands, so as oceans warm the increased volume of water is causing sea level rise. Melting glaciers and snowpack also contribute to rising seas.
- **Ocean acidification:** Oceans absorb about 25% of emitted CO<sub>2</sub> from the atmosphere, leading to acidification of seawater.

### Economic Toll of Climate Change

The health, social and economic costs of climate change are likely to be enormous. One recent study linked temperature rise to economic impacts on agriculture, crime, coastal storms, energy, and human mortality. Nationally, every 1°C (1.8°F) rise in average temperatures could cost 1.2% of gross domestic product and could raise death rates by 5.4 per 100,000. If unabated, climate change could cause damages that cost the poorest third of U.S. counties up to 20% of their income.<sup>32</sup> Another study estimated the health costs of just six climate-related events at \$14 billion.<sup>33</sup> In 2017 alone, the U.S. experienced 16 billion dollar climate-related disasters ranging from wildfires to tropical cyclones to crop freezes.<sup>34</sup> The rising costs of climate-related damages to infrastructure and economic productivity are likely to have ripple effects on funding for health and social needs. In contrast, a global assessment that monetized the health co-benefits of climate mitigation found that the value of avoided mortality averaged \$50–\$380 per ton of carbon dioxide, which far exceeds projected abatement costs.<sup>35</sup>

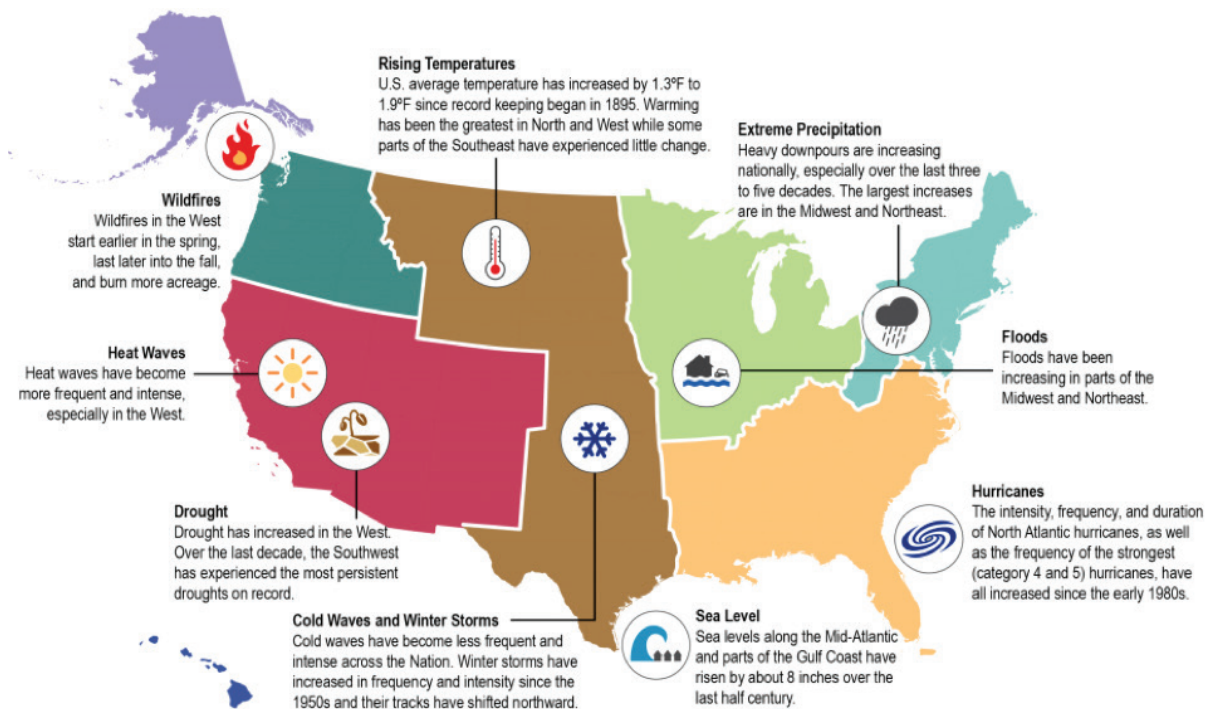
These global changes result in what we experience as changes in our local weather and climate.

- Greater variability, with “hotter hots,” “drier dries,” and “wetter wets”
- Higher average temperatures and longer frost-free seasons
- Longer wildfire seasons and more intense wildfires
- Loss of snowpack and earlier spring runoff
- Recurrent coastal flooding with high tides and storm surges
- Worsening air quality: Higher temperatures increase production of ozone (a key contributor to smog) and pollen, as well as increasing the risk of wildfires
- Longer pollen seasons and more pollen production

## 3.5 Climate Change in the United States

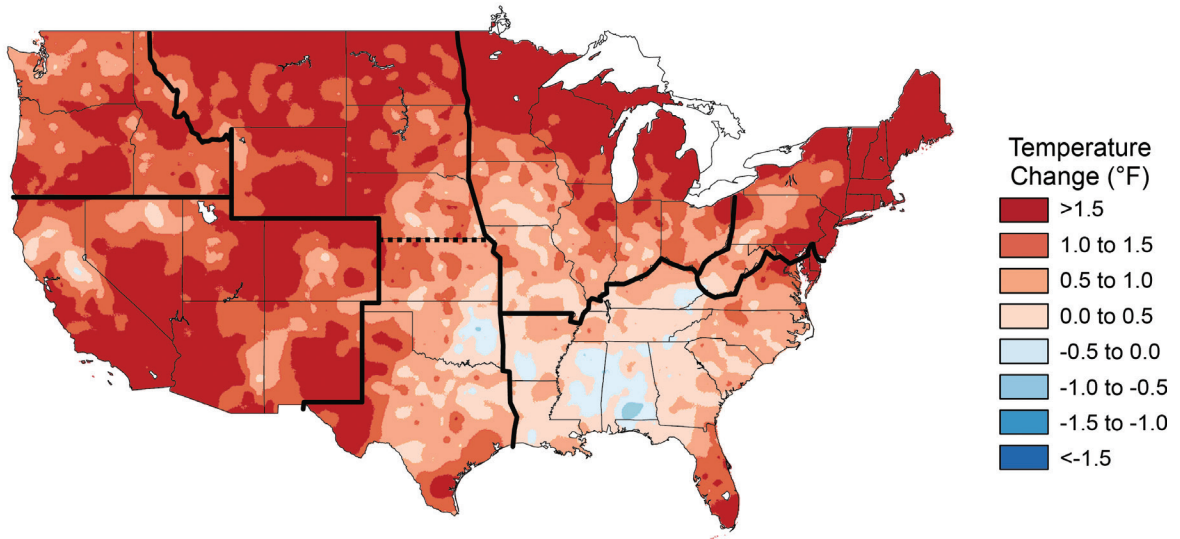
Various regions of the U.S. will experience climate change differently. Figures 3.5.1 and 3.5.2 show climate change in the U.S. and its effect on weather-related events and temperatures.<sup>36</sup> For a more comprehensive view, see the [Fourth National Climate Assessment](#).<sup>37</sup>

**Figure 3.5.1:** Climate Change Across the United States<sup>38</sup>

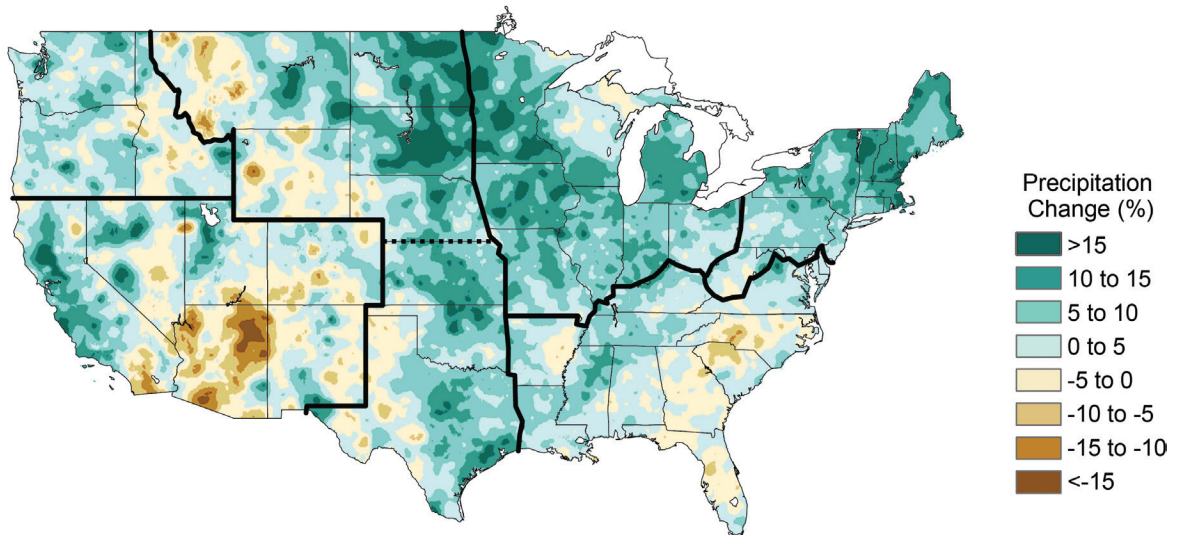


**Figure 3.5.2:** Observed Changes in Temperature and Precipitation in the United States Due to Climate Change (1991–2012 compared to 1901–1960)<sup>39</sup>

### Observed U.S. Temperature Change



### Observed U.S. Precipitation Change



Every community is experiencing the impacts of climate change, albeit in different ways. These impacts will worsen as GHG accumulate in the atmosphere. To protect health, we must act to both reduce GHGE and prepare for the impacts of climate change.