Climate Change: Science and Impacts

The Earth’s Climate

Climate change is altering temperature, precipitation, and sea levels, and will adversely impact human and natural systems, including water resources, human settlements and health, ecosystems, and biodiversity. The unprecedented acceleration of climate change over the last 50 years and the increasing confidence in global climate models add to the compelling evidence that climate is being affected by greenhouse gas (GHG) emissions from human activities. Changes in climate should not be confused with changes in weather. Weather is observed at a particular location on a time scale of hours or days, and exhibits a high degree of variability, whereas climate is the long-term average of short-term weather patterns, such as the annual average temperature or rainfall.

Changes in climate are driven by climate forcings. Disturbances of the Earth’s balance of incoming and outgoing energy are referred to as positive or negative climate forcings. Positive forcings, such as GHGs, exert a warming influence on the Earth, while negative forcings, such as sulfate aerosols, exert a cooling influence.

Anthropogenic GHG emissions, to date, amount to a climate forcing roughly equal to 1% of the net incoming solar energy, or the energy equivalent of burning 13 million barrels of oil every minute.

Climate Feedbacks and Inertia

Climate change is also affected by the Earth’s responses to forcings, known as climate feedbacks. For example, the increase in water vapor that occurs with warming further increases climate forcing and evaporation, as water vapor is a powerful GHG. As polar ice melts, less sunlight is reflected and the oceans absorb more solar radiation. Due to increasing temperature, large reserves of organic matter frozen in subarctic permafrost will thaw and decay, releasing additional CO₂ and methane to the atmosphere.

If GHG emissions were completely eliminated today, climate change impacts would still continue for centuries. The Earth’s temperature requires 25 to 50 years to reach 60% of its equilibrium response. Today’s emissions will affect future generations; CO₂ persists in the atmosphere for hundreds of years.

Human Influence on Climate

Separately, neither natural forcings (e.g., volcanic activity and solar variation) nor anthropogenic forcings (e.g., GHGs and aerosols) can fully explain the warming experienced since 1850. Climate models most closely match the observed temperature trend only when natural and anthropogenic forcings are considered together. In 2013, the Intergovernmental Panel on Climate Change (IPCC) concluded that: “It is extremely likely (>95% certainty) that human influence has been the dominant cause of the observed warming since the mid-20th century.”

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Observed Impacts

Physical Systems

• Global average temperature was 0.98°C (1.76°F) higher in 2020 than in the late 1800s.16
• The warmest year on record since records began in 1880 was 2016, with 2020 ranking second. In 2020 global average land temperatures experienced a record high, while 2016 global ocean temperatures remain the highest on record. The seven warmest years since 1880 have all occurred since 2014 and in 2020 annual global temperatures were above average for the 44th consecutive year.17
• Annual 2020 arctic temperatures rose to 1.9°C above the 1981-2010 average. Arctic sea ice is becoming younger, thinner, and less expansive. The 2020 extent of ice reached the second lowest annual cover on record since 1979, 3.74 million square kilometers.18
• U.S. average annual precipitation has increased by 4% since 1901, but the intensity and frequency of extreme precipitation events has increased even more, a trend that is expected to continue.19
• In the 20th century, global mean sea level rose between 17 and 21 cm, after having been quite stable over the previous several thousand years.5
• Snow cover has noticeably decreased in the Northern Hemisphere. From 1967-2012, snow cover extent decreased by approximately 53% in June, and around 7% in March and April.5

Biological Systems

• Warming that has already occurred is affecting the biological timing (phenology) and geographic range of plant and animal communities.19
• Relationships such as predator-prey interactions are affected by these shifts, especially when changes occur unevenly between species.20
• Since the start of the 20th century, the average growing season in the contiguous 48 states has lengthened by nearly two weeks.21

Predicted Changes

Increased Temperature

• By 2035, IPCC predicts that the temperature will rise between 0.3-0.7°C (0.5-1.3°F). In the long term, global mean surface temperatures are predicted to rise 0.4-2.6°C (0.7-4.7°F) from 2045-2065 and 0.3-4.8°C (0.5-8.6°F) from 2081-2100, relative to the reference period of 1986-2005. Since 1970, global average temperatures have been rising at a rate of 1.7°C per century, significantly higher than the average rate of decline of 0.01°C per year during the past 7,000 years.5,22
• A warming planet does not simply result in higher average daytime temperatures, the frequency and magnitude of extreme hot days will increase.22

Ocean Impacts

• Models anticipate sea level rise between 26 and 77 cm for a 1°C increase in temperature. The rise will be a result of thermal expansion from warming oceans and additional water added to the oceans by melting glaciers and ice sheets.22
• The oceans absorb about 27% of anthropogenic CO₂ emissions, resulting in increased acidity. Even under conservative projections, coral reefs will be severely impacted.23

Implications for Human and Natural Systems

• Impacts of climate change will vary regionally but are very likely to impose costs that will increase as global temperatures increase.24
• This century, an unprecedented combination of climate change, associated disturbances, and other global change drivers will likely exceed many ecosystems’ capacities for resilience.24 Species extinction, food insecurity, human activity constraints, and limited adaptability are risks associated with warming at or above predicted temperatures for the year 2100 (4°C or 7°F above pre-industrial levels).10
• With an increase in average global temperatures of 2°C, nearly every summer would be warmer than the hottest 5% of recent summers.25
• Due to regional variation, a 2-foot rise in sea level would cause relative increases of 3.5 feet in Galveston, TX and 1 foot in Neah Bay, WA.24
• Increased temperatures, changes in precipitation and climate variability would alter the geographic ranges and seasonality of diseases spread by organisms like mosquitoes.26
• Although higher CO₂ concentrations and slight temperature increases can boost crop yields, the negative effects of warming on plant health and soil moisture lead to lower yields at higher temperatures. Intensified soil and water resource degradation resulting from changes in temperature and precipitation will further stress agriculture in certain regions.27

References

1. Adapted from image by W. Elder, National Park Service.
18. Photo courtesy of the National Snow and Ice Data Center/World Data Center for Glaciology.


September 2021