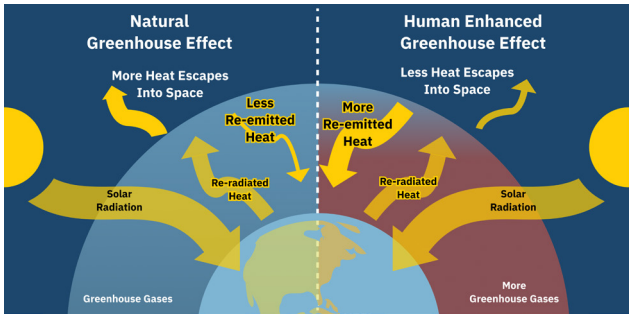
Climate Change: Science and Impacts

Earth's Climate

Climate change is altering temperature, precipitation, sea levels, and will adversely impact human and natural systems, including water resources, human settlements and health, ecosystems, and biodiversity.[1] 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.[1] 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.[2] Under a stable climate, there is an energy balance between incoming short wave solar radiation and outgoing long wave infrared radiation.[3] Solar radiation passes through the atmosphere and most is absorbed by the Earth's surface. The surface then re-emits energy as infrared radiation, a portion of which escapes into space.[3] Increases in the concentrations of GHGs in the atmosphere reduce the energy the Earth's surface radiates to space, thus warming the

The Earth's Greenhouse Effect[4]



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.[5]
- Anthropogenic GHG emissions, to date, amount to a climate forcing roughly equal to 1% of the net incoming solar energy, or the equivalent of burning 13 M barrels of oil every minute.[6,7]
- Increased concentrations of GHGs from anthropogenic sources have increased the absorption of infrared radiation, enhancing the natural greenhouse effect. Methane and other GHGs are more potent, but CO_2 contributes most to warming because of its prevalence.[5]

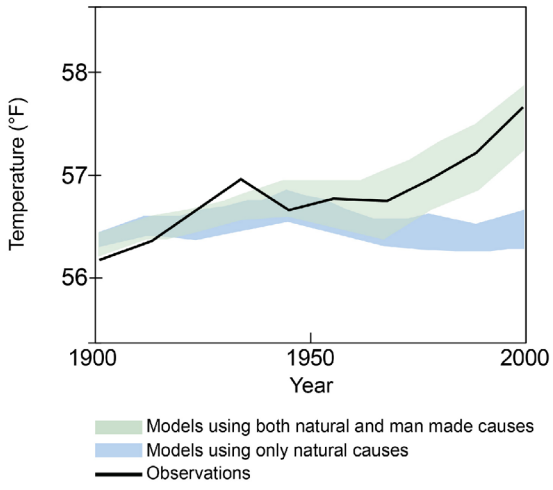
Climate Feedbacks and Inertia

- 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 surface warming and evaporation, as water vapor is a powerful GHG.[5]
- The volume of the ocean results in large thermal inertia that slows the response of climate change to forcings; energy balance changes result in delayed climate response with high momentum.[8]
- As polar ice melts, less sunlight is reflected and the oceans absorb more solar radiation.[5]
- As temperatures increase, large reserves of organic matter frozen in subarctic permafrost will thaw and decay, releasing additional CO_2 and methane to the atmosphere.[9] Extreme temperatures in the Artic have contributed to large wildfires and further thawing of permafrost.[10]
- If GHG emissions were completely eliminated today, climate change impacts would continue for centuries.[11] The Earth's temperature requires 25 to 50 years to reach 60% of its equilibrium response.[12] CO_2 persists in the atmosphere for hundreds of years.[13] Emissions now will affect future generations.

Human Influence on Climate

- Neither natural forcings (e.g., volcanic activity and solar variation) nor anthropogenic forcings (e.g., GHGs and aerosols) alone can fully explain the warming experienced since 1850.[14]
- In 2023, the Intergovernmental Panel on Climate Change (IPCC) concluded that "human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850-1900 in 2011-2020."[15]

Modeled and Observed Global Average Temperatures[16]



Physical Systems

- 2023 was the warmest year since global records began in 1850, 1.18°C (2.12°F) above the 20th century average and 0.15°C (0.27°F) warmer than the previous record set in 2016.[17]
- Global average land and ocean temperatures hit record highs in 2023.[17] The 10 warmest years on record have all occurred during the last decade and in 2023 global temperatures were above average for the 47th consecutive year.[17]
- Average 2023 summer surface air temperatures were the warmest on record.[18] Arctic sea ice is younger, thinner, and less expansive than in the 1980s and 90s.[19]
- The 2021 extent of ice reached the twelfth lowest annual cover on record since 1979, 4.92M km^2.[20]
- The intensity and frequency of extreme precipitation events has increased, a trend that is expected to continue.[21]
- Throughout the 1980s there were an average of 3.3 $1B weather disasters per year. From 2019 to 2023 the average was over 20 per year.[22]
- Global mean sea level has risen 15 - 25 cm since 1901. Due to deep ocean warming and ice sheet melting, sea level rise is unavoidable and will remain for centuries to millennia.[15]
- Snow cover has noticeably decreased in the Northern Hemisphere. North American arctic snow cover extent set a record low in 2023.[18] Under a 4°C warming scenario, snow cover is predicted to decrease by 15%-30%.[11]

Northwestern Glacier melt, Alaska 1940-2005[23]

Biological Systems

- Warming that has already occurred is affecting the biological timing and geographic ranges of plants and animals.[24] Often biological responses cannot handle the rapid spatial and temporal shifts that climate change is causing.[15]
- Globally, approximately half of species assessed have shifted polewards or to higher elevations.[15] Relationships such as predator-prey interactions are affected by these shifts, especially when changes occur unevenly between species.[25]
- Since the start of the 20th century, the average growing season in the contiguous 48 states has lengthened by more than two weeks.[26]

Predicted Changes

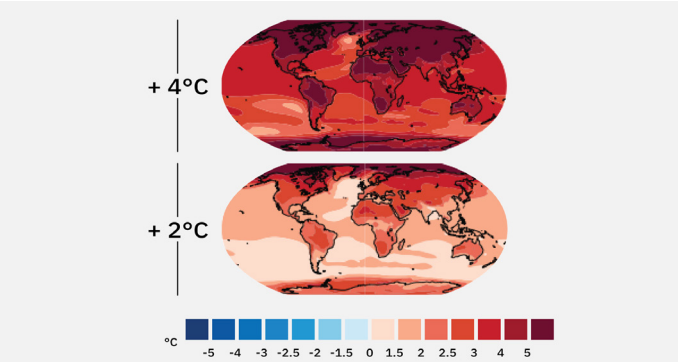
Increased Temperature

- IPCC predicts global temperature will rise by 1.5°C (2.7°F) by the early 2030s.[11] 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.[5]
- 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 over the past 7,000 years.[27]

Ocean Impacts

- Models anticipate sea level rise between 26 and 77 cm for a 1.5°C increase in temperature by 2100. The rise is a result of thermal expansion from warming oceans and water added to the oceans by melting glaciers and ice sheets.[27]
- The oceans absorb about 31% of anthropogenic CO_2 emissions, resulting in increased acidity. Coral reefs are projected to decline by 70–90% under a 1.5°C global warming scenario.[28,15]

Projected Near Surface Temperature Change[11]



- Risks associated with a warming scenario of 4°C include more frequent and intense hot and cold extreme temperatures, precipitation events, droughts, and hurricanes.[11]
- Weather disasters in the U.S. cost an average of $21.8B and $33.3B per year in the 1980s and 90s, respectively. These costs have risen to an average of $61.8B per year in the 2000s and $98.8B per year in the 2010s.[22]
- In 2023, the IPCC stated with very high confidence that "There is a rapidly closing window of opportunity to secure a liveable and sustainable future for all."[15]
- Due to regional variation, a 2-ft rise in sea level would cause increases of 3.5 ft in Galveston, TX and 1 ft in Neah Bay, WA.[1]
- Increased temperature, changes in precipitation, and climate variability have increased the occurrence of food-borne and water-borne diseases. Vector-borne diseases are also occurring more often and in new geographic regions.[15,29]

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Sources for this factsheet are here, help with units and abbreviations is here.