
Climate Change

Position Statement. Decades of scientific research have shown that climate can change from both natural and anthropogenic causes. The Geological Society of America (GSA) concurs with assessments by the National Academies of Science (2005), the National Research Council (2011), the Intergovernmental Panel on Climate Change (IPCC, 2013) and the U.S. Global Change Research Program (Melillo et al., 2014) that global climate has warmed in response to increasing concentrations of carbon dioxide (CO₂) and other greenhouse gases. The concentrations of greenhouse gases in the atmosphere are now higher than they have been for many thousands of years. Human activities (mainly greenhouse-gas emissions) are the dominant cause of the rapid warming since the middle 1900s (IPCC, 2013). If the upward trend in greenhouse-gas concentrations continues, the projected global climate change by the end of the twenty-first century will result in significant impacts on humans and other species. The tangible effects of climate change are already occurring. Addressing the challenges posed by climate change will require a combination of adaptation to the changes that are likely to occur and global reductions of CO₂ emissions from anthropogenic sources.

Purpose. This position statement (1) summarizes the scientific basis for the conclusion that human activities are the primary cause of recent global warming; (2) describes the significant effects on humans and ecosystems as greenhouse-gas concentrations and global climate reach projected levels; and (3) provides information for policy decisions guiding mitigation and adaptation strategies designed to address the current and future impacts of anthropogenic warming.

RATIONALE

Scientific advances have greatly reduced previous uncertainties about recent global warming. Ground-station measurements have shown a warming trend of ~0.85 °C since 1880, a trend consistent with (1) retreat of northern hemisphere snow and Arctic sea ice; (2) greater heat storage in the ocean; (3) retreat of most mountain glaciers; (4) an ongoing rise in global sea level; and (5) proxy reconstructions of temperature change over past centuries from archives that include ice cores, tree rings, lake sediments, boreholes, cave deposits, and corals. Both instrumental records and proxy indices from geologic sources show that global mean surface temperature was higher during the last few decades of the 20th century and the first decade of the 21st than during any comparable period during the preceding four centuries (National Research Council, 2006). Earth's surface has been successively warmer in each of the last three decades and each of those has been warmer than any decade since 1850. The period from 1983 to 2012 is likely the warmest 30 years in the northern hemisphere during the last 1,400 years (IPCC, 2013). This recent warming of Earth's surface is now consistently supported by a wide range of measurements and proxies, including land- and satellite-based measurements.

The geologic record contains unequivocal evidence of former climate change, including periods of greater warmth with limited polar ice, and colder intervals with more widespread glaciation. These and other changes were accompanied by major shifts in species and ecosystems. Paleoclimatic research has demonstrated that these major changes in climate and biota are associated with significant changes in climate forcing, such as continental positions and topography, patterns of ocean circulation, the greenhouse gas composition of the atmosphere, and the distribution and amount of solar energy at the top of the atmosphere caused by changes in Earth's orbit and the evolution of the sun as a main sequence star. Cyclic changes in ice volume during glacial periods over the last three million years have been correlated to orbital cycles and changes in greenhouse gas concentrations, but may also reflect internal responses generated by large ice sheets. This rich history of Earth's climate has been used as one of several key sources of information for assessing the predictive capabilities of modern climate models. The testing of increasingly sophisticated climate models by comparison to geologic proxies is continuing, leading to refinement of hypotheses and improved understanding of the drivers of past and current climate

change. Climate models have improved continuously and now reproduce observed continental-scale warming patterns over multiple decades (IPCC, 2013).

Given the knowledge gained from paleoclimatic studies, several explanations for the ongoing warming trend can be eliminated. Changes in Earth's tectonism and its orbit are far too slow to have played a significant role in the observed rate of temperature increase over the last 150 years. At the other extreme, large volcanic eruptions have cooled global climate for a year or two, and El Niño episodes have warmed it for about a year, but neither factor dominates longer-term trends. Extensive efforts to find any other natural explanation for the recent trend have similarly failed.

As a result, greenhouse-gas concentrations and solar output are the principal remaining factors that could have changed rapidly enough and lasted long enough to explain the observed changes in global temperature. The 5th IPCC report (2013) concluded that solar irradiance changes contributed only a few percent to changes in radiative forcing of the atmosphere over the past century. Throughout the era of satellite observation, during periods of strong warming, the data show little evidence of increased solar influence (Foster and Rahmstorf, 2011; Lean and Rind, 2008).

Greenhouse gas concentrations remain the major explanation for the warming. Observations and climate model assessments of the natural and anthropogenic factors responsible for this warming conclude that rising anthropogenic emissions of greenhouse gases have been an increasingly important contributor since the mid-1800s and the major factor since the mid-1900s (Meehl et al., 2004). The CO₂ concentration in the atmosphere is now ~40% higher than peak levels measured in ice cores spanning 800,000 years of age, and the methane concentration is 1.5 times higher (IPCC, 2013). The measured increases in greenhouse gases are more than enough to explain the observed global temperature increase at Earth's surface. In fact, considered in isolation, the greenhouse gas increases during the last 150 years would have caused a warming larger than that actually measured, but mechanisms that limit increases in near-surface air temperatures from aerosols, ocean heat storage, and possibly clouds have offset part of the warming. In addition, because the oceans take decades to centuries to respond fully to climatic forcing, the climate system has yet to register the full effect of recent greenhouse gas increases.

These advances in scientific understanding of recent warming form the basis for projections of future changes. If greenhouse-gas emissions follow a likely trajectory with little to no effort to stabilize emissions (IPCC, 2013, RCP 8.5), by 2100 atmospheric CO₂ concentrations will reach four times pre-industrial levels, for a total warming of 2.6 °C to 4.8 °C compared to 1850. Even under scenarios that take into account efforts to stabilize emissions, expected increases in global mean temperature exceed 2 °C by the year 2100. The likely changes in greenhouse gas concentrations and temperature would substantially alter the functioning of the planet in many ways. The projected changes involve the following risks to humans and other species: (1) continued shrinking of Arctic sea ice, with effects on native cultures and ice-dependent biota; (2) less snow accumulation and earlier melt in mountains, with reductions in spring and summer runoff for agricultural and municipal water; (3) disappearance of mountain glaciers and their late-summer runoff; (4) increased evaporation from farmland soils and stress on crops; (5) greater soil erosion due to increases in heavy convective summer rainfall; (6) longer fire seasons and increases in fire frequency; (7) severe insect outbreaks in vulnerable forests; (8) acidification of the global ocean; and (9) fundamental changes in the composition, functioning, and biodiversity of many terrestrial and marine ecosystems. In addition, melting of Greenland and West Antarctic ice (still highly uncertain as to amount), along with thermal expansion of seawater and melting of mountain glaciers and small ice caps, will cause substantial future sea-level rise, affecting densely populated coastal regions, inundating farmlands, and dislocating large populations (Melillo et al, 2014; IPCC, 2013). Because large, abrupt climatic changes occurred within spans of just decades during previous ice-sheet fluctuations, the possibility exists for rapid future changes as ice sheets become vulnerable to enhanced global warming associated with the greenhouse gas increases. Finally, carbon-climate model simulations indicate that 15%–40% of the anthropogenic CO₂ “pulse” could stay in the atmosphere for longer than a thousand years, extending the duration of fossil-fuel warming and its effects on humans and other species. The acidification of the global ocean and its effects on ocean life

are projected to last for tens of thousands of years and, on the basis of documented climate changes in the past, lead to extinction of species.

PUBLIC POLICY ASPECTS

Recent scientific investigations have strengthened the case for policy action to reduce greenhouse gas emissions and to adapt to unavoidable climate change. There will be significant economic, health, and safety impacts in the absence of global action on climate change. Public policy should include effective strategies for the reduction of greenhouse gas emissions. To strengthen the scientific contributions to policy discussions on how to address climate change, this statement from The Geological Society of America is intended to inform policymakers about improved knowledge of Earth's climate system based on advances in climate science. Robust scientific investigation has contributed to an improved understanding of the climate system and has supplied strong evidence for human-induced global warming, providing policy makers with a unique perspective on which to base mitigation and adaptation strategies. Carefully researched and tested adaptation strategies can both reduce and limit negative impacts and explore potential positive impacts. Current and future climate change poses societal, biological, economic, and strategic challenges that will require a combination of national and international emissions reductions and adaptations. These challenges require balanced and thoughtful national and international discussions leading to careful long-term planning and sustained policy actions.

RECOMMENDATIONS

Policies to address the challenges posed by climate change should include adaptation and mitigation measures:

- Cost-effective investments to improve the efficient use of Earth's energy resources can reduce the economic impacts of future adaptation efforts. Strategies for reducing greenhouse-gas emissions should be evaluated based on their impacts on climate, on costs to global and national economies, and on positive and negative impacts on the health, safety, and welfare of humans and ecosystems.
- Comprehensive local, state, national, and international planning is needed to address challenges posed by future climate change. Near-, mid-, and long-term strategies for mitigation of and adaptation to climate change should be developed, based in part on knowledge gained from studies of previous environmental changes.
- Public investment is needed to improve our understanding of how climate change affects society, including on local and regional scales, and to formulate adaptation measures. Sustained support of climate-related research to advance understanding of the past and present operation of the climate system is needed, with particular focus on the major remaining uncertainties in understanding and predicting Earth's future climate at regional and global scales. Research is needed to improve our ability to assess the response and resilience of natural and human systems to past, present, and future changes in the climate system.

REFERENCES CITED

REPORTS

1. IPCC (Intergovernmental Panel on Climate Change), 2013, Summary for Policymakers. In: *Climate Change 2013: The physical science basis*: Cambridge, United Kingdom, and New York, NY, USA, Cambridge University Press, 29 p.
2. IPCC (Intergovernmental Panel on Climate Change), 2007, Summary for policymakers, in *Climate Change 2007: The physical science basis*: Cambridge, United Kingdom, Cambridge University Press, 18 p.
3. IPCC (Intergovernmental Panel on Climate Change), 2001, Summary for policymakers, in *Climate Change 2001: Synthesis Report*: Cambridge, United Kingdom, Cambridge University Press, 34 p.
4. Melillo, J.M., Richmond, T.C., and Yohe, G.W., Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

5. National Academies of Science (2005). Joint academes statement: Global response to climate change. (<http://nationalacademies.org/onpi/06072005.pdf>)
6. National Research Council (2011). America's Climate Choices. Washington, DC: The National Academies Press, 144 p.

PEER-REVIEWED ARTICLES

1. Foster, G. and Rahmstorf, S., 2011, Global temperature evolution 1979–2010, Environmental Research Letters, doi: 10.1088/1748-9326/6/4/044022.
2. Foukal, P.G., et al., 2004, A stellar view on solar variations and climate: Science, v. 306, p. 68–69.
3. Lean, J.L., and Rind, D.H., 2008, How natural and anthropogenic influences alter global and regional surface temperatures: 1889 to 2006, Geophysical Research Letters, doi: 10.1029/2008GL034864.
4. Meehl et al., 2004, Combinations of natural and anthropogenic forcings in twentieth-century climate: J. of Climate, v. 17, p. 3721-3727.
5. Wang, Y.-M., Lean, J.L., and Sheeley, N.R. Jr., 2005, Modeling the Sun's magnetic field and irradiance since 1713: Astrophysical Journal, v. 625, p. 522–538.

SELECTED WEB SITES

Intergovernmental Panel on Climate Change

1. IPCC reports: www.ipcc.ch

U.S. National Academies

2. Climate Change at the National Academies: www.nas-sites.org/americasclimatechoices/
3. Surface temperature reconstructions: www.nap.edu/catalog.php?record_id=11676#toc

U.S. Global Change Research Program: www.globalchange.gov

ABOUT THE GEOLOGICAL SOCIETY OF AMERICA

The Geological Society of America, founded in 1888, is a scientific society with more than 26,000 members from academia, government, and industry in more than 100 countries. Through its meetings, publications, and programs, GSA enhances the professional growth of its members and promotes the geosciences in the service of humankind. GSA encourages cooperative research among earth, life, planetary, and social scientists, fosters public dialogue on geoscience issues, and supports all levels of earth science education. Inquiries about the GSA or this position statement should be directed to GSA's Director for Geoscience Policy, Kasey S. White, at +1-202-669-0466 or kwhite@geosociety.org.

OPPORTUNITIES FOR GSA AND GSA MEMBERS TO HELP IMPLEMENT RECOMMENDATIONS

To facilitate implementation of the goals of this position statement, the Geological Society of America recommends that its members take the following actions:

- Actively participate in professional education and discussion activities to be technically informed about the latest advances in climate science. Members should plan symposia at regional, national, and international meetings to inform members on mainstream understanding among geoscientists and climate scientists of the causes and future effects of global warming within the broader context of natural variability. These symposia should seek to actively engage members in hosted discussions that clarify issues, possibly utilizing educational formats other than the traditional presentation and Q&A session.
- Engage in public education activities in the community, including at the local level. Public education is a critical element of a proactive response to the challenges presented by global climate change. GSA members are encouraged to take an active part in outreach activities to educate the public at all levels (local, regional, national, and international) about the science of climate change and the importance of geological research in framing policy development. Such activities can include organizing and participating in community school activities; leading discussion groups in civic organizations; meeting with local and state community leaders and congressional staffs; participating in GSA's Congressional Visits Day; writing opinion pieces and letters to the editor for local and regional newspapers; contributing to online forums; and volunteering for organizations that support efforts to mitigate and adapt to global climate change.
- Collaborate with a wide range of stakeholders and help educate and inform them about the causes and impacts of global climate change from the geosciences perspective. GSA members are encouraged to discuss with businesses and policy makers the science of climate change, as well as opportunities for transitioning from our predominant dependence on fossil fuels to greater use of low-carbon energies and energy efficiencies.
- Work interactively with other science and policy societies to help inform the public and ensure that policymakers have access to scientifically reliable information. GSA should actively engage and collaborate with other earth-science organizations in recommending and formulating national and international strategies to address impending impacts of anthropogenic climate change.
- Take advantage of the following list of references for a current scientific assessment of global climate change.