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 (2006), and the Intergovernmental Panel on Climate Change (IPCC, 2007) that global climate has warmed and that human activities (mainly greenhouse-gas emissions) account for most of the warming since the middle 1900s. If current trends continue, the projected increase in global temperature by the end of the twenty-first century will result in large impacts on humans and other species. 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 CO_2 emissions from anthropogenic sources.

Purpose. This position statement (1) summarizes the strengthened basis for the conclusion that humans are a major factor responsible for recent global warming; (2) describes the large effects on humans and ecosystems if 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 future impacts of anthropogenic warming.

RATIONALE

Scientific advances in the first decade of the 21st century have greatly reduced previous uncertainties about the amplitude and causes of recent global warming. Ground-station measurements have shown a warming trend of ~0.7 °C since the mid-1800s, a trend consistent with (1) retreat of northern hemisphere snow and Arctic sea ice in the last 40 years; (2) greater heat storage in the ocean over the last 50 years; (3) retreat of most mountain glaciers since 1850; (4) an ongoing rise of global sea level for more than a century; and (5) proxy reconstructions of temperature change over past centuries from 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 than during any comparable period during the preceding four centuries (National Research Council, 2006).

Measurements from satellites, which began in 1979, initially did not show a warming trend, but later studies (Mears and Wentz, 2005; Santer et al., 2008) found that the satellite data had not been fully adjusted for losses of satellite elevation through time, differences in time of arrival over a given location, and removal of higher-elevation effects on the lower tropospheric signal. With these factors taken into account, the satellite data are now in basic agreement with ground-station data and confirm a warming trend since 1979. In a related study, Sherwood et al. (2005) found problems with corrections of tropical daytime radiosonde measurements and largely resolved a previous discrepancy with ground-station trends. With instrumental discrepancies having been resolved, recent warming of Earth's surface is now consistently supported by a wide range of measurements and proxies and is no longer open to serious challenge.

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

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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.

Given the knowledge gained from paleoclimatic studies, several long-term causes of the current warming trend can be eliminated. Changes in Earth's tectonism and its orbit are far too slow to have played a significant role in a rapidly changing 150-year trend. 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.

As a result, greenhouse gas concentrations, which can be influenced by human activities, and solar fluctuations are the principal remaining factors that could have changed rapidly enough and lasted long enough to explain the observed changes in global temperature. Although the 3rd IPCC report allowed that solar fluctuations might have contributed as much as 30% of the warming since 1850, subsequent observations of Sun-like stars (Foukal et al., 2004) and new simulations of the evolution of solar sources of irradiance variations (Wang et al., 2005) have reduced these estimates. The 4th (2007) IPCC report concluded that changes in solar irradiance, continuously measured by satellites since 1979, account for less than 10% of the last 150 years of warming.

Greenhouse gases remain as the major explanation. 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 CO_2 concentration in the atmosphere is now ~30% higher than peak levels that have been measured in ice cores spanning 800,000 years of age, and the methane concentration is 2.5 times higher. About half of Earth's warming has occurred through the basic heat-trapping effect of the gases in the absence of any feedback processes. This "clear-sky" response to climate is known with high certainty. The other half of the estimated warming results from the net effect of feedbacks in the climate system: a very large positive feedback from water vapor; a smaller positive feedback from snow and ice albedo; and sizeable, but still uncertain, negative feedbacks from clouds and aerosols. The vertical structure of observed changes in temperature and water vapor in the troposphere is consistent with the anthropogenic greenhouse-gas "fingerprint" simulated by climate models (Santer et al., 2008). Considered in isolation, the greenhouse-gas increases during the last 150 years would have caused a warming larger than that actually measured, but negative feedback from clouds and aerosols has 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 gas increases in recent decades.

These advances in scientific understanding of recent warming form the basis for projections of future changes. If greenhouse-gas emissions follow the current trajectory, by 2100 atmospheric CO_2 concentrations will reach two to four times pre-industrial levels, for a total warming of less than 2 °C to more than 5 °C compared to 1850. This range of changes in greenhouse gas concentrations and temperature would substantially alter the functioning of the planet in many ways. The projected changes involve risk 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 along densely populated coastal regions, inundating farmland and dislocating large populations. 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 large greenhouse-gas increases. Finally, carbon-climate model simulations indicate that 10–20% of the anthropogenic CO_2 "pulse" could stay in the atmosphere for thousands of 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.

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. To strengthen the consensus for action, 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. Recent scientific investigations have contributed to this improved understanding of the climate system and 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. Future climate change will pose societal, biological, economic, and strategic challenges that will require a combination of national and international emissions reductions and adaptations. These challenges will also require balanced and thoughtful national and international discussions leading to careful long-term planning and sustained policy actions.

Recommendations

- *Public policy should include effective strategies for the reduction of greenhouse gas emissions.* 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.

About the Geological Society of America

The Geological Society of America, founded in 1888, is a scientific society with over 22,000 members from academia, government, and industry in more than 90 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 2009-2010 President, Dr. Jean M. Bahr, at +1-608-262-5513, or president@geosociety.org.

OPPORTUNITIES FOR GSA AND ITS 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.* GSA should encourage 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 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 global warming 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 global warming, 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.*

REFERENCES CITED

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SELECTED WEB SITES

Intergovernmental Panel on Climate Change

IPCC reports: www.ipcc.ch/

U.S. National Academies

Climate Change at the National Academies: dels.nas.edu/climatechange/

Surface temperature reconstructions: www.nap.edu/catalog.php?record_id=11676#toc

U.S. Global Change Research Program

Home page: www.globalchange.gov/

Satellite issue: www.climatescience.gov/Library/sap/sap1-1/finalreport/default.htm

Geologic record of abrupt changes: www.climatescience.gov/Library/sap/sap3-4/final-report/

Global climate change impacts in the United States: www.globalchange.gov./publications/reports/scientific-assessments/us-impacts