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Evolving Assessments of Human and Natural Contributions to Climate Change

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Summary

This CRS report provides context for the Administration's Climate Science Special Report (October 2017) by tracing the evolution of scientific understanding and confidence regarding the drivers of recent global climate change.

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Introduction

As Congress continues to deliberate whether and how to address climate change, a key question has been the degree to which humans and natural factors have influenced observed global climate change.¹ Members of Congress sometimes stress that policies or actions “must be based on sound science.”² Officials in the Trump Administration have expressed uncertainty about the human influence, and some have called for public debate on the topic.³

To help inform policymaking, researchers and major scientific assessment processes have analyzed the attribution of observed climate change to various possible causes. Scientific assessments of both climate change and the extent to which humans have influenced it have varied in expressed confidence over time but have achieved greater scientific consensus. The latest major U.S. assessment, the Climate Science Special Report (CSSR), was released in October 2017 by the U.S. Global Change Research Program (USGCRP). It stated

It is extremely likely [$>95\%$ likelihood] that human influence has been the dominant cause of the observed warming since the mid-20th Century. For the warming over the last century, there is no convincing alternative explanation supported by the extent of the observational evidence.⁴

This CRS report provides context for the CSSR’s statement by tracing the evolution of scientific understanding and confidence regarding the drivers of recent global climate change.⁵

¹ Rep. Lamar Smith, in U.S. Congress, House Committee on Science, Space, and Technology, *Climate Science: Assumptions, Policy Implications, and the Scientific Method*, 115th Cong., 1st sess., March 29, 2017, Serial No. 115-10 (Washington: GPO, 2017), p. 4; Sen. John Barrasso, as quoted in “Republican Leader: Climate Change Science ‘Not Known,’” *The Hill*, June 4, 2014, <http://thehill.com/policy/energy-environment/208431-gop-leader-climate-change-science-not-known>; See also the discussion of Senate votes in 2015 regarding climate change attribution to human activities in Dustin Weaver, “Senate Votes That Climate Change Is Real,” *The Hill*, January 21, 2015, <http://thehill.com/policy/energy-environment/230316-senate-votes-98-1-that-climate-change-is-real>.

² *Ibid.* The full quotation from Rep. Smith is as follows:

I believe the climate is changing and that humans play a role. However, I also believe significant questions remain as to the extent. Our actions must be based on sound science. This is the only way we will be able to better address climate change.

³ For example, the Administrator of the U.S. Environmental Protection Agency, Scott Pruitt, told Fox News, “Human activity contributes to that [climate] change in some measure.... The issue is how much we contribute to it from a human activity perspective and then what can be done about it from a process perspective.” Quoted in Anna Giaritelli, “Trump EPA Chief: Humans Contribute to Global Warming, But How Much?,” April 2, 2017, <http://www.foxnews.com/politics/2017/04/02/trump-epa-chief-humans-contribute-to-global-warming-but-how-much.html>. It is presently unclear whether the Administration might proceed with a “Red Team, Blue Team” debate on climate science, as proposed by Administrator Pruitt, continue with the periodic science assessments required by the Global Change Research Act of 1990 (P.L. 110-606), or pursue another approach. See, for example, Robin Bravender, “Climate Science Debate ‘On Hold’ After White House Meeting,” *ClimateWire*, December 15, 2017, <http://thehill.com/policy/energy-environment/365104-trump-admin-puts-epa-climate-science-debate-plan-on-hold>.

⁴ Donald J. Weubbles et al., *Climate Science Special Report: Fourth National Climate Assessment, Volume I*, USGCRP, 2017, https://science2017.globalchange.gov/downloads/CSSR2017_FullReport.pdf. A brief explanation of development of the CSSR is available at <https://www.globalchange.gov/content/cssr>. The CSSR is the first volume of the fourth national assessment required periodically by the Global Change Research Act of 1990 (P.L. 101-606).

⁵ Scientists and commentators often discuss climate change referring to different periods of time. Such time differences can explain some or all of the differences among some perspectives. The factors having greatest influence on global climate typically vary depending on whether the period of interest is one decade, several decades to a century, or tens of thousands to millions of years. While scientific assessments of the drivers of climate change cover all time scales, most assessments consider the human contribution since the Industrial Revolution beginning in the 19th century.

Climate change science can be traced back to the early 1800s. Through the 20th century, academic institutions, federal and state agencies, foreign governments, and other entities invested significant time and billions of dollars in climate research. This investment has led to substantial advances in empirical observations, atmospheric and ocean physics and chemistry, climate and economic simulation models, statistical methods, and other achievements. As a result, scientists have increased their confidence in their detection and understanding of climate change and attribution of observed changes to their causes. There is now high scientific confidence that the global climate is warming, primarily as a result of increased human-related greenhouse gas (GHG) emissions and other activities.⁶ This confidence has evolved from nearly two centuries of research and assessments.

This report describes a chronology (in the **Appendix**) of 200 years of major scientific statements, selected to represent views at each time, regarding the human and natural contributions to global climate change. The chronology demonstrates how scientific views and confidence in those views evolved over time.

That GHGs, including carbon dioxide (CO₂),⁷ water vapor, and other gases, warm the Earth's climate is not a recent concept. The greenhouse effect,⁸ as it is sometimes called, was deduced as early as 1827⁹ with relatively little dispute since the 19th century among scientists about the role of GHGs: Some level of GHGs in the atmosphere is necessary for maintaining a temperate climate on Earth. Instead, the debate that unfolded involved whether the climate had been warming overall¹⁰ and, if so, to what the changes may be attributable (such as industrial releases

⁶ Weubbles et al., *Climate Science Special Report*. The CSSR (p. 127) provided the following summary paragraph regarding scientific confidence in detection of climate change and attribution to human and natural causes:

Detection and attribution studies, climate models, observations, paleoclimate data, and physical understanding lead to *high confidence (extremely likely)* that more than half of the observed global mean warming since 1951 was caused by humans, and *high confidence* that internal climate variability played only a minor role (and possibly even a negative contribution) in the observed warming since 1951. The key message and supporting text summarizes extensive evidence documented in the peer-reviewed detection and attribution literature, including in the [Fifth Assessment Report of the Intergovernmental Panel on Climate Change].

⁷ CO₂ was referred to as carbonic acid in the 1800s, as will appear in some entries in **Table A-1**.

⁸ GHGs in the atmosphere allow shortwave solar radiation to pass through to the Earth's surface but block longwave energy (i.e., heat) from re-radiating into space. GHGs are similar to glass that allows sunlight to enter a greenhouse but keeps heat from escaping. An early description is present in T. Sterry Hunt, "On the Earth's Climate in Palæozoic Times." *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, vol. 26, no. 175 (October 1, 1863):

The late researches of Tyndall on the relation of gases and vapours to radiant heat are important in their bearing upon the temperature of the earth's surface in former geological periods. He has shown that heat, from whatever source, passes through hydrogen, oxygen, and nitrogen gases, or through dry air, with nearly the same facility as through a vacuum.... Gases and some other solid substances, which are readily permeable to light and to solar heat, offer, as is well known, great obstacles to the passage of radiant heat from non-luminous bodies; and Tyndall has recently shown that many colourless vapours and gases have a similar effect, intercepting the heat from such sources, by which they become warmed and in their turn radiate heat.... The diffusion of olefiant gas ... carbonic acid gas ... ozone ... watery vapour present in the air.... *Like a covering of glass, it allows the sun's rays to reach the earth but prevents to a great extent the loss by radiation of the heat thus communicated.* (p. 323, emphasis added)

⁹ Jean-Baptiste Joseph Fourier, "Mémoire Sur Les Températures Du Globe Terrestre et Des Espaces Planétaires," *Mémoires de l'Académie Royale Des Sciences de l'Institut de France*, 1827, <https://geosci.uchicago.edu/~rtp1/papers/Fourier1827Trans.pdf>.

¹⁰ The focus of this report is on attribution of global temperature changes, but much research and many scientific assessments address other metrics of climate, such as precipitation and seasonality.

of GHGs, volcanoes, solar activity, or other natural variations). (See text box, **Human and Natural Influences on Climate**.)

Chronology of Climate Change Science

As indicated by the information presented in **Table A-1**, scientists have noted, dating back to early in the 19th century, both human and natural factors potentially influencing climate. As one scholar observed, “by 1900, most of the chief theories of climate change had been proposed, if not yet fully explored.”¹¹ There were a number of contending theories—including changes in solar energy, the Earth’s orbital geometry, volcanoes, the geography of continents, and changes in GHGs—in the late 1800s as the quotations in **Table A-1** indicate. Well into the 1900s, the state of the science relating CO₂ concentrations in the atmosphere to the Earth’s temperature was primarily theoretical inference. Scientists debated whether increases in CO₂ in the atmosphere due to increasing emissions from fossil fuels would lead to further warming.

Human and Natural Influences on Climate¹²

There are several ways that climate can be affected by both human and natural causes.

Humans: Climate is affected by changing concentrations in the atmosphere of GHGs such as CO₂, methane, water vapor, chlorofluorocarbons, hydrofluorocarbons, and other gases and aerosols. GHGs trap heat in the atmosphere and warm the atmosphere. Most human-related GHGs are emitted in the production and use of fossil fuels. Though not typically considered GHGs, emissions of polluting sulfur and carbonaceous aerosols also alter the atmosphere’s reflection of solar radiation and its absorption of heat. Humans change land cover, affecting both the reflectivity of land and the removal of CO₂ from the atmosphere by vegetation. Higher CO₂ concentrations in the atmosphere fertilize vegetation, increasing removals of CO₂ from the atmosphere when other factors (e.g., nutrient and water availability, temperature, solar insolation, etc.) are not constraining.

Natural: Natural influences on the climate may include changes in solar energy, naturally occurring water vapor and CO₂ in the atmosphere, volcanic aerosol and GHG emissions, and cyclical oscillations in the oceans. These factors impact climate by affecting the amount of solar radiation reaching earth’s surface, modulating how much heat is retained within the atmosphere, or changing oceanic and atmospheric temperature circulation. Over scales of centuries to tens of thousands of years, the Earth’s rotational wobble and orbit around the sun also affect the pattern of incoming solar radiation and affect climate on geologic time scales (e.g., glacial and inter-glacial periods).

Since then, a number of factors—including better measurement technologies; development of physics- and empirically based simulation models; more research, review, and revision; and longer series of observations—have improved the foundations of climate science. As a result, scientists have improved quantification of the relationships between observed conditions:

1. Natural and human-related GHG emissions (the latter mostly from fossil-fuel-based energy) to the atmosphere;
2. Increasing GHG concentrations in the atmosphere and changes in other influences on climate (e.g., changes in solar and volcanic activity);
3. Rising global average surface temperature; and
4. Other observed changes in the spatial and temporal patterns of climate.

The magnitudes of factors, and therefore their influences on climate, vary over time. With acceleration of human population growth and industrialization since the 19th century, the factors related to human activities have increased relative to those of natural processes. Increased

¹¹ James Rodger Fleming, *Historical Perspectives on Climate Change*, Oxford University Press (2005).

¹² Weubbles et al., *Climate Science Special Report*.

scientific capacity has made climate change increasingly detectable and attributable to the varying influences over the past two centuries.¹³

In the late 1930s, Guy Callendar compiled existing data on atmospheric CO₂ concentrations and regional temperatures.¹⁴ Through imprecise calculations, he showed a correlation between observed increases in both over time. Some scientists considered the correlation merely coincidence. Callendar's calculations provided early quantitative indications of a climate warming as a result of human activity. At the time, however, the relative contribution of human activity compared with natural factors could not be determined.¹⁵ David Keeling later established more consistent and repeatable measurements of atmospheric CO₂ in the 1950s.¹⁶ Keeling's precise measurements provided strong evidence of a connection between increasing human-related CO₂ emissions and the increasing CO₂ concentrations in the atmosphere. The measurements established a quantitative benchmark for later studies examining the linkage between increasing CO₂ concentrations and rising global temperatures. Keeling's concentration data facilitated additional research on the global carbon cycle, the oceans, and the effects of human activities.

In the middle of the 20th century, scientists (and many in the public) recognized that a general warming of the climate had occurred (**Table A-1**).¹⁷ This was followed by a 30-year period of relatively flat or decreasing global average temperatures from around 1946 to 1977¹⁸ (**Figure 1**). Arguably, the apparent change in trajectory heightened scientific uncertainty about the direction of future climate changes and any human influence on them. It coincided with concerns about “global dimming,”¹⁹ at least in part attributed to sulfur and particulate pollution,²⁰ which increased rapidly during that period before leveling off around 1980.²¹ Current assessments indicate that the mid-20th century warming hiatus may have been due to a combination of human

¹³ Before robust observations of the climate and the factors that influence it became available, scientists theorized how future climate would evolve with, for example, continued increases in fossil fuel emissions, as can be seen in the quotations in **Table A-1**. Since the 1990s, projections of future climate changes rely on formally produced and peer-reviewed scenarios of how different climate forcing factors may evolve, including how economic activities and public policies may alter those factors.

¹⁴ Guy S. Callendar, “The Artificial Production of Carbon Dioxide and Its Influence on Temperature,” *Quarterly Journal of the Royal Meteorological Society*, vol. 64, no. 275 (April 1938), pp. 223-40, https://www.eas.ualberta.ca/jdwilson/EAS372_15/exams/Callendar_QJRMS1938.pdf.

¹⁵ Substantial scientific research suggests that solar radiation and other natural factors are important in the global temperature increase in the first half of the 20th century. See, among other research, P.A. Stott et al, “Attribution of Twentieth Century Temperature Change to Natural and Anthropogenic Causes,” *Climate Dynamics*, vol.17, no. 1 (January 1, 2001), pp. 1-21, <https://doi.org/10.1007/PL00007924>.

¹⁶ Scripps Institute of Oceanography, “The Early Keeling Curve,” http://scrippsco2.ucsd.edu/history_legacy/early_keeling_curve.

¹⁷ See, for example, Albert Abarbanel and Thorp McClusky, “Is the World Getting Warmer?,” *The Saturday Evening Post*, July 1, 1950.

¹⁸ National Academy of Sciences, *Energy and Climate* (Washington, DC: National Academies Press, 1977), <https://www.nap.edu/download/12024>.

¹⁹ For a relatively recent review of research on the variability of solar radiation reaching the Earth's surface—sometimes called “global dimming” and “brightening” by scientists—and how it may have influenced non-linear changes in 20th century climate, see Martin Wild, “Global Dimming and Brightening: A Review,” *Journal of Geophysical Research*, vol. 114, June 27, 2009, <https://doi.org/2009J011470>.

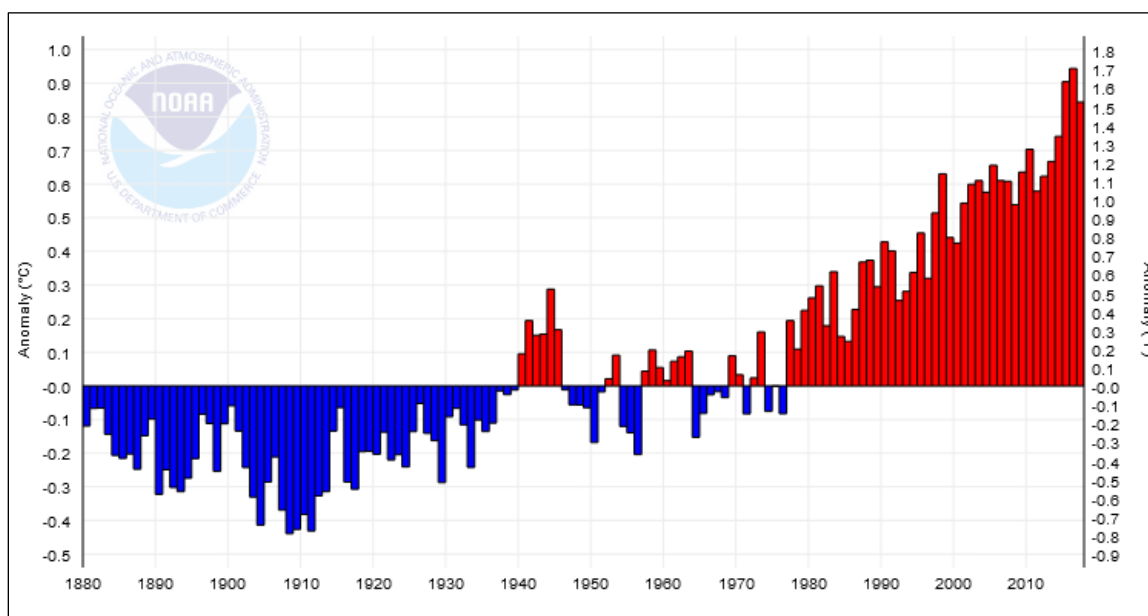
²⁰ According to this theory, global dimming and cooling during this time was probably at least partially influenced by human activities in the form of aerosol pollution, as explained in the article cited above.

²¹ See, among others, Martin Wild, “Enlightening Global Dimming and Brightening,” *Bulletin of the American Meteorological Society*, vol. 93, no. 1 (July 15, 2011), <http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-11-00074.1>.

(GHG, pollution) and natural influences (solar variability, volcanoes).²² As temperatures began to rise again in the late 1970s, authoritative scientific assessments performed by various governmental and nongovernmental institutions, supported by an expanding body of peer-reviewed published research, pointed to an emerging consensus regarding a probable human contribution to climate change, primarily due to increasing GHG emissions.

Figure 1. Anomalies of Global Average Surface Temperature, 1880-2017

(in degrees Celsius and Fahrenheit)



Source: National Oceanic and Atmospheric Administration, National Centers for Environmental Information, “Climate at a Glance: Global Time Series,” annual data for 1880-2017, retrieved on January 24, 2018, https://www.ncdc.noaa.gov/cag/time-series/global/globe/land_ocean/ytd/12/1880-2017.

Notes: The temperature “anomaly” is the difference between the measured temperature and the average over the 20th century. Statisticians consider computation of the anomalies to be more reliable than using absolute temperature measurements. For documentation, see <https://www.ncdc.noaa.gov/ghcnm/v3.php>. Four other research organizations analyze and publish global temperature anomalies. They use different methods and produce similar estimates—particularly regarding trends—with NOAA’s typically being slightly below those of the National Aeronautics and Space Administration, for example.

The relative role of human versus natural influences became more clear in the early 2000s. Longer series of improved observations (e.g., solar radiation, clouds, land cover change), statistical methods, and computational models enabled more robust analyses and comparisons of research methods and results. Major, collaborative, authoritative assessments—U.S. and international—were established to compile, debate, and consider the strengths or weaknesses of scientific analysis regarding climate change in order to inform policymakers.

²² N. L. Bindoff et al, “Detection and Attribution of Climate Change: from Global to Regional,” chapter 10 in T. F. Stocker et al. (eds.), *Climate Change 2013: The Physical Science Basis: Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge: U.K.: Cambridge University Press, 2013), p. 883, <http://ipcc.ch/report/ar5/wg1/>. This chapter also describes the methods and data for “detection and attribution” of climate change over different time scales.

What Are Scientific Assessments of Climate?

Policymakers, when seeking thoroughly vetted and balanced scientific information, sometimes commission scientific assessments. On climate change, periodic assessments have been mandated under domestic law (e.g., the Global Change Research Act of 1990, P.L. 101-606) and by international agreements (United Nations General Assembly Resolution 43/53 of 6 December 1988). According to the Office of Management and Budget, a scientific assessment is

an evaluation of a body of scientific or technical knowledge, which typically synthesizes multiple factual inputs, data, models, assumptions, and/or applies best professional judgment to bridge uncertainties in the available information. These assessments include, but are not limited to, state-of-science reports; technology assessments; weight-of-evidence analyses; meta-analyses....²³

The National Academy of Sciences (NAS), the Intergovernmental Panel on Climate Change (IPCC), and the United States Global Change Research Program (USGCRP) have organized scientific climate assessments involving hundreds to thousands of individual scientists and subject to expert peer reviews and, for the IPCC and USGCRP, public peer reviews.

Table A-2 contains the relevant conclusions regarding human and natural influences on climate change from the major assessments conducted, with those of

- NAS beginning in 1977,²⁴
- IPCC beginning in 1990, and
- the USGCRP beginning in 2001.

These inclusive assessments underpinned growing scientific confidence that human activities were likely the major cause of the observed global warming since the mid-20th century.

Conclusions

Many factors have contributed to increased scientific confidence in quantifying the human and natural contributions to climate change. Longer records of observational data have provided more evidence of the concordance between higher GHG levels and temperature increases. Satellites have provided important observations of temperatures; atmospheric pollution; and land, snow, and ice cover beginning in the late 1970s. Additionally, improved scientific understanding of atmospheric physics, together with vastly more powerful computers, has led to climate models that better simulate atmospheric and oceanic conditions. Uncertainties in the models remain on how they simulate the effects of clouds, for example, and the model simulations are at smaller scales of space and time. Despite these uncertainties, current climate scientific assessment states high confidence (extremely likely) that human influence is the dominant cause of the observed warming over the past half-century. While the near consensus has developed relatively recently, it has evolved based on increasing confidence through research on scientific concepts established as early as 200 years ago. Future climate outcomes depend on many additional factors, such as the future rates and character of socio-economic development and efforts to curtail the growth of GHG emissions.

²³ U.S. Office of Management and Budget, "Final Information Quality Bulletin for Peer Review," 70 *Federal Register* 2667, January 14, 2005, <https://www.gpo.gov/fdsys/pkg/FR-2005-01-14/pdf/05-769.pdf>.

²⁴ NAS is a private, nonprofit society of distinguished scholars. It was established by Congress in statute in 1863 and is charged with providing independent, objective advice to the nation on matters related to science and technology.

Appendix. Chronology of Scientific Statements on Attribution of Global Climate Change

This appendix contains bibliographic references and quotations regarding scientific understanding of global climate change and the influence of CO₂, other GHGs, and natural factors on observed and prospective global climate. Because the capacities and methods of science have changed markedly over the past 200 years, the references appear in two tables representing selected scientific literature and national or international scientific assessments.

Table A-1 presents representative statements excerpted from key scientific literature from 1827 to 1987 regarding human-related and other contributions to climate change. Sources include selected, widely cited academic papers, government reports, and NAS reports. The table's selections largely precede the establishment of broadly inclusive scientific assessments to compile and assess the weight of scientific evidence. For the period up to 1987, CRS selected key academic scientific papers and reports that were influential to scientific contemporaries during and after their respective times.

Scientific assessments began in the mid-20th century to more systematically and inclusively evaluate the full body of scientific literature on specific topics.

Table A-2 compiles the conclusions pertinent to this report from major U.S. and international scientific assessments, beginning in 1977, that address the human contribution to global climate change. The assessments have been produced by the USGCRP, NAS, and IPCC.²⁵

Table A-1. Select Scientific Statements Regarding the Influences on Global Climate of Human Activities and Natural Factors, 1827-1987

Year	Title	Key Quotation(s)	Reference
1827	Mémoire sur les Températures du Globe Terrestre et des Espaces Planétaires [On the Temperatures of the Terrestrial Sphere and Interplanetary Space]	"The establishment and progress of human societies, and the action of natural forces, can notably change the state of the ground surface over vast regions, as well as the distribution of waters and the great movements of the air. Such effects have the ability to make the mean degree of heat vary over the course of several centuries."	Jean-Baptiste Joseph Fourier, "Mémoire Sur Les Températures Du Globe Terrestre et Des Espaces Planétaires," <i>Mémoires de l'Académie Royale Des Sciences de l'Institut de France</i> , 1827, https://geosci.uchicago.edu/~rtp1/papers/Fourier1827Trans.pdf .
1856	Circumstances Affecting the Heat of the Sun's Rays	"An atmosphere of [carbonic acid] would give to our earth a high temperature; and if as some suppose, at one period of its history the air had mixed with it a larger proportion than at present, an increased temperature from its own action as well as from increased weight must have necessarily resulted."	Eunice Foote, "Circumstances Affecting the Heat of the Sun's Rays," <i>American Journal of Science and Arts</i> , vol. 22 (1856), pp. 382-83, https://books.google.com/books?id=6xhFAQAAMAAJ&pg=PA382#v=onepage&q&f=false .

²⁵ Individual scientists, and some organizations, may not agree with the conclusions of major scientific assessments. CRS is not aware of any national or international climate-related scientific body that dissented from the recent assessments quoted in this report.

Year	Title	Key Quotation(s)	Reference
1896	On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground	<p>“If the quantity of carbonic acid increases in geometric progression, the augmentation of the temperature will increase nearly in arithmetic progression.”</p> <p>“This quantity of carbonic acid, which is supplied to the atmosphere chiefly by modern industry, may be regarded as completely compensating the quantity of carbonic acid that is consumed in the formation of limestone (or other mineral carbonates) by the weathering or decomposition of silicates.”</p> <p>“We must regard volcanic exhalations as the chief source of carbonic acid for the atmosphere.”</p>	<p>Svante Arrhenius, “On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground,” <i>Philosophical Magazine and Journal of Science</i>, vol. 41, series 5 (April 1896), pp. 237-76, http://www.trunity.net/files/108501_108600/108531/arrhenius1896_greenhouse-effect.pdf.</p>
1897	A Group of Hypotheses Bearing on Climatic Changes	<p>“A comparison of early with later life, stripped of theoretical presumptions, does not seem to me clearly to imply any great difference in the content of carbon dioxide.”</p> <p>“For it is almost axiomatic to say that climatic changes would attend changes in the constitution of the atmosphere. I assume that atmospheric poverty, especially in the critical item of carbon dioxide, is correlated with low temperature.”</p>	<p>Thomas C. Chamberlin, “A Group of Hypotheses Bearing on Climatic Changes,” <i>Journal of Geology</i>, vol. 5, no. 7 (1897), pp. 653-683, https://www.jstor.org/stable/pdf/30054630.pdf?refreqid=excelsior%3Aa77b10a39bbe564c432a9204d719cec.</p>
1898	Monthly Weather Review and Annual Summary	<p>“We have therefore an alternation of cold and warm periods due to the interaction of elevation [of the Earth’s surface] and carbon dioxide [in the atmosphere].... [W]e hope eventually to be able to deduce the resulting climatic peculiarities, and to show that very slight changes in oceans and continents have produced all the variations of geological climate, and that little or nothing need be hypothesized as to the variations of solar heat, of atmospheric gases, of terrestrial latitudes, or the many other climatological elements.”</p>	<p>U.S. Department of Agriculture, Weather Bureau, <i>Monthly Weather Review and Annual Summary</i>, July 1898, http://congressional.proquest.com/congressional/result/pqpresultpage.gispdfhitspanel.pdfink/\$2fapp-s3\$2fjllh-content\$2fPT4-A2906-8\$2fPT4-A2906-8_From_1_to_752.pdf/entitlementkeys=1234%7Capp-gis%7Cexecutive-branch%7Ca2906-8.</p>
1911	USGS: The Data of Geochemistry	<p>“In a thousand years, then, if the rate were constant and no disturbing factors interfered, the amount of CO₂ in the atmosphere would be doubled. If we take into account the combustion of fuels other than coal and the large additions to the atmosphere from the sources previously mentioned the result becomes still more startling. Were there no counterbalancing of this increase in atmospheric carbon, animal</p>	<p>Frank Wigglesworth Clark, U.S. Geological Survey, “The Data of Geochemistry”, <i>Bulletin 491, 2nd ed., U.S. House of Representatives</i>, 1911, pp. 47, 135, https://congressional.proquest.com/congressional/result/pqpresultpage.gispdfhitspanel.pdfink/\$2fapp-bin\$2fgis-serialset\$2f0\$2fd\$2f4\$2fa\$2f5997_hdoc1499_from_1_to_779.pdf/</p>

Year	Title	Key Quotation(s)	Reference
1939	The Composition of the Atmosphere Through the Ages	<p>life would soon become impossible upon our planet.”</p> <p>“Whether the theory of Arrhenius is in harmony with the facts of historical geology—that is, whether periods of volcanic activity [releasing carbon dioxide] have coincided with warmer climates, and a slackening of activity with lowering of temperatures is also in dispute. Apparently, the controversy is not yet ended.”</p> <p>“Water vapor, then, is the chief agent in the atmospheric regulation of climate and to this conclusion; The climatic conditions may vary as Chamberlin claims, but the relative dryness or wetness of the atmosphere may be the true cause of fluctuating temperatures, rather than the carbon dioxide.”</p>	<p>entitlementkeys=1234%7Capp-gis%7Cserialset%7C5997_h.doc.1499.</p>
1939	The Composition of the Atmosphere Through the Ages	<p>“It is a commonplace that man is able to speed up the processes of Nature, and he has now plunged heavily into her slow-moving carbon cycle by throwing some 9,000 tons of carbon dioxide into the air each minute. This great stream of gas results from the combustion of fossil carbon (coal, oil, peat, etc.), and it appears to be much greater than the natural rate of fixation.”</p> <p>“From the best laboratory observations it appears that the principal result of increasing atmospheric carbon dioxide, apart from a slight speeding up of rock weathering and plant growth, would be a gradual increase in the mean temperature of the colder regions of the earth.”</p>	<p>Guy S. Callendar, “The Composition of the Atmosphere Through the Ages,” <i>Meteorological Magazine</i>, vol. 74, no. 878 (March 1939), pp. 33-39, https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjBjtHfoP3WAhXB4SYKHGYFA9UQFggmMAA&url=https%3A%2F%2Fdigital.nmla.metoffice.gov.uk%2Fdownload%2Ffile%2Fsdb%253AdigitalFile%257Cedc8aafc-a27a-4afe-bd29-619b052bd199%2F&usg=AOvVaw0R8QW-XaTql-iGP-cjF1I</p>
1948	Circular Causal Systems in Ecology	<p>“Callendar (1940), considering the best data available since 1866, concludes that during the present century there has been an increase of the order of 10 per cent in the CO₂ content of the atmosphere. This he attributes to the modern industrial combustion of fuel... It seems far more likely that the observed increment in the carbon dioxide of air at low levels in both Europe and eastern North America is due to changes in the biological mechanisms of the cycle rather than to an increase in industrial output.... The</p>	<p>George Evelyn Hutchinson, “Circular Causal Systems in Ecology,” <i>Annals of the New York Academy of Sciences</i>, vol. 50, (1948), pp. 221-246, http://people.wku.edu/charles.smith/biogeog/HUTC1948.htm.</p>

Year	Title	Key Quotation(s)	Reference
		self-regulating mechanisms of the carbon cycle can cope with the present influx of carbon of fossil origin."	
1966	U.S. House of Representatives: Environmental Pollution: A Challenge to Science and Technology	<p>"Carbon dioxide accumulations from the burning of gas, petroleum, and coal change the nature of the atmosphere. Weather patterns can be altered purposefully or accidentally by human activity. These powerful forces have only come about recently and are not well understood. As a consequence, in many risk-benefit questions, the magnitude of the risk is relatively unknown."</p> <p>"By the year 2000 at present and projected rate of fossil fuel consumption, the carbon dioxide level in the air will cause a significant rise in the air temperature."</p>	Rep. George P. Miller, "Environmental Pollution: A Challenge to Science and Technology," <i>Report of the Subcommittee on Science, Research, and Development. Committee on Science and Astronautics, U.S. House of Representatives, 1966</i> , pp. 3, 43, 263, https://congressional.proquest.com/congressional/result/pqresultpage.gispdfhitspanel.pdfink/\$2fapp-bin\$2fgis-congresearch\$2f6\$2f7\$2f2\$2f9\$2fcmp-1966-sah-0009_from_1_to_67.pdf/entitlementkeys=1234%7Capp-gis%7Ccongresearch%7Ccmp-1966-sah-0009 .
1970	Man-Made Climatic Changes	"It appears that on the local scale man-made influences on climate are substantial but that on the global scale natural forces still prevail.... The potential for anthropogenic changes of climate on a larger and even a global scale is real.... In my opinion, man-made aerosols, because of their optical properties and possible influences on cloud and precipitation processes constitute a more acute problem than CO ₂ Over longer intervals, energy added to the atmosphere by heat rejection and CO ₂ absorption remain matters of concern."	Helmut E. Landsberg, "Man-Made Climatic Changes," <i>Science</i> , vol. 170, no. 3964 (December 18, 1970), http://www.jstor.org/stable/pdf/1730486.pdf?refreqid=excelsior%3Ae79d4c4c72387997406c413dafdebbaf .
1972	NSF: Patterns and Perspectives in Environmental Science	"Judging from the record of the past interglacial ages, the present time of high temperatures should be drawing to an end, to be followed by a long period of considerably colder temperatures leading into the next glacial age some 20,000 years from now. However, it is possible, or even likely, that human interference has already altered the environment so much that the climatic pattern of the near future will follow a different path. For instance, widespread deforestation in recent centuries, especially in Europe and North America, together with increased atmospheric opacity due to man-made dust storms and industrial wastes, should have increased the earth's reflectivity. At the same time, increasing concentration of industrial carbon dioxide in the atmosphere should lead	National Science Board, National Science Foundation, "Patterns and Perspectives in Environmental Science," 1972, https://archive.org/details/patternsperspect00nati .

Year	Title	Key Quotation(s)	Reference
1974	NSF: Science and the Challenges Ahead	to a temperature increase by absorption of infrared radiation from the earth's surface. When these human factors are added to such other natural factors as volcanic eruptions, changes in solar activity, and resonances within the hydro-atmosphere, their effect can only be estimated in terms of direction, not of amount."	National Science Board, National Science Foundation, "Science and the Challenges Ahead," 1974, https://archive.org/details/sciencechallenge00nati .
1975	NAS: Understanding Climate Change: A Program for Action	"While the natural variations of climate have been larger than those that may have been induced by human activities during the past century, the rapidity with which human impacts threaten to grow in the future, and increasingly to disturb the natural course of events, is a matter of concern. These impacts include man's changes of the atmospheric composition and his direct interference with factors controlling the all important heat balance.... Of the two forms of pollution [CO ₂ and aerosols], the carbon dioxide increase is probably the more influential at the present time in changing temperatures near the earth's surface. If both the CO ₂ and particulate inputs to the atmosphere grow at equal rates in the future, the widely differing atmospheric residence times of the two pollutants means that the particulate effect will grow in importance relative to that of CO ₂ . There are other possible impacts of human activities that should be considered in projecting future climates."	National Academy of Sciences. <i>Understanding Climate Change: A Program for Action</i> (Washington, DC: National Academies Press, 1975), https://ia801806.us.archive.org/7/items/understandingcli00unit/understandingcli00unit.pdf .
1983	World Climate Research Programme: Report of the Fifth Session of the Joint	"The existing observational evidence does not allow concluding with confidence that the observed variations are caused specifically by the increasing concentration of atmospheric carbon dioxide. On the other hand, the surface	International Council of Scientific Unions, World Meteorological Organization, <i>Report of the Fifth Session of the Joint Scientific Committee (Hangzhou, China, 12-17 March 1984)</i> ,

Year	Title	Key Quotation(s)	Reference
	Scientific Committee	warming indicated by the record of the global mean temperature is not inconsistent with the computed effect of the observed increase of atmospheric CO ₂ since the beginning of the industrial revolution.”	September 1984, https://library.wmo.int/pmb_ged/wmo-td_1.pdf .
1985	Villach Conference Statement	“Based on analyses of observational data, the estimated increase in global mean temperature during the last one hundred years of between 0.3 and 0.7°C is consistent with the projected temperature increase attributable to the observed increase in CO ₂ and other greenhouse gases, although it cannot be ascribed in a scientifically rigorous manner to these factors alone.”	World Meteorological Organisation, <i>Report of the International Conference on the assessment of the role of carbon dioxide and of other greenhouse gases in climate variations and associated impacts</i> , Villach, Austria, October 9-15, 1985, WMO No. 661, 1986, https://web.archive.org/web/20131121040937/http://www.scopenvironment.org/downloadpubs/scope29/statement.html .
1987	Mankind's Impact on Climate: The Evolution of an Awareness	“There is now a strong consensus that the observed increase in the atmospheric concentrations of carbon dioxide and other infrared-absorbing trace gases is indeed warming the earth, and that this change is caused by mankind.”	William W. Kellogg, “Mankind's Impact on Climate: The Evolution of an Awareness,” <i>Climatic Change</i> , vol. 10 (1987), pp. 113-36, https://link.springer.com/content/pdf/10.1007%2FBF00140251.pdf .

Source: Compiled by CRS.

Table A-2. Excerpted Statements on the Human Contribution to Global Climate in Scientific Assessments of the NAS, the IPCC, and the USGCRP, 1977-2017

Year	Title	Key Quotation(s)	Reference
1977	NAS: Energy and Climate: Studies in Geophysics	“In the first half of the twentieth century ... a general warming of the earth occurred... There is considerable evidence that, between the 1940s and about 1970, the climatic changes of the earlier part of this century had tended to undergo a reversal. Temperatures had mostly fallen.” “Today, we find ourselves uneasy because through our use of energy we may be significantly disturbing the natural climate system. This uneasiness is justified.”	National Academy of Sciences, <i>Energy and Climate</i> (Washington, DC: National Academies Press, 1977), https://www.nap.edu/download/12024 .
1979	NAS: Carbon Dioxide and Climate: A Scientific Assessment	“None of the model calculations predicts negligible warming. The primary effect of an increase of CO ₂ is to cause more absorption of thermal radiation from the earth's surface and thus to increase the air temperature in the troposphere.”	National Academy of Sciences, “Carbon Dioxide and Climate: A Scientific Assessment,” Report of an Ad Hoc Study Group on Carbon Dioxide and Climate, Woods Hole, Massachusetts, July 23-27, 1979, to the Climate Research Board, Assembly of Mathematical and Physical Sciences,

Year	Title	Key Quotation(s)	Reference
		“We conclude that the predictions of CO ₂ -induced climate changes made with the various models examined are basically consistent and mutually supporting.”	National Research Council, https://www.nap.edu/download/19856 .
1990	IPCC: Climate Change: The IPCC Scientific Assessment - 1 st Report	“The size of the warming over the last century is broadly consistent with the predictions of climate models but is also of the same magnitude as natural climate variability. If the sole cause of the observed warming were the human made greenhouse effect, then the implied climate sensitivity would be near the lower end of the range inferred from the models. The observed increase could be largely due to natural variability, alternatively this variability and other man-made factors could have offset a still larger man-made greenhouse warming. The unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more, when the commitment to future climate change will then be considerably larger than it is today.”	J. T. Houghton et al., <i>Climate Change: The IPCC Scientific Assessment</i> . Report prepared for Intergovernmental Panel on Climate Change by Working Group I (Cambridge, U.K.: Cambridge University Press, 1990), https://www.ipcc.ch/ipccreports/far/wg_1/ipcc_far_wg_1_full_report.pdf .
1994	NAS: Solar Influences on Global Change	“Taken collectively, the above evidence, although circumstantial, does suggest that solar variability could influence future global change.... Lack of knowledge of solar influences will limit the certainty with which anthropogenic climate change can be detected. But it is unlikely that solar influences on global change will be comparable to the expected anthropogenic influences.”	National Academy of Sciences, <i>Solar Influences on Global Change</i> (Washington, DC: National Academies Press, 1994), https://www.nap.edu/download/4778 .
1995	IPCC Second Assessment: Climate Change 1995	“Carbon dioxide remains the most important contributor to anthropogenic forcing of climate change; projections of future global mean temperature change and sea level rise confirm the potential for human activities to alter the Earth's climate to an extent unprecedented in human history.... [O]bservations suggest a ‘discernible human influence on global climate.’” “Most of these studies have detected a significant change and show that the observed warming trend is unlikely to be entirely natural in origin.”	B. Bolin et al., <i>Climate Change 1995: A report of the Intergovernmental Panel on Climate Change</i> (Cambridge, U.K.: Cambridge University Press, 1995), http://www.ipcc.ch/ipccreports/sar/wg_1/ipcc_sar_wg_1_full_report.pdf .
2001	USGCRP: 1 st National Climate Assessment	“The observed magnitude, pattern, and timing of the global warming indicate that the rising concentrations of CO ₂ and other greenhouse gases caused by	National Assessment Synthesis Team, <i>Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change</i> , Report for

Year	Title	Key Quotation(s)	Reference
		human activities are contributing significantly to the recent warming.”	the USGCRP (Cambridge, U.K.: Cambridge University Press, 2001), https://data.globalchange.gov/assets/e9/97/436129058f2107f4925aeec13ed8/nca-2000-foundation-report.pdf .
2001	NAS: Climate Change Science: An Analysis of Some Key Questions	“The changes observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these changes is also a reflection of natural variability.”	National Academy of Sciences, <i>Climate Change Science: An Analysis of Some Key Questions</i> (Washington, DC: National Academy Press, 2001), https://www.nap.edu/download/10139 .
2001	IPCC: Climate Change 2001: The IPCC Third Assessment Report	“There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.”	R. T. Watson et al. (eds.), <i>Climate Change 2001: Synthesis Report</i> , Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, U.K.: Cambridge University Press, 2001), https://www.ess.uci.edu/researchgrp/prather/files/2001IPCC_SyR-Watson.pdf .
2007	IPCC: The Fourth Assessment Report: Climate Change	“Most of the observed increase in global average temperatures since the mid-20 th century is very likely [>90%] due to the observed increase in anthropogenic GHG concentrations.”	R. K. Pachuri et al. (eds.), <i>Climate Change 2007: Synthesis Report</i> , Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Geneva, Switzerland: IPCC Secretariat, 2007), http://www.slvwd.com/agendas/Full/2007/06-07-07/Item%2010b.pdf .
2009	USGCRP: 2 nd National Climate Assessment	“The global warming of the past 50 years is due primarily to human-induced increases in heat trapping gasses.... Recent scientific assessments find that most of the warming of the Earth’s surface over the past 50 years has been caused by human activities.”	Thomas R. Karl et al. (eds.), <i>Global Climate Change Impacts in the United States</i> (Cambridge, UK: Cambridge University Press, 2009), https://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf .
2010	NAS: Advancing the Science of Climate Change	“Climate change is occurring, is caused largely by human activities, and poses significant risks for—and in many cases is already affecting—a broad range of human and natural systems.”	National Academy of Sciences, <i>Advancing the Science of Climate Change, America’s Climate Choices: Panel on Advancing the Science of Climate Change</i> (Washington, DC: National Academy Press, 2010), https://www.nap.edu/download/12782 .
2012	NAS: Climate Change: Evidence, Impacts, and Choices	“The overwhelming majority of climate scientists agree that human activities, especially the burning of fossil fuels (coal, oil, and gas), are responsible for most of the climate change currently being observed.”	National Academy of Sciences, <i>Climate Change: Evidence, Impacts, and Choices</i> , 2012, http://nas-sites.org/americasclimatechoices/files/2012/06/19014_cvtx_R1.pdf

Year	Title	Key Quotation(s)	Reference
2014	NAS: Climate Change: Evidence and Causes	“Rigorous analysis of all data and lines of evidence shows that most of the observed global warming over the past 50 years or so cannot be explained by natural causes and instead requires a significant role for the influence of human activities.”	National Academy of Sciences, <i>Climate Change: Evidence and Causes</i> , 2014, http://dels.nas.edu/resources/static-assets/exec-office-other/climate-change-full.pdf
2014	IPCC: The Fifth Assessment Report: Climate Change 2014	“[Anthropogenic GHG emissions] effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely [>95%] to have been the dominant cause of the observed warming since the mid-20 th century.”	R. K. Pachuri et al. (eds.), <i>Climate Change 2014: Synthesis Report</i> , Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Geneva, Switzerland: IPCC Secretariat, 2014), http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf .
2014	USGCRP: 3 rd National Climate Assessment	“The majority of the warming at the global scale over the past 50 years can only be explained by the effects of human influences, especially the emissions from burning fossil fuels (coal, oil, and natural gas) and from deforestation.”	Jerry M. Melillo et al., (eds.), <i>Highlights of Climate Change Impacts in the United States: The Third National Climate Assessment</i> , USGCRP (Washington, DC: U.S. Government Printing Office, 2014), http://www.globalchange.gov/sites/globalchange/files/NCA3_Highlights_LowRes-small-FINAL_posting.pdf .
2017	USGCRP: Climate Science Special Report: Fourth National Climate Assessment	“It is extremely likely [>95%] that human influence has been the dominant cause of the observed warming since the mid-20 th century. For the warming over the last century, there is no convincing alternative explanation supported by the extent of the observational evidence.”	Donald J. Weubles et al., <i>Climate Science Special Report: Fourth National Climate Assessment, Volume I</i> , USGCRP, 2017, https://science2017.globalchange.gov/downloads/CSSR2017_FullReport.pdf .

Source: Compiled by CRS.

Notes: The documents cited reflect the evolution of select aspects of climate change science. This list is not comprehensive of, and is not intended to highlight, all aspects of the scientific efforts in climate research.

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Table A-3. Select Scientific Statements Regarding the Influences on Global Climate of Human Activities and Natural Factors, 1827-1987

Year	Title	Key Quotation(s)	Reference
1827	Mémoire sur les Températures du Globe Terrestre et des Espaces Planétaires [On the Temperatures of the Terrestrial Sphere and Interplanetary Space]	“The establishment and progress of human societies, and the action of natural forces, can notably change the state of the ground surface over vast regions, as well as the distribution of waters and the great movements of the air. Such effects have the ability to make the mean degree of heat vary over the course of several centuries.”	Jean-Baptiste Joseph Fourier, “Mémoire Sur Les Températures Du Globe Terrestre et Des Espaces Planétaires,” <i>Mémoires de l'Académie Royale Des Sciences de l'Institut de France</i> , 1827, https://geosci.uchicago.edu/~rtp1/papers/Fourier1827Trans.pdf .

Year	Title	Key Quotation(s)	Reference
1856	Circumstances Affecting the Heat of the Sun's Rays	"An atmosphere of [carbonic acid] would give to our earth a high temperature; and if as some suppose, at one period of its history the air had mixed with it a larger proportion than at present, an increased temperature from its own action as well as from increased weight must have necessarily resulted."	Eunice Foote, "Circumstances Affecting the Heat of the Sun's Rays," <i>American Journal of Science and Arts</i> , vol. 22 (1856), pp. 382-83, https://books.google.com/books?id=6xhFAQAAMAJ&pg=PA382#v=onepage&q&f=false .
1896	On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground	"If the quantity of carbonic acid increases in geometric progression, the augmentation of the temperature will increase nearly in arithmetic progression." "This quantity of carbonic acid, which is supplied to the atmosphere chiefly by modern industry, may be regarded as completely compensating the quantity of carbonic acid that is consumed in the formation of limestone (or other mineral carbonates) by the weathering or decomposition of silicates." "We must regard volcanic exhalations as the chief source of carbonic acid for the atmosphere."	Svante Arrhenius, "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground," <i>Philosophical Magazine and Journal of Science</i> , vol. 41, series 5 (April 1896), pp. 237-76, http://www.trinity.net/files/108501_108600/108531/arrhenius1896_greenhouse-effect.pdf .
1897	A Group of Hypotheses Bearing on Climatic Changes	"A comparison of early with later life, stripped of theoretical presumptions, does not seem to me clearly to imply any great difference in the content of carbon dioxide." "For it is almost axiomatic to say that climatic changes would attend changes in the constitution of the atmosphere. I assume that atmospheric poverty, especially in the critical item of carbon dioxide, is correlated with low temperature."	Thomas C. Chamberlin, "A Group of Hypotheses Bearing on Climatic Changes," <i>Journal of Geology</i> , vol. 5, no. 7 (1897), pp. 653-683, https://www.jstor.org/stable/pdf/30054630.pdf?refreqid=excelsior%3Aa77b10a39bbbe564c432a9204d719cec .
1898	Monthly Weather Review and Annual Summary	"We have therefore an alternation of cold and warm periods due to the interaction of elevation [of the Earth's surface] and carbon dioxide [in the atmosphere].... [W]e hope eventually to be able to deduce the resulting climatic peculiarities, and to show that very slight changes in oceans and continents have produced all the variations of geological climate, and that little or nothing need be hypothecated as to the variations of solar heat, of atmospheric gases, of terrestrial latitudes, or the many other climatological elements."	U.S. Department of Agriculture, Weather Bureau, <i>Monthly Weather Review and Annual Summary</i> , July 1898, http://congressional.proquest.com/congressional/result/ppresultpage.gispdfhitspanel.pdf?link/\$2fapp-s3\$2fjfh-content\$2fPT4-A2906-8\$2fPT4-A2906-8_From_1_to_752.pdf?entitlementkeys=1234%7Capp-gis%7Cexecutive-branch%7Ca2906-8 .
1911	USGS: The Data of Geochemistry	"In a thousand years, then, if the rate were constant and no disturbing factors interfered, the amount of CO ₂ in the atmosphere would be doubled. If we take into account the combustion of fuels other than coal and the large additions to the atmosphere from the sources previously mentioned the result becomes still more startling. Were there no counterbalancing of this increase in	Frank Wigglesworth Clark, U.S. Geological Survey, "The Data of Geochemistry," <i>Bulletin 491, 2nd ed., U.S. House of Representatives</i> , 1911, pp. 47, 135, https://congressional.proquest.com/congressional/result/ppresultpage.gispdfhitspanel.pdf?link/\$2fapp-bin\$2fgis-serialset\$2f0\$2fd\$2f4\$2fa\$2f5997_hdoc1499_from_1_to_779.pdf?entitlementkeys=1234%7Capp-gis%7Cserialset%7C5997_h.doc.1499 .

Year	Title	Key Quotation(s)	Reference
		<p>atmospheric carbon, animal life would soon become impossible upon our planet.”</p> <p>“Whether the theory of Arrhenius is in harmony with the facts of historical geology—that is, whether periods of volcanic activity [releasing carbon dioxide] have coincided with warmer climates, and a slackening of activity with lowering of temperatures is also in dispute. Apparently, the controversy is not yet ended.”</p> <p>“Water vapor, then, is the chief agent in the atmospheric regulation of climate and to this conclusion; The climatic conditions may vary as Chamberlin claims, but the relative dryness or wetness of the atmosphere may be the true cause of fluctuating temperatures, rather than the carbon dioxide.”</p>	
1939	The Composition of the Atmosphere Through the Ages	<p>“It is a commonplace that man is able to speed up the processes of Nature, and he has now plunged heavily into her slow-moving carbon cycle by throwing some 9,000 tons of carbon dioxide into the air each minute. This great stream of gas results from the combustion of fossil carbon (coal, oil, peat, etc.), and it appears to be much greater than the natural rate of fixation.”</p> <p>“From the best laboratory observations it appears that the principal result of increasing atmospheric carbon dioxide, apart from a slight speeding up of rock weathering and plant growth, would be a gradual increase in the mean temperature of the colder regions of the earth.”</p>	<p>Guy S. Callendar, “The Composition of the Atmosphere Through the Ages,” <i>Meteorological Magazine</i>, vol. 74, no. 878 (March 1939), pp. 33-39, https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjBjtHfoP3WAhXB4SYKHYGFA9UQFggmMAA&url=https%3A%2F%2Fdigital.nmla.metoffice.gov.uk%2Fdownload%2Ffile%2Fsd%253AdigitalFile%257Cedc8aafc-a27a-4afe-bd29-619b052bd199%2F&usg=AOvVaw0R8QW-XaTql-iGP-cjF1</p>
1948	Circular Causal Systems in Ecology	<p>“Callendar (1940), considering the best data available since 1866, concludes that during the present century there has been an increase of the order of 10 per cent in the CO₂ content of the atmosphere. This he attributes to the modern industrial combustion of fuel.... It seems far more likely that the observed increment in the carbon dioxide of air at low levels in both Europe and eastern North America is due to changes in the biological mechanisms of the cycle rather than to an increase in industrial output.... The self-regulating mechanisms of the carbon cycle can cope with the present influx of carbon of fossil origin.”</p>	<p>George Evelyn Hutchinson, “Circular Causal Systems in Ecology,” <i>Annals of the New York Academy of Sciences</i>, vol. 50, (1948), pp. 221-246, http://people.wku.edu/charles.smith/biogeog/HUTC1948.htm.</p>
1966	U.S. House of Representatives: Environmental Pollution: A Challenge	<p>“Carbon dioxide accumulations from the burning of gas, petroleum, and coal change the nature of the atmosphere. Weather patterns can be altered purposefully or</p>	<p>Rep. George P. Miller, “Environmental Pollution: A Challenge to Science and Technology,” <i>Report of the Subcommittee on Science, Research, and Development. Committee</i></p>

Year	Title	Key Quotation(s)	Reference
	to Science and Technology	<p>accidentally by human activity. These powerful forces have only come about recently and are not well understood. As a consequence, in many risk-benefit questions, the magnitude of the risk is relatively unknown."</p> <p>"By the year 2000 at present and projected rate of fossil fuel consumption, the carbon dioxide level in the air will cause a significant rise in the air temperature."</p>	<p>on Science and Astronautics, U.S. House of Representatives, 1966, pp. 3, 43, 263, https://congressional.proquest.com/congressional/result/pqpresultpage.gispdfhitspanel.pdf?link/\$2fapp-bin\$2fgis-congresearch\$2f6\$2f7\$2f2\$2f9\$2fcmp-1966-sah-0009_from_1_to_67.pdf/entitlementkeys=1234%7Capp-gis%7Ccongresearch%7Ccmp-1966-sah-0009.</p>
1970	Man-Made Climatic Changes	<p>"It appears that on the local scale man-made influences on climate are substantial but that on the global scale natural forces still prevail.... The potential for anthropogenic changes of climate on a larger and even a global scale is real.... In my opinion, man-made aerosols, because of their optical properties and possible influences on cloud and precipitation processes constitute a more acute problem than CO₂.... Over longer intervals, energy added to the atmosphere by heat rejection and CO₂ absorption remain matters of concern."</p>	<p>Helmut E. Landsberg, "Man-Made Climatic Changes," <i>Science</i>, vol. 170, no. 3964 (December 18, 1970), http://www.jstor.org/stable/pdf/1730486.pdf?refreqid=excelsior%3Ae79d4c4c72387997406c413dafdebba.</p>
1972	NSF: Patterns and Perspectives in Environmental Science	<p>"Judging from the record of the past interglacial ages, the present time of high temperatures should be drawing to an end, to be followed by a long period of considerably colder temperatures leading into the next glacial age some 20,000 years from now. However, it is possible, or even likely, that human interference has already altered the environment so much that the climatic pattern of the near future will follow a different path. For instance, widespread deforestation in recent centuries, especially in Europe and North America, together with increased atmospheric opacity due to man-made dust storms and industrial wastes, should have increased the earth's reflectivity. At the same time, increasing concentration of industrial carbon dioxide in the atmosphere should lead to a temperature increase by absorption of infrared radiation from the earth's surface. When these human factors are added to such other natural factors as volcanic eruptions, changes in solar activity, and resonances within the hydro-atmosphere, their effect can only be estimated in terms of direction, not of amount."</p>	<p>National Science Board, National Science Foundation, "Patterns and Perspectives in Environmental Science," 1972, https://archive.org/details/patternsperspect00nati.</p>
1974	NSF: Science and the Challenges Ahead	<p>"Human activity may be involved on an even broader scale in changing the global climate.... The cause of the cooling trend is not known with certainty. But there is increasing concern that man himself may be implicated, not only in the recent cooling trend but also</p>	<p>National Science Board, National Science Foundation, "Science and the Challenges Ahead," 1974, https://archive.org/details/sciencechallenge00nati.</p>

Year	Title	Key Quotation(s)	Reference
		in the warming temperatures over the last century.... By the middle of this century, the cooling effect of the dust particles more than compensated for the warming effect of the carbon dioxide, and world temperature began to fall.”	
1975	NAS: Understanding Climate Change: A Program for Action	“While the natural variations of climate have been larger than those that may have been induced by human activities during the past century, the rapidity with which human impacts threaten to grow in the future, and increasingly to disturb the natural course of events, is a matter of concern. These impacts include man’s changes of the atmospheric composition and his direct interference with factors controlling the all important heat balance.... Of the two forms of pollution [CO ₂ and aerosols], the carbon dioxide increase is probably the more influential at the present time in changing temperatures near the earth’s surface. If both the CO ₂ and particulate inputs to the atmosphere grow at equal rates in the future, the widely differing atmospheric residence times of the two pollutants means that the particulate effect will grow in importance relative to that of CO ₂ . There are other possible impacts of human activities that should be considered in projecting future climates.”	National Academy of Sciences. <i>Understanding Climate Change: A Program for Action</i> (Washington, DC: National Academies Press, 1975), https://ia801806.us.archive.org/7/items/understandingcli00unit/understandingcli00unit.pdf .
1983	World Climate Research Programme: Report of the Fifth Session of the Joint Scientific Committee	“The existing observational evidence does not allow concluding with confidence that the observed variations are caused specifically by the increasing concentration of atmospheric carbon dioxide. On the other hand, the surface warming indicated by the record of the global mean temperature is not inconsistent with the computed effect of the observed increase of atmospheric CO ₂ since the beginning of the industrial revolution.”	International Council of Scientific Unions, World Meteorological Organization, <i>Report of the Fifth Session of the Joint Scientific Committee (Hangzhou, China, 12-17 March 1984)</i> , September 1984, https://library.wmo.int/pmb_ged/wmo-td_1.pdf .
1985	Villach Conference Statement	“Based on analyses of observational data, the estimated increase in global mean temperature during the last one hundred years of between 0.3 and 0.7°C is consistent with the projected temperature increase attributable to the observed increase in CO ₂ and other greenhouse gases, although it cannot be ascribed in a scientifically rigorous manner to these factors alone.”	World Meteorological Organisation, <i>Report of the International Conference on the assessment of the role of carbon dioxide and of other greenhouse gases in climate variations and associated impacts</i> , Villach, Austria, October 9-15, 1985, WMO No. 661, 1986, https://web.archive.org/web/20131121040937/http://www.scopenvironment.org/downloadpubs/scope29/statement.html .
1987	Mankind’s Impact on Climate: The Evolution of an Awareness	“There is now a strong consensus that the observed increase in the atmospheric concentrations of carbon dioxide and other infrared-absorbing trace gases is indeed warming the earth, and that this change is caused by mankind.”	William W. Kellogg, “Mankind’s Impact on Climate: The Evolution of an Awareness,” <i>Climatic Change</i> , vol. 10 (1987), pp. 113-36, https://link.springer.com/content/pdf/10.1007%2FBF00140251.pdf .

Source: Compiled by CRS.

Table A-4. Excerpted Statements on the Human Contribution to Global Climate in Scientific Assessments of the NAS, the IPCC, and the USGCRP, 1977-2017

Year	Title	Key Quotation(s)	Reference
1977	NAS: Energy and Climate: Studies in Geophysics	<p>"In the first half of the twentieth century ... a general warming of the earth occurred.... There is considerable evidence that, between the 1940s and about 1970, the climatic changes of the earlier part of this century had tended to undergo a reversal. Temperatures had mostly fallen."</p> <p>"Today, we find ourselves uneasy because through our use of energy we may be significantly disturbing the natural climate system. This uneasiness is justified."</p>	National Academy of Sciences, <i>Energy and Climate</i> (Washington, DC: National Academies Press, 1977), https://www.nap.edu/download/12024 .
1979	NAS: Carbon Dioxide and Climate: A Scientific Assessment	<p>"None of the model calculations predicts negligible warming. The primary effect of an increase of CO₂ is to cause more absorption of thermal radiation from the earth's surface and thus to increase the air temperature in the troposphere."</p> <p>"We conclude that the predictions of CO₂-induced climate changes made with the various models examined are basically consistent and mutually supporting."</p>	National Academy of Sciences, "Carbon Dioxide and Climate: A Scientific Assessment," Report of an Ad Hoc Study Group on Carbon Dioxide and Climate, Woods Hole, Massachusetts, July 23-27, 1979, to the Climate Research Board, Assembly of Mathematical and Physical Sciences, National Research Council, https://www.nap.edu/download/19856 .
1990	IPCC: Climate Change: The IPCC Scientific Assessment - 1 st Report	<p>"The size of the warming over the last century is broadly consistent with the predictions of climate models but is also of the same magnitude as natural climate variability. If the sole cause of the observed warming were the human made greenhouse effect, then the implied climate sensitivity would be near the lower end of the range inferred from the models. The observed increase could be largely due to natural variability, alternatively this variability and other man-made factors could have offset a still larger man-made greenhouse warming. The unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more, when the commitment to future climate change will then be considerably larger than it is today."</p>	J. T. Houghton et al., <i>Climate Change: The IPCC Scientific Assessment</i> . Report prepared for Intergovernmental Panel on Climate Change by Working Group I (Cambridge, U.K.: Cambridge University Press, 1990), https://www.ipcc.ch/ipccreports/far/wg_1/ipcc_far_wg_1_full_report.pdf .
1994	NAS: Solar Influences on Global Change	<p>"Taken collectively, the above evidence, although circumstantial, does suggest that solar variability could influence</p>	National Academy of Sciences, <i>Solar Influences on Global Change</i> (Washington,

Year	Title	Key Quotation(s)	Reference
		future global change.... Lack of knowledge of solar influences will limit the certainty with which anthropogenic climate change can be detected. But it is unlikely that solar influences on global change will be comparable to the expected anthropogenic influences.”	DC: National Academies Press, 1994), https://www.nap.edu/download/4778 .
1995	IPCC Second Assessment: Climate Change 1995	“Carbon dioxide remains the most important contributor to anthropogenic forcing of climate change; projections of future global mean temperature change and sea level rise confirm the potential for human activities to alter the Earth's climate to an extent unprecedented in human history.... [O]bservations suggest a ‘discernible human influence on global climate.’” “Most of these studies have detected a significant change and show that the observed warming trend is unlikely to be entirely natural in origin.”	B. Bolin et al., <i>Climate Change 1995: A report of the Intergovernmental Panel on Climate Change</i> (Cambridge, U.K.: Cambridge University Press, 1995), http://www.ipcc.ch/ipccreports/sar/wg_1/ipcc_sar_wg_1_full_report.pdf .
2001	USGCRP: 1 st National Climate Assessment	“The observed magnitude, pattern, and timing of the global warming indicate that the rising concentrations of CO ₂ and other greenhouse gases caused by human activities are contributing significantly to the recent warming.”	National Assessment Synthesis Team, <i>Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change</i> , Report for the USGCRP (Cambridge, U.K.: Cambridge University Press, 2001), https://data.globalchange.gov/assets/e9/97/436129058f2107f4925aeec13ed8/nca-2000-foundation-report.pdf .
2001	NAS: Climate Change Science: An Analysis of Some Key Questions	“The changes observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these changes is also a reflection of natural variability.”	National Academy of Sciences, <i>Climate Change Science: An Analysis of Some Key Questions</i> (Washington, DC: National Academy Press, 2001), https://www.nap.edu/download/10139 .
2001	IPCC: Climate Change 2001: The IPCC Third Assessment Report	“There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.”	R. T. Watson et al. (eds.), <i>Climate Change 2001: Synthesis Report</i> , Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, U.K.: Cambridge University Press, 2001), https://www.ess.uci.edu/researchgrp/prather/files/2001IPCC_SyR-Watson.pdf .
2007	IPCC: The Fourth Assessment Report: Climate Change	“Most of the observed increase in global average temperatures since the mid-20 th century is very likely [>90%] due to the observed increase in anthropogenic GHG concentrations.”	R. K. Pachuri et al. (eds.), <i>Climate Change 2007: Synthesis Report</i> , Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Geneva, Switzerland: IPCC Secretariat, 2007), http://www.slvwd.com/agendas/Full/2007/06-07-07/Item%2010b.pdf .

Year	Title	Key Quotation(s)	Reference
2009	USGCRP: 2 nd National Climate Assessment	“The global warming of the past 50 years is due primarily to human-induced increases in heat trapping gasses.... Recent scientific assessments find that most of the warming of the Earth’s surface over the past 50 years has been caused by human activities.”	Thomas R. Karl et al. (eds.), <i>Global Climate Change Impacts in the United States</i> (Cambridge, UK: Cambridge University Press, 2009), https://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf .
2010	NAS: Advancing the Science of Climate Change	“Climate change is occurring, is caused largely by human activities, and poses significant risks for—and in many cases is already affecting—a broad range of human and natural systems.”	National Academy of Sciences, <i>Advancing the Science of Climate Change, America’s Climate Choices: Panel on Advancing the Science of Climate Change</i> (Washington, DC: National Academy Press, 2010), https://www.nap.edu/download/12782 .
2012	NAS: Climate Change: Evidence, Impacts, and Choices	“The overwhelming majority of climate scientists agree that human activities, especially the burning of fossil fuels (coal, oil, and gas), are responsible for most of the climate change currently being observed.”	National Academy of Sciences, <i>Climate Change: Evidence, Impacts, and Choices</i> , 2012, http://nas-sites.org/americasclimatechoices/files/2012/06/19014_cvtx_R1.pdf
2014	NAS: Climate Change: Evidence and Causes	“Rigorous analysis of all data and lines of evidence shows that most of the observed global warming over the past 50 years or so cannot be explained by natural causes and instead requires a significant role for the influence of human activities.”	National Academy of Sciences, <i>Climate Change: Evidence and Causes</i> , 2014, http://dels.nas.edu/resources/static-assets/exec-office-other/climate-change-full.pdf
2014	IPCC: The Fifth Assessment Report: Climate Change 2014	“[Anthropogenic GHG emissions] effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely [>95%] to have been the dominant cause of the observed warming since the mid-20 th century.”	R. K. Pachuri et al. (eds.), <i>Climate Change 2014: Synthesis Report, Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change</i> (Geneva, Switzerland: IPCC Secretariat, 2014), http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf .
2014	USGCRP: 3 rd National Climate Assessment	“The majority of the warming at the global scale over the past 50 years can only be explained by the effects of human influences, especially the emissions from burning fossil fuels (coal, oil, and natural gas) and from deforestation.”	Jerry M. Melillo et al., (eds.), <i>Highlights of Climate Change Impacts in the United States: The Third National Climate Assessment</i> , USGCRP (Washington, DC: U.S. Government Printing Office, 2014), http://www.globalchange.gov/sites/globalchange/files/NCA3_Highlights_LowRes-small-FINAL_posting.pdf .
2017	USGCRP: Climate Science Special Report: Fourth National Climate Assessment	“It is extremely likely [>95%] that human influence has been the dominant cause of the observed warming since the mid-20 th century. For the warming over the last century, there is no convincing alternative explanation supported by the extent of the observational evidence.”	Donald J. Weubbles et al., <i>Climate Science Special Report: Fourth National Climate Assessment, Volume I</i> , USGCRP, 2017, https://science2017.globalchange.gov/downloads/CSSR2017_FullReport.pdf .

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Notes: The documents cited reflect the evolution of select aspects of climate change science. This list is not comprehensive of, and is not intended to highlight, all aspects of the scientific efforts in climate research.

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