NATIONAL ASSOCIATION OF CLEAN AIR AGENCIES

Primer on Climate Change Science

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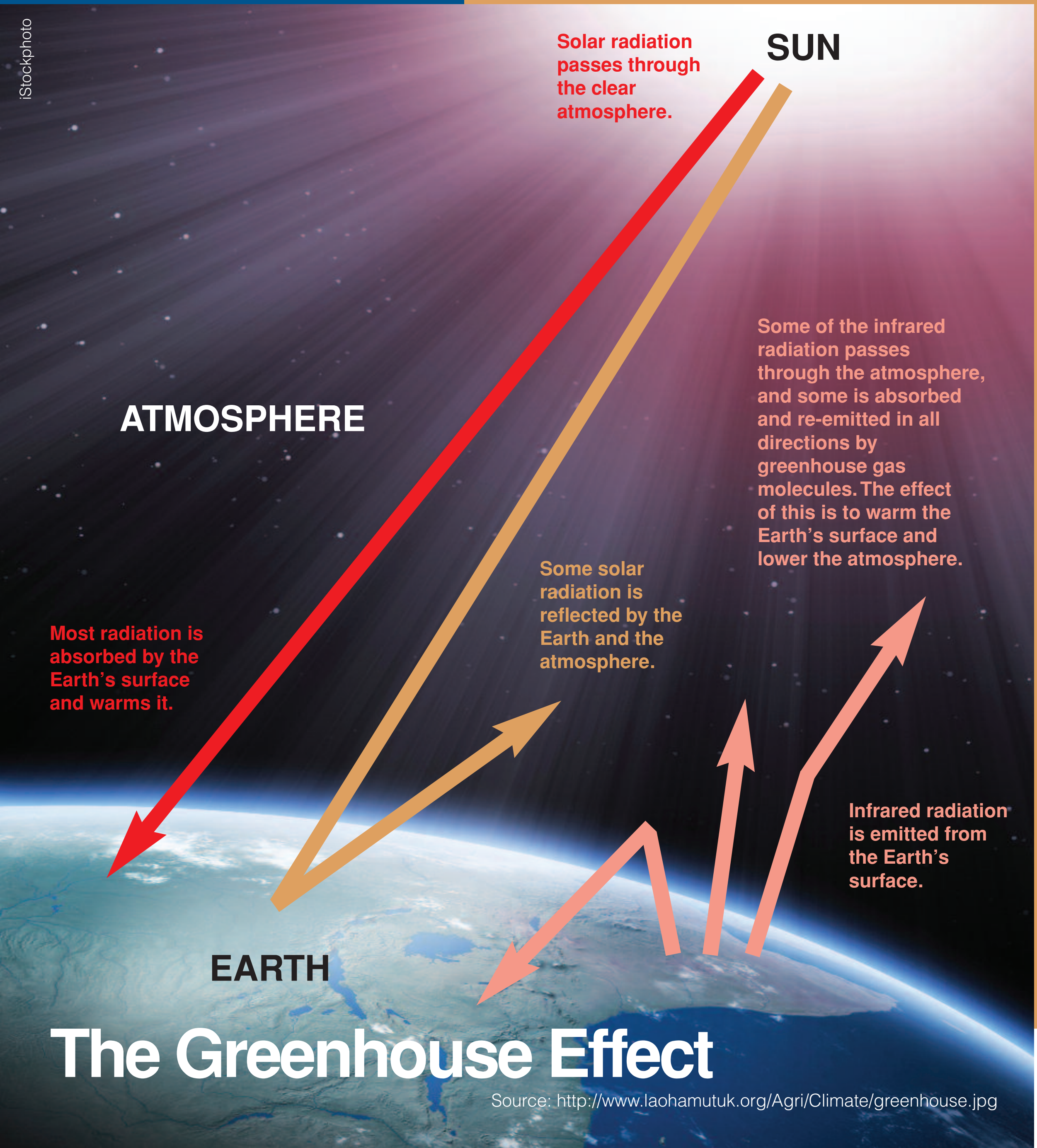
NACAA
national association of clean air agencies

The purpose of this brochure is to provide a summary of the most important information on climate change science in one document, with the view to answering some of the key questions posed by members of the National Association of Clean Air Agencies (and others) about climate change science.

What is the greenhouse effect?

The Earth's greenhouse effect is a natural phenomenon, whereby a delicate balance of certain gases, called "greenhouse gases" (GHGs) for their heat-trapping abilities, helps keep the temperature of the Earth at a level that supports life. When the sun heats the Earth, some of this heat escapes back to space. The rest of the heat is trapped in the atmosphere by clouds and GHGs in the form of infrared radiation. If all of these GHGs were to suddenly disappear, our planet would be 60 degrees Fahrenheit (°F) colder and would not support life as we know it.[1] Conversely, adding more GHGs into the atmosphere increases the strength of the greenhouse effect, resulting in more heat being trapped and held near the Earth's surface.



What is global warming?

Is climate change the same phenomenon as global warming?

Global warming is the warming of the Earth's atmosphere due to increased concentrations of GHGs. The addition of these GHGs in the atmosphere amplifies the Earth's existing greenhouse effect.

The global climate system is a dynamic system, with changes driven by a number of factors including ocean and air circulation, atmospheric and ocean chemistry and solar radiation, for example. Changes in the radiative balance of the Earth are referred to as climate *forcings*. "Forcings" are physical factors external to the climate system that force a net increase (positive forcing) or net decrease (negative forcing) of heat in the climate system as a whole. Thus, positive forcings (such as an increased amount of GHGs) lead to global warming, while negative ones (such as large volcanic eruptions that produce particles that reflect the sun's heat back into space) lead to global cooling. This type of change is distinct from internal climate variability, in which heat is transported by winds or ocean currents with no net change in the total heat within the system.[2]

While the terms "global warming" and "climate change" are often used interchangeably, "climate change" (or "climate disruption") is a more accurate description because it conveys the multitude of impacts – such as increased drought, increased number of extreme precipitation events, rising sea level and ocean acidification – beyond higher temperatures caused by the increased amount of GHGs.[3]

What are the causes of climate change?

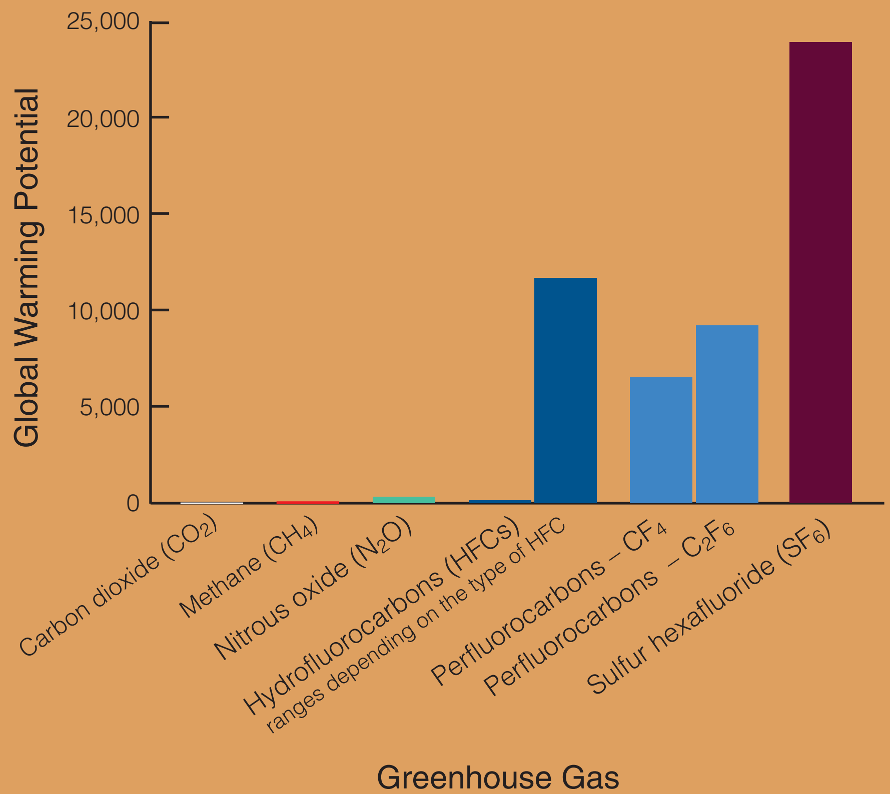
Both natural and human-made causes contribute to climate change. Natural contributors include changes in the Earth's orbit, the sun's intensity, the circulation of the ocean and the atmosphere, and volcanic activity. GHG emissions from human activities that contribute to climate change include the burning of fossil fuels (such as coal, oil and natural gas), cutting down trees (deforestation) and developing land (land-use changes).[4] The burning of fossil fuels emits GHGs into the atmosphere, while deforestation and land-use changes remove trees and other kinds of vegetation that store ("sequester") carbon dioxide (CO_2).

What are the most important GHGs and how much do they warm the atmosphere?

Six major GHGs have been the focus of efforts to reduce emissions: CO_2, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6). They are regulated under the Kyoto Protocol[5] and by the Environmental Protection Agency.[6]

These six anthropogenic (human-caused) GHGs differ in their warming potential. Using CO_2 as a reference point, the bar chart below indicates how powerful the different GHGs are in terms of their ability to trap heat over a 100-year timeframe.[7] Each gas's global warming potential (GWP) is defined relative to CO_2. For example, N_2O's GWP is 310, meaning a unit mass of N_2O warms the atmosphere 310 times more than a unit mass of CO_2.

SF_6 and PFCs have extremely long atmospheric lifetimes, resulting in their essentially irreversible accumulation in the atmosphere once emitted.[8] However, in terms of quantity of emissions, CO_2 dominates world and U.S. GHG emissions (see page 6).



Water vapor is also a GHG. However, it is not regulated because, on a global basis, the concentration of water vapor in the lower atmosphere is controlled by the rate of evaporation and precipitation, which are much more strongly influenced by changes in atmospheric temperature and circulation than by human activities directly.[9]

There are also several gases that do not have a direct global warming effect but indirectly affect terrestrial or solar radiation absorption by influencing the formation or destruction of GHGs, including tropospheric and stratospheric ozone. These gases include carbon monoxide, oxides of nitrogen and non-methane volatile organic compounds. Aerosols, which are extremely small particles or liquid droplets such as those produced by sulfur dioxide or elemental carbon emissions, can also affect the ability of the atmosphere to absorb radiation.[10]

What role does soot or black carbon play in global warming?

Soot particles (also called black carbon) – which are largely emitted from biomass burning and diesel exhaust – warm the climate in two ways. First, they heat the air by absorbing sunlight and warming the air around them. This heating differs from that of GHGs, which do not absorb much sunlight; instead, they absorb the Earth's heat radiation and reemit it to the air. Second, soot particles that fall on snow and sea ice surfaces, either on their own or

within ice crystals or snow flakes, darken those surfaces. This allows more of the sun's heat to be absorbed, thus contributing to the melting of snow and ice and reducing the Earth's reflective surface and causing more heat absorption. Because black carbon remains in the atmosphere for only one to four weeks, its climate effects are strongly regional.[11]

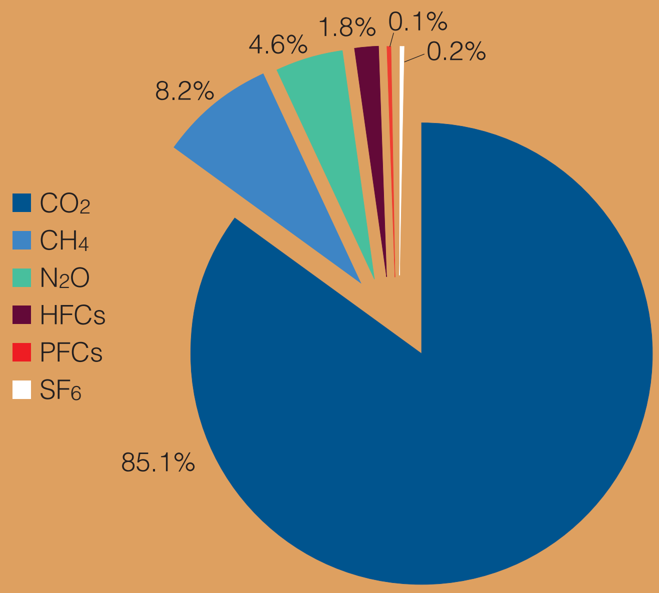
Soot or black carbon is not currently regulated as a GHG but as fine particulate matter ($PM_{2.5}$).

What are the largest sources of human-caused GHG emissions in the U.S.?

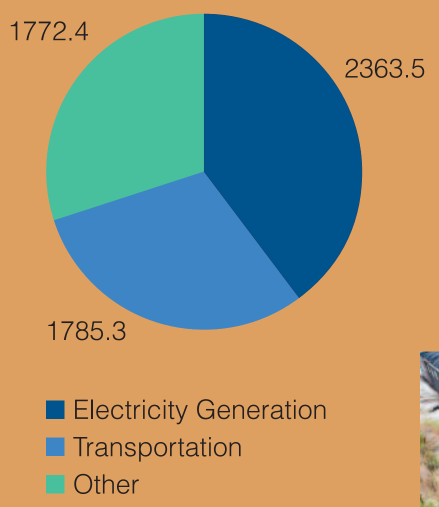
As shown in the pie chart below, 85.1% of U.S. GHG emissions are CO_2 emissions. The vast majority of CO_2 emissions – 94% – are from fossil fuel combustion. The second pie chart illustrates the major sources of CO_2 emitted through fossil fuel combustion in million metric tons of CO_2 equivalent (MMT CO_2e).

The remaining GHGs make up 14.9% of the U.S. GHG emissions inventory. Sources of these emissions include enteric fermentation (CH_4), landfills (CH_4), agricultural soil management (N_2O), substitution of ozone-depleting substances in refrigeration (HFCs), semi-conducture manufacturing (PFCs), aluminum production (PFCs) and electrical transmission and distribution (SF_6).[12]

Composition by Gases of U.S. GHG Inventory in 2008



Sources of Fossil Fuel Combustion CO_2 Emissions in 2008 (MMT CO_2e)



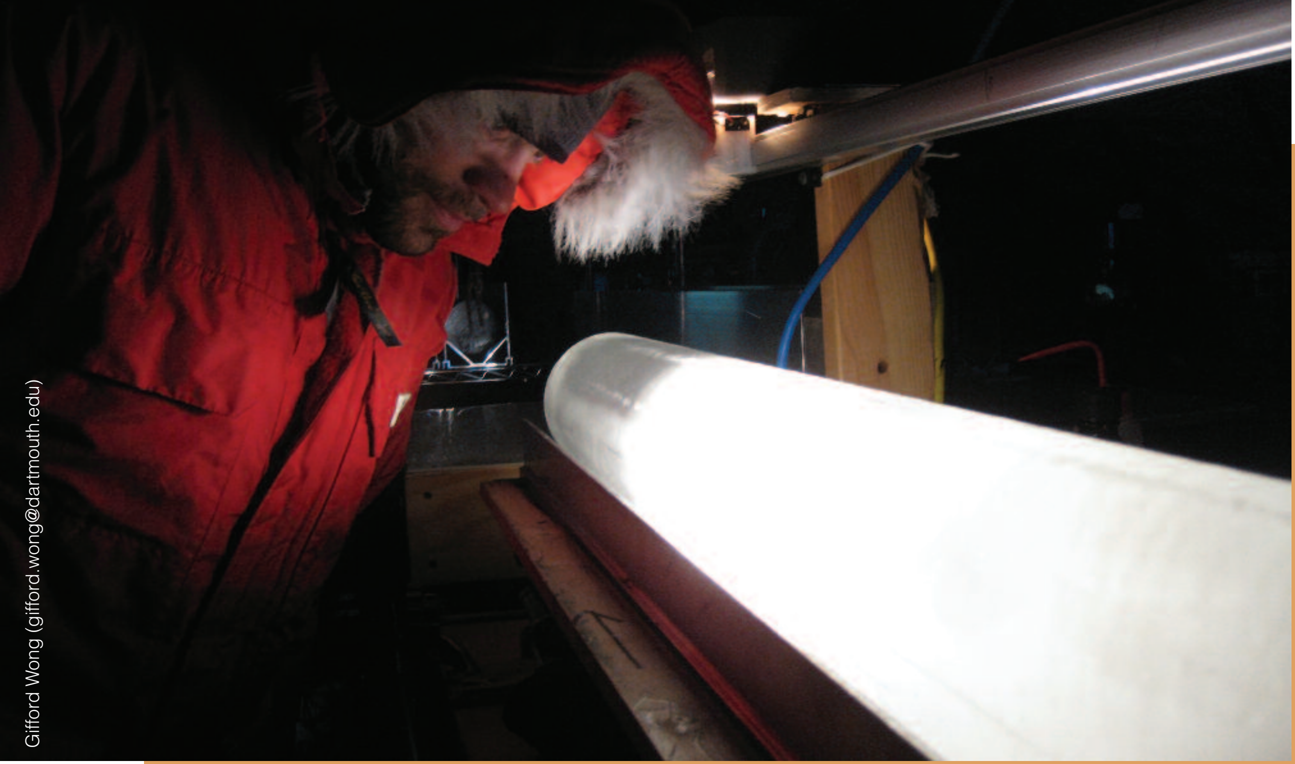
How do GHGs differ from conventional air pollutants? How are they similar?

GHGs differ from conventional air pollutants in several important ways. The major GHGs have much longer atmospheric lives, while conventional air pollutants typically remain airborne for only days or weeks.[13] Because the major GHGs have longer lives, they:

- Become well-mixed in the atmosphere and their concentration tends to be evenly distributed around the world. (However, some recent research has found that there can be CO_2 "hot spots.")[14]
- Build up in the atmosphere so that past, present and future emissions ultimately contribute to total atmospheric concentrations. Thus, while reducing emissions of conventional air pollutants decreases their concentrations in the atmosphere in a relatively short time, atmospheric concentrations of the major GHGs can only be gradually reduced over years and decades.
- Exert their climate change effects over a very long time.[15]

However, there are also similarities:

- Many of the same activities that emit conventional air pollutants also emit GHGs – the burning of fossil fuels to produce electricity, heat or drive engines and the burning of biomass, for example.[16]
- Most of the largest emitters of GHGs are also large emitters of conventional air pollutants.[17]
- Some conventional air pollutants are also GHGs – for example, soot/black carbon and tropospheric ozone.[18]
- Both GHGs and conventional air pollutants affect public health and welfare, albeit through different mechanisms.[19]



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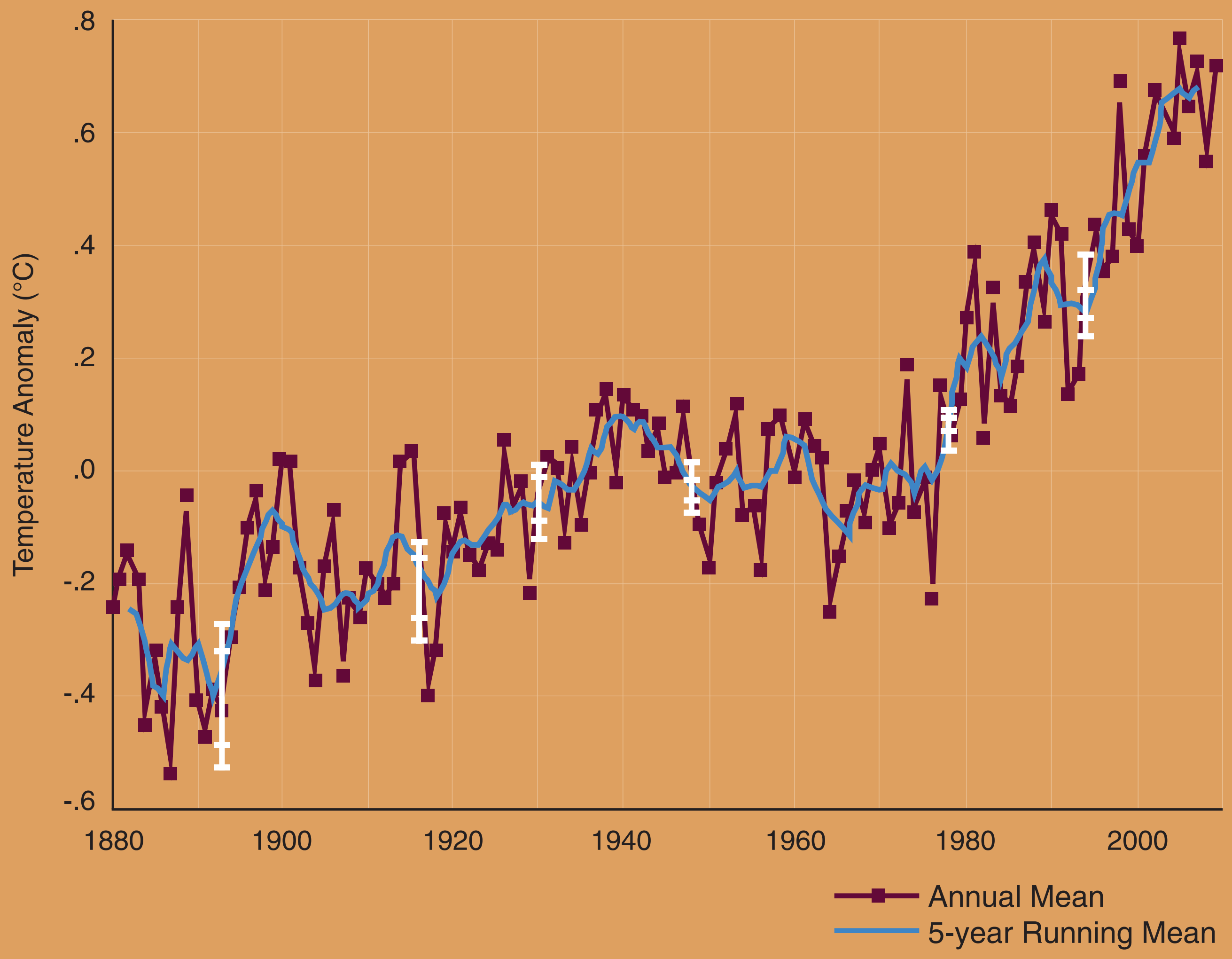
Global Temperature

(Meteorological stations)



Source: http://data.giss.nasa.gov/gistemp/graphs/. The white bars show uncertainty estimates.

How much has the planet warmed?
How much have GHG concentrations increased?

Measurements show that averaged over the globe, the Earth's surface has warmed by about 0.8 degrees Centigrade (ºC) (1.44°F) (with an uncertainty of about ±0.2ºC) since 1850. This warming has not been gradual; instead, it has been largely concentrated in two periods – from around 1910 to around 1940 and from around 1975 to around 2000.[20] Since 2000, this warming trend has continued – the decade 2000-2009 was, globally, around 0.15ºC warmer than the decade 1990-1999.[21]

Global-average CO_2 concentrations have increased from levels of around 280 parts per million (ppm) in the mid-19th century (prior to the Industrial Revolution) to 394.35 ppm in May 2011.[22] The atmospheric concentration of CO_2 exceeds by far the natural range over the last 650,000 years (180 to 300 ppm) as determined from ice cores extracted from Antarctic and Greenland ice sheets.[23]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How do we know that water vapor is not driving global warming?

While water vapor is a strong GHG and is an important contributor to the natural greenhouse effect, it readily evaporates into and condenses out of the atmosphere. The amount of water in the air is primarily a function of temperature, with warmer air holding more water than colder air. Water vapor stays in the atmosphere an average of just a few days.[24] For these reasons, it could not be the sole cause of global temperature increases. However, since global temperatures are rising and warmer air holds more water, research from the National Aeronautics and Space Administration suggests that this increase in humidity amplifies the warming from CO_2 due to positive feedback loops.[25]


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What evidence do we have that global warming is anthropogenic (man-made) rather than from natural causes?

The size and sustained nature of the observed global-average surface warming on decadal and longer timescales greatly exceeds the internal climate variability simulated by the complex climate models. Unless this variability has been grossly underestimated, the observed climate change must result from natural and/or human-induced climate forcing.[26]

When natural factors alone are considered, computer models do not reproduce the climate warming we have observed. Only when human-made GHGs are included do they accurately recreate what has happened in the real world.[27]

There are four particular examples that show a human "fingerprint" on the warming that has been recorded.[28]

- **Twentieth-century warming.** During the twentieth century, the warming of the planet was not gradual but occurred in two distinct phases. There was a large warming between 1910 and 1940, moderate cooling between 1940 and 1975 and a large warming from the 1975 to the present. Scientists at the National Center for Atmospheric Research explored the extent to which natural and man-made forcings contributed to this pattern of warming, then cooling, then warming. The results of this study identify the enhanced GHG effect as the dominant cause of global warming over the past three decades. If not for the temporary cooling between 1940 and 1975 from volcanic and man-made aerosol emissions, the Earth might be even warmer than it is today.[29]

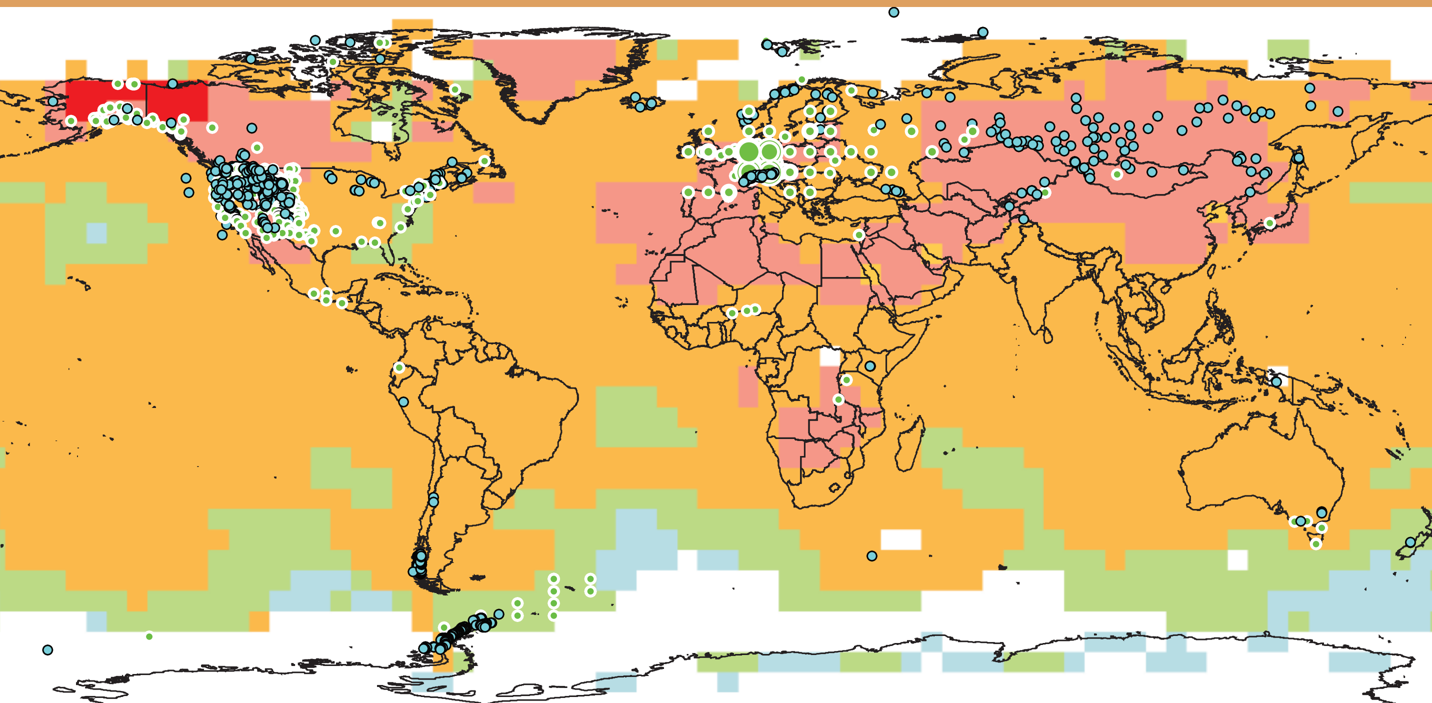
- **Ocean heat content.** Scientists at the National Oceanic and Atmospheric Administration (NOAA) in 2005 reported that the ocean as a whole has been warming over the past five decades. Simultaneous warming of all the world's oceans could only occur through external forcing, as there is no other source of this much energy within the climate system. Further study found that the warming has occurred from the surface downward, meaning that the heat in the oceans must be coming from the atmosphere. Modeling of internal variability alone or internal variability combined with solar and volcanic forcings did not produce temperature profiles that matched this fingerprint. However, the combined influence of human-induced forcings, natural forcings and internal variability reproduced the pattern of heat penetration for each ocean. Human-caused GHGs strongly dominated the overall forcing.[30]

- **Vertical structure of the atmosphere.** The height of the tropopause, which represents the transition between the Earth's lower atmosphere (troposphere) and upper atmosphere (stratosphere), has increased. Scientists in 2003 examined what factors (forcings) caused this increase in height – was it the troposphere getting hotter or the stratosphere getting cooler, or both? When they used a model that included natural and human-induced forcings, the tropopause's height expanded to the same extent as what has been measured. Human-caused GHGs, which warm the troposphere, and stratospheric ozone depletion (by man-made chemicals), which cools the stratosphere, dominated the forcing. Human-caused GHGs caused about 40% of the rise, whereas ozone depletion caused about 60%. Overall, the effect of solar forcing, which contributed slightly (less than 10%) to the rise of the tropopause, was canceled by a small negative forcing (decrease in tropopause height) from volcanoes. Thus, human-induced forcings from GHGs and ozone-depleting chemicals provide the best explanation for the observed increase in the elevation of the tropopause over the past few decades.[31]

- **The ratio of radioactive-free carbon and carbon-14 (^{14}C)[32] in the atmosphere.** Fossil fuels do not contain ^{14}C because all of the radiocarbon initially present in the fossils has decayed away. Scientists can use ^{14}C measurements to determine the age of CO_2 collected in air samples and from this method can calculate what proportion of the CO_2 in the sample comes from fossil fuels. Since the Industrial Revolution, the concentration of ^{14}C has decreased steadily in the atmosphere, which means that the atmospheric increase in CO_2 is dominated by fossil fuel emissions.[33]

Furthermore, the Intergovernmental Panel on Climate Change (IPCC) has identified four sets of evidence supporting the conclusion that changes in many physical and biological systems are linked to human-caused warming.[34] For example, of the more than 29,000 observational data series from 75 studies that show significant change in many physical and biological systems, more than 89% are consistent with the direction of change expected as a response to warming. In addition, the geographical regions of significant warming across the globe align closely to the locations of significant observed changes consistent with warming. This alignment is very unlikely to be due solely to natural variability of temperatures or natural variability of the systems, according to the IPCC. See Figure SPM.1, on page 12, taken from the IPCC report.

Changes in physical and biological systems and surface temperature 1970-2004



	NAM		LA		EUR		AFR		AS		ANZ		PR*		TER		MFW**		GLO	
Number	355	455	53	5	119	28,115	5	2	106	8	6	0	120	24	764	28,586	1	85	765	28,671
Percentage	94%	92%	98%	100%	94%	89%	100%	100%	96%	100%	100%	—	91%	100%	94%	90%	100%	99%	94%	90%

Observed data series

- Physical systems (snow, ice and frozen ground; hydrology; costal processes
- Biological systems (terrestrial, marine, and freshwater)

* Polar regions include also observed changes in marine and freshwater biological systems.
** Marine and freshwater includes observed changes at sites and large areas in oceans, small islands and continents.
Locations of large-area marine changes are not shown on the map.
*** Circles in Europe represent 1 to 7,500 data series.

Europe***
1-30
31-100
101-800
801-1,200
1,201-7,500

Physical	Biological
Number of significant observed changes	Number of significant observed changes
Percentage of significant changes consistent with warming	Percentage of significant changes consistent with warming

Temperature change °C 1970-2004

FIGURE SPM.1. Locations of significant changes in data series of physical systems (snow, ice and frozen ground; hydrology; and coastal processes) and biological systems (terrestrial, marine, and freshwater biological systems), are shown together with surface air temperature changes over the period 1970-2004. White areas do not contain sufficient observational climate data to estimate a temperature trend. The 2 x 2 boxes show the total number of data series with significant changes (top row) and the percentage of those consistent with warming (bottom row). Locations of large-area marine changes are not shown on the map. [Working Group II Fourth Assessment F1.8, F1.9; Working Group I Fourth Assessment F3.9b].[35]

In addition, other possible causes of warming have been evaluated and discarded:[36]

- While the climate system varies naturally, a rigorous statistical evaluation of climate trends, in addition to analyses using sophisticated computer models, indicates that the observed warming, especially the warming since the 1970s, cannot be solely attributed to natural variation.

- Satellite measurements unequivocally show that solar output has not increased over the past 30 years, so an increase in solar energy cannot be responsible for warming since the 1970s.

- Direct measurements show that cosmic rays have neither increased nor decreased during the past 30 years. (Some scientists have hypothesized that cosmic rays could influence cloud formation (and thus climate).) Moreover, scientists have not found a plausible mechanism that would explain how cosmic rays would influence climate.

Finally, the basic physics by which GHGs, including CO_2, warm the Earth has been understood for more than a century, and direct measurements show clearly that CO_2 concentrations in the atmosphere have increased significantly in response to emissions from fuel combustion and other human activities. Therefore, even absent any direct evidence that warming has occurred, one would expect the Earth's climate to change over time in response to continued emissions of CO_2 and other GHGs.

What is the scientific consensus on climate change?

The overwhelming scientific consensus is that there is clear evidence that climate change is affecting the Earth and will continue to affect the planet unless we reduce GHG emissions:

- The IPCC, formed in 1988, is a group commissioned by the World Meteorological Organization and the UN Environment Program to report on the latest scientific knowledge on climate change. Thousands of scientists participate in the IPCC process and their work is reviewed by the 194 governments that are members of the IPCC (which include the U.S.). In 2007, the IPCC published its latest review of global warming science, called the Fourth Assessment Report. In that review, the IPCC concluded that "[w]arming of the climate system is unequivocal"[37] and that "[m]ost of the observed increase in global average temperatures since the mid-20th century is *very likely* [(more than 90% likely)][38] due to the observed increase in anthropogenic [human-caused] greenhouse gas concentrations."[39]

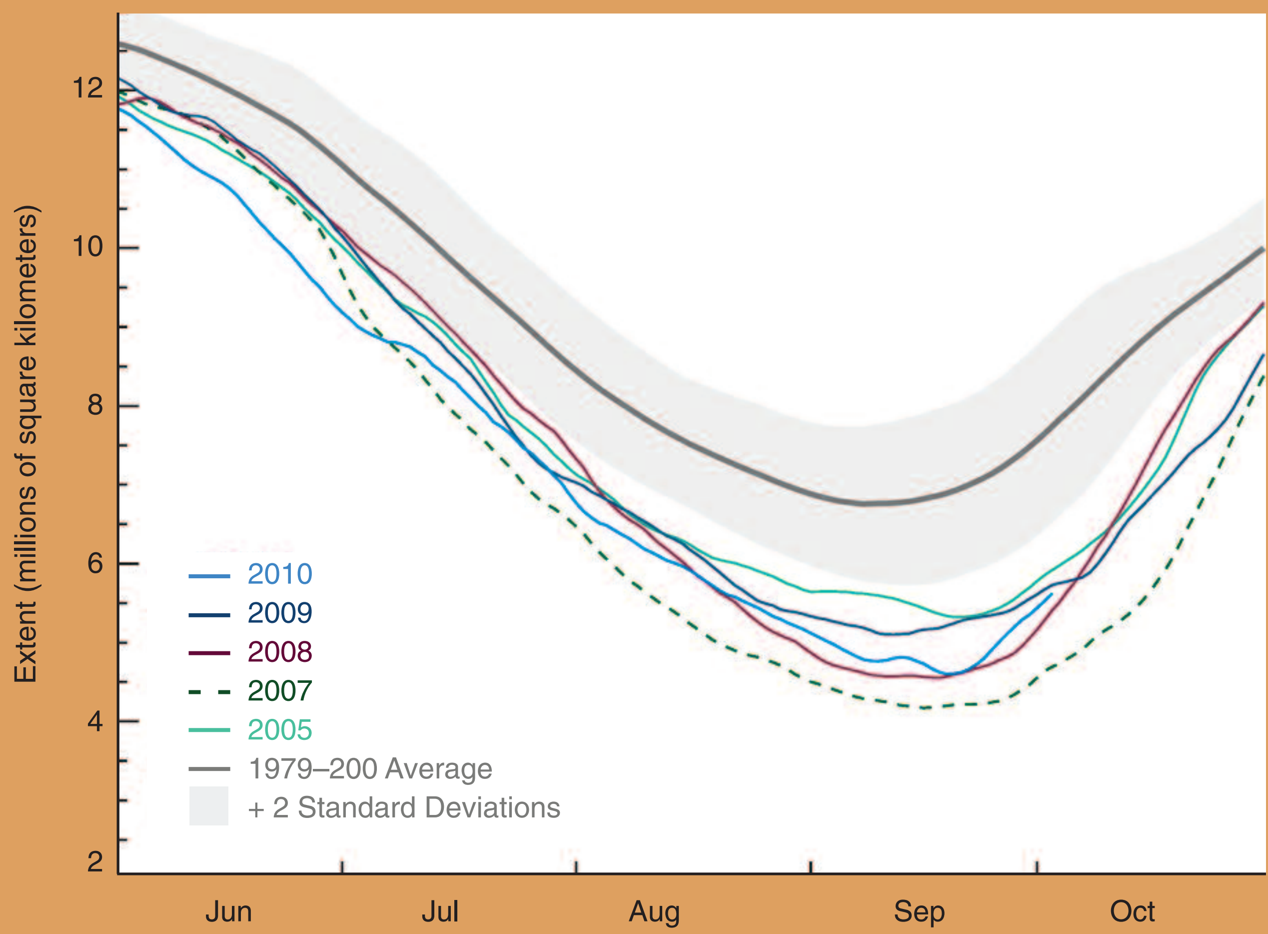
- The National Academies of Science released a report in 2010 finding that a strong, credible body of scientific evidence shows that climate change is occurring, is caused largely by human activities and poses significant risks for a broad range of human and natural systems.[40]

- NOAA's *State of the Climate* report released July 2010 examined ten key climate indicators to see if they supported the premise that the globe has warmed. Seven of the key climate indicators would be expected to increase if the Earth were warming, and they are increasing: the air temperature near the surface of the planet (troposphere); humidity; the temperature over the oceans; sea surface temperature; sea level; ocean heat content; and temperature over land. Three key climate indicators would be expected to decrease and they are: glaciers; snow cover; and sea ice.[41]

- A 2004 survey of peer-reviewed abstracts published between 1993 and 2003 on global warming found that 75% of the papers agreed with the consensus that global warming is occurring and that human activity is responsible for the warming. The other 25% of the papers expressed no view on the consensus. In other words, the survey found not a single peer-reviewed paper that contradicted the scientific consensus.[42]

Arctic Sea Ice Extent

(Area of ocean with at least 15% sea ice)



Source: National Snow and Ice Data Center[43]

Endnotes

[1] For further information, see EPA's web site on global warming, http://epa.gov/climatechange/basicinfo.html, and the Pew Center on Global Climate Change's fact sheets on global warming, http://www.pewclimate.org/science-impacts/factsheets.

[2] Pew Center on Global Climate Change, "The Causes of Climate Change," Science Brief 1 (August 2008) at 2, available at http://www.pewclimate.org/docUploads/global-warming-science-brief-august08.pdf. See also National Research Council of the National Academies of Science, "Advancing the Science of Climate Change," (2010), p. 189, available at http://dels.nas.edu/Report/Advancing-Science-Climate-Change/12782.

[3] For further information, see EPA's web site on global warming, http://epa.gov/climatechange/basicinfo.html.

[4] EPA, "Frequently Asked Questions About Global Warming and Climate Change: Back to Basics," available at http://www.epa.gov/climatechange/downloads/Climate_Basics.pdf.

[5] The text of the Kyoto Protocol is available at http://unfccc.int/resource/docs/convkp/kpeng.pdf.

[6] EPA Endangerment and Cause or Contribute Findings for GHGs Under Section 202(a) of the Clean Air Act, http://www.epa.gov/climatechange/endangerment.html.

[7] Department of State, US Climate Action Report 2010, Chapter 3 – GHG Inventory, available at http://www.state.gov/documents/organization/140009.pdf and EPA web site on high GWP GHGs, http://www.epa.gov/highgwp/scientific.html.

[8] Department of State, US Climate Action Report 2010, Chapter 3 – GHG Inventory, p. 31, available at http://www.state.gov/documents/organization/140009.pdf.

[9] National Research Council of the National Academies of Science, "Advancing the Science of Climate Change," (2010), p. 194, available at http://dels.nas.edu/Report/Advancing-Science-Climate-Change/12782

[10] Department of State, US Climate Action Report 2010, Chapter 3 – GHG Inventory, p. 23, available at http://www.state.gov/documents/organization/140009.pdf.

[11] The Pew Center on Global Climate Change, "What is Black Carbon?" (April 2010), available at http://www.pewclimate.org/global-warming-basics/blackcarbon-factsheet. See also National Research Council of the National Academies of Science, "Advancing the Science of Climate Change," (2010), pp. 196-197, available at http://dels.nas.edu/Report/Advancing-Science-Climate-Change/12782.

[12] EPA, US GHG Inventory, available at: http://epa.gov/climatechange/emissions/downloads10/US-GHG-Inventory-2010_ExecutiveSummary.pdf.

[13] EPA's Advance Notice of Proposed Rulemaking on Regulating Greenhouse Gases Under the Clean Air Act, 73 *Federal Register* (July 30, 2008), pp. 44400-44401.

[14] Study on the Enhancement of Local Air Pollution by Urban Carbon Dioxide Domes (Mark Jacobson, Stanford University), available at http://www.stanford.edu/group/efmh/jacobson/Articles/V/urbanCO2domes.html.

[15] 73 *Federal Register*, pp. 44400-44401.

[16] Id., p. 44407.

[17] Id.

[18] Id, pp. 44424-44425.

[19] EPA Endangerment and Cause or Contribute Findings for GHGs Under Section 202(a) of the Clean Air Act, available at http://www.epa.gov/climatechange/endangerment.html.

[20] The Royal Society, "Climate Change: A Summary of the Science," (Sept. 2010), p.5, available at http://royalsociety.org/climate-change-summary-of-science/. See also National Research Council of the National Academies of Science, "Advancing the Science of Climate Change," (2010), pp. 30-32, available at http://dels.nas.edu/Report/Advancing-Science-Climate-Change/12782.

[21] The Royal Society, "Climate Change: A Summary of the Science," (Sept. 2010), p.5, available at http://royalsociety.org/climate-change-summary-of-science/.

[22] The Royal Society, "Climate Change: A Summary of the Science," (Sept. 2010), p.6, available at http://royalsociety.org/climate-change-summary-of-science/, and http://co2now.org/ (which posts the most recent monthly CO_2 concentrations measured at the Mauna Loa Observatory in Hawaii).

[23] Intergovernmental Panel on Climate Change (IPCC), Summary for Policymakers, in Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, p. 2, available at http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf. See also National Research Council of the National Academies of Science, "Advancing the Science of Climate Change," (2010), pp. 187-188, available at http://dels.nas.edu/Report/Advancing-Science-Climate-Change/12782.

[24] National Research Council of the National Academies of Science, "Advancing the Science of Climate Change," (2010), pp. 36-37 and 195, available at http://dels.nas.edu/Report/Advancing-Science-Climate-Change/12782. See also Environmental Defense Fund, "Carbon Dioxide, Water Vapor and Global Warming," (Nov. 8, 2006), available at http://www.edf.org/documents/5596_GlobalWarmingWaterVapor_onepager.pdf, and National Aeronautics and Space Administration (NASA), "Carbon Dioxide Controls Temperature," available at http://www.nasa.gov/topics/earth/features/co2-temperature.html.

[25] Kathryn Hansen, "Water Vapor Confirmed as Major Player in Climate Change," available at http://www.nasa.gov/topics/earth/features/vapor_warming.html.

[26] The Royal Society, "Climate Change: A Summary of the Science," (Sept. 2010), p.9, available at http://royalsociety.org/climate-change-summary-of-science/. See also National Research Council of the National Academies of Science, "Advancing the Science of Climate Change," (2010), p. 28, available at http://dels.nas.edu/Report/Advancing-Science-Climate-Change/12782

[27] The Royal Society, "Climate Change: A Summary of the Science," (Sept. 2010), p.9, available at http://royalsociety.org/climate-change-summary-of-science/. See also National Research Council of the National Academies of Science, "Advancing the Science of Climate Change," (2010), p. 38, available at http://dels.nas.edu/Report/Advancing-Science-Climate-Change/12782.

[28] Adapted in part from the Pew Center on Global Climate Change, "The Causes of Climate Change," Science Brief 1 (August 2008), available at http://www.pewclimate.org/docUploads/global-warming-science-brief-august08.pdf.

[29] IPCC, Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Chapter 12. Available at http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg1/index.htm.

[30] Barnett et al., "Penetration of human-induced warming into the world's oceans," (2005), Science 309:284-287.

[31] Santer, B.D. et al., "Contributions of anthropogenic and natural forcing to recent tropopause height changes," (2003), Science 301:479-483; and Santer, B. D., et al., "Identification of anthropogenic climate change using a second generation reanalysis," (2004), Journal of Geophysical Research-Atmospheres 109:D21104, doi:10.1029/2004JD005075.

[32] Carbon-14 or 14C is also known as radiocarbon, because it is the only carbon isotope that is radioactive.

[33] Lauren Shoemaker, "Fingerprints of Emissions and Carbon Cycle: Stable and Radioactive Isotopes of Carbon Dioxide," (August 2010), available at http://www.esrl.noaa.gov/gmd/outreach/isotopes/c14tracer.html.

[34] IPCC, Climate Change 2007: Working Group II: Impacts, Adaptation and Vulnerability, posted at http://www.ipcc.ch/publications_and_data/ar4/wg2/en/contents.html.

[35] IPCC, Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Figure SPM.1 Cambridge University Press, posted at http://www.ipcc.ch/publications_and_data/ar4/wg2/en/spmsspm-b.html.

[36] National Research Council of the National Academies of Science, "Advancing the Science of Climate Change," (2010), p. 38, available at http://dels.nas.edu/Report/Advancing-Science-Climate-Change/12782.

[37] IPCC, Fourth Assessment Report: Climate Change 2007 – Synthesis Report, Summary for Policymakers, Chapter 1 (Observed changes in climate and their effects), available at http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms1.html.

[38] The IPCC described what terms such as "very likely," "likely," "not likely" and others meant in the Introduction to the Synthesis Report. "Very likely" means greater than a 90% probability of occurrence. IPCC, Fourth Assessment Report: Climate Change 2007 – Synthesis Report, Introduction, available at http://www.ipcc.ch/publications_and_data/ar4/syr/en/mainssyr-introduction.html.

[39] IPCC Fourth Assessment Report: Climate Change 2007 – Synthesis Report, Summary for Policymakers, Chapter 2 (Causes of Change), available at http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms2.html.

[40] National Research Council of the National Academies of Science, "Advancing the Science of Climate Change," (2010), available at http://dels.nas.edu/Report/Advancing-Science-Climate-Change/12782.

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The National Association of Clean Air Agencies (NACAA) is an association of air pollution control agencies in 51 states and territories and over 165 major metropolitan areas across the United States.

State and local air pollution control officials formed NACAA (formerly, STAPPA/ALAPCO) over 30 years ago to improve their effectiveness as managers of air quality programs. The associations serve to encourage the exchange of information among air pollution control officials, to enhance communication and cooperation among federal, state, and local regulatory agencies, and to promote good management of our air resources.

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