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Attribution of Global Warming

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ATTRIBUTION OF GLOBAL warming refers to the recent effort to scientifically prove the cause of the warming effect. Many factors can cause changes in the Earth's heat balance, and changes large enough to cause major episodes of warming and cooling have taken place many times in the Earth's past. One cause of change of great concern to scientists is the amount of heat-absorbing gas in the atmosphere. Carbon dioxide, water vapor, and several secondary gases absorb thermal infrared radiation released from the Earth's surface and the lower atmosphere.

Greenhouse effect is the phrase for when a planet's atmosphere and surface are warmed by the absorption and emission of infrared radiation of atmospheric gases. When absorption takes place, the gas molecules take on heat and air temperature rises. If the atmosphere is heavy with water vapor and carbon dioxide, then heat tends to be retained in roughly the same way as the glass of a greenhouse contains longwave infrared radiation and heat. Hence, greenhouse effect is commonly used to describe the role of carbon dioxide (CO_2) and H_2O vapor and various secondary gases in holding heat within the atmosphere.

To illustrate the importance of the greenhouse effect, scientists estimate that if it were eliminated, the Earth's equilibrium surface temperature would fall 59 degrees F to 0 degrees F (33 degrees C to minus 18 degrees C). Global warming is one of the specific examples of climate change, referring to recent warming, and implying a human influence. Global warming is the status quo of the increasing average temperature of the Earth's near-surface air and oceans. It also refers to its projected continuation.

Human-Induced Climate Change

The dominant mechanisms to which recent global warming and climate change have been attributed all result from human activity, such as increasing atmospheric concentrations of greenhouse gases, or aerosols. These attributions are supported by observations from the Intergovernmental Panel on Climate Change (IPCC). The IPCC concluded that most of the observed increase in globally averaged temperatures since the mid-20th century is “very likely” due to the observed increase in anthropogenic greenhouse gas concentrations via the greenhouse effect. It also concluded that it is “extremely likely” that human activities have exerted a substantial net warming influence on climate since 1700. These conclusions have probabilities greater than 90 and 95 percent, respectively.

Since the 1700s, the CO_2 content of the atmosphere has been increasing as a result of air pollution emitted by human activities. Pollution has also caused a significant increase in secondary greenhouse gases, namely methane from animal digestion and bacteria, ozone and nitrogen oxides from urban air pollution, and chlorofluorocarbons from spray cans and fugitive refrigerants. The increase in CO_2 and the four secondary greenhouse gases is a global trend. Since 1760, the atmospheric concentrations of CO_2 and methane have increased by 32 percent and 151 percent, respectively, compared to the pre-industry period. Therefore, the biggest root cause is worldwide population growth.

According to the IPCC, the projected increase of global surface temperatures is likely to be 2.1–11.7 degrees F (1.2–6.5 degrees C) between 1995 and 2100, based on the different scenarios of future greenhouse gas emissions and climate sensitivity. These conclusions have been endorsed by at least 30 scientific societies and academies of science, including all of the national academies of science of the major industrialized countries.

The argument related to global warming focuses on how much the greenhouse effect will be increased with the growing atmospheric concentrations of some greenhouse gases by human activities. Naturally occurring greenhouse gases consist of about 36–70 percent water vapor (not including clouds), 9–26 percent CO_2, 4–9 percent methane (CH_4), and 3–7 percent ozone. Comparatively small fractions of the greenhouse effect are caused by naturally occurring gases such as nitrous oxide (N_2O). Concentrations of N_2O are increasing because of human activity such as agriculture. CO_2 is produced mainly by natural processes such as volcanoes and rock weathering, and is recycled through the atmosphere by the biological processes of respiration and photosynthesis.

Over geologic time, atmospheric CO_2 has varied appreciably, causing shifts in the Earth's heat balance. Over periods of thousands of years, however, the CO_2 cycle can keep a fairly stable balance, thereby helping maintain a relatively stable global temperature regime. CO_2 from human sources, however, represents a surcharge on the natural system.

Human sources of CO_2 fall into roughly two major classes: fossil fuel combustion and open fires. Use of fossil fuels by humans contributes to three-quarters of the increase in CO_2 over the past 25 years. The fossil fuel sources are industry, power plants, automobiles, and households; the developed countries are the principal contributors. The open-fire sources are associated with the clearing of tropical forests, forest fires in general, grassland fires, household cooking and heating, and wars. The rate of increase in atmospheric carbon dioxide approximates that of global economic growth, about 2 percent annually. Current carbon dioxide levels are about 30 percent above the 18th century (pre-industrial) level.

It is crucial to scientifically determine mechanisms responsible for the observed warming of the Earth, and many efforts have been made to prove changes observed during the last 50 years, when human activity has grown fastest and observations of the upper atmosphere have become available. There are measurable signs that warming is underway, because the global atmospheric temperature has increased at least 0.9 degrees F (0.5 degrees C) in the last 100 years. This rise corresponds to the measured increase in atmospheric CO_2. Even though short-term temperature trends on the order of 50 or 100 years generally have little meaning with respect to global-scale warming, it is curious to note that studies of global temperature records dating from the late 1800s indicate that the 1980s and 1990s were the warmest two decades on record.

The IPCC has played an important role in providing the attribution of global warming, however, there are still several uncertainties that have to be resolved, including the exact degree of global warming expected in the future, and how changes will vary from region to region around the globe. One reason for scientists' uncertainty about how much global warming will take place is related to the rate of removal of CO_2 from the atmosphere. CO_2 is removed from the atmosphere by two main absorbing agents, vegetation and the oceans.

Under natural circumstances, it can be assumed that the oceans annually extracted 90 billion tons of CO_2 from the atmosphere, an amount equal to the quantity they put into the atmosphere yearly. However, with the rise of global air pollution, the oceans appear to have increased their CO_2 intake and now absorb a large part of the 7 billion tons of excess CO_2 put into the atmosphere annually from human sources. The amount may be as great as three billion additional tons a year. Therefore, the net amount of CO_2 left to accumulate in the atmosphere is about 4 billion tons a year.

At this rate, coupled with allowances for population growth, atmospheric CO_2 is expected to double by 2050. Whether the oceans and land vegetation will increase or decrease their intake of CO_2 in the future is difficult to claim at this point. Recent researchers concluded that the estimate of 3 billion tons of annual ocean intake may be high. The oceans may actually be taking in closer to 2 billion tons a year, and some other agency is responsible for extracting the remaining 1 billion tons of CO_2. Perhaps the world s forests might be a good candidate to increase the rate of intake. Some studies suggest that air pollutants such as CO_2 and sulfur dioxide may actually increase forest growth and intake CO_2 in some regions. The annual rate of rainforest destruction, as much as 65,000 sq mi. (168,349 sq. km.) a year, is a considerable loss, especially when forests have very high annual CO_2 intake capacities.

Feedback Processes

The second category of the attribution of the warming is the various feedback processes caused by the forcing agents on the climate. Evaporation of water might be the most evident feedback effect that contributes to global warming. The initial warming generated by CO_2 will cause more water to be evaporated into the atmosphere. Then, water vapor acts as a greenhouse gas and causes more global warming. As a result, the global warming causes still more water vapor to be evaporated until the concentration of water vapor has reached the dynamic equilibrium, with a much larger greenhouse effect than that due to CO_2 alone. This increases the amount of the absolute moisture in the air, but the relative humidity of the atmosphere rarely changes because the air is warmer.

Cloud feedback effects are an area of ongoing research. In the air, clouds emit infrared radiation from the ground back to the surface and enforce the warming effect. The same clouds reflect sunlight and emit infrared radiation from sun to space and enforce the cooling effect. Because the type, altitude, and other variables are important factors in deciding the net effect of clouds on cooling or warming, it is very difficult to represent in climate models. Nevertheless, cloud feedback is reported as the second largest positive feedback that contributes to the global warming models that were used in the IPCC Fourth Assessment Report.

Ice albedo feedback is another feedback process that contributes to global warming. As global temperatures increase, the melting process of the ice near the poles increases rapidly. The resulting land and open water are, on average, less reflective than ice, and, thus, absorb more solar radiation. This causes more warming, which in turn causes more melting, and this cycle continues. Positive feedback due to release of CO_2 and CH_4 from thawing permafrost is an additional mechanism contributing to warming. Possible positive feedback due to CH_4 release from melting seabed ice is a further mechanism to be considered.

A Counterargument

In contrast to the scientific consensus, there is a counterargument by a few individual scientists who cast doubt on the global warming forecast. Their claims are based on the blocking effect on solar radiation caused by aerosols. Aerosols are particles of solids and liquids suspended in the atmosphere that backscatter incoming solar radiation. Aerosols are produced from both natural sources such as volcanoes, and pollution sources such as forest fires and urban emissions. They occur in both primary and secondary forms, meaning that

some enter as particles, whereas others develop into particles from gaseous pollutants. In addition, pollutants increase condensation and cloud formation, thereby increasing reflection of solar radiation. Because aerosols and clouds reduce solar radiation receipt in the lower atmosphere and at the Earth's surface, they also reduce solar heating and may cause temperatures to decline as a result.

The effect of aerosols on solar heating of the lower atmosphere was dramatically demonstrated in the hours immediately after 9/11. The U.S. government ordered grounding of all aircraft, and for a short time, skies over the United States and Canada were clear of condensation trails from high-flying jetliners. During that time, a distinct rise in surface temperature was recorded over broad areas.

With the resumption of flying, temperatures fell back to pre-9/11 levels. With the dramatic increase in global air pollution in this century, the atmosphere has grown dirtier and less transparent to solar radiation. Less solar energy reaches the Earths surface, and if there were no counterbalancing factors, the lower atmosphere would probably be growing cooler. But there are counterfactors in the form of CO_2 and warming gases.

Effects of Global Warming

If global warming proceeds, Earth's equilibrium surface temperature will rise 3–11 degrees F (2–6 degrees C) over the next 100 years. Earth's equilibrium surface temperature will reach 62–68 degrees F (17–20 degrees C). This means that more thermal energy will be available to drive atmospheric processes such as winds, air mass movement, and evaporation. How all of this will interrelate to shape the broad picture of global climate is difficult to forecast. Based on computer simulation models illustrating anticipated changes in atmospheric circulation, scientists forecast that warming will not be geographically uniform; in some regions it will be significantly greater than others, and the climatic changes will likely be different in different parts of the world.

Specific examples of the modeling approach for change of global temperature scenarios are simple climate models (SCMs). SCMs are the simplified models used by the Intergovernmental Panel on Climate Change (IPCC) to provide projections of the atmospheric concentrations of greenhouse gases, global mean temperature, and sea-level change response, using as input emissions scenarios describing the future developments in the emissions of greenhouse gases.

The increased heat content of the troposphere will strengthen certain air masses, increasing their moisture content, leading to greater storminess in some regions. It is already known that that storminess and precipitation on the Pacific coast of the Americas increases substantially with only 1.8–3.6 degrees F (1–2 degrees C) of atmospheric warming associated with El Nino, the periodic buildup of warm water in the east Pacific near the equator. Increased ocean temperatures may also lead to increased magnitude and frequency of hurricanes. Hurricanes are driven by the energy of water vapor, called latent heat. Warmer ocean waters supply more vapor, and thus more energy, to the atmosphere to fuel storms. Hurricanes are the most powerful storms on the planet, and the greater their fuel supply, the bigger and more destructive they are.

Although it is difficult to connect specific weather events to global warming, an increase in global temperatures may, in turn, cause other changes, including glacial retreat and worldwide sea-level rise. Changes in the amount and pattern of precipitation may result in

flooding and drought.

There may also be changes in the frequency and intensity of extreme weather events. Other effects may include changes in agricultural yields, reduced summer stream flows, species extinctions, and increases in the range of disease vectors. Some effects on both the natural environment and human life are, at least in part, already being attributed to global warming.

The broad agreement among climate scientists that global temperatures will continue to increase has led nations, states, corporations, and individuals to implement actions to try to curtail global warming or adjust to it. Many environmental groups encourage action against global warming, often by the consumer, but also by community and regional organizations. There has also been business action on climate change, including efforts at increased energy efficiency, and moves to alternative fuels. One important innovation has been the development of greenhouse gas emissions trading through which companies, in conjunction with government, agree to cap their emissions or to purchase credits from those below their allowances.

The Kyoto Protocol

The world's primary international agreement on combating global warming is the Kyoto Protocol, an amendment to the United Nations Framework Convention on Climate Change (UNFCCC), negotiated in 1997. The protocol now covers more than 160 countries and over 55 percent of global greenhouse gas emissions. As of 2007, the United States (historically the world's largest greenhouse gas emitter), Australia, and Kazakhstan had not ratified the treaty. China and India have ratified the treaty, but as developing countries, are exempt from its provisions. This treaty expires in 2012, and international talks began in May 2007 on a treaty to succeed the current one. Increased awareness of the scientific findings surrounding global warming has resulted in political and economic debate. Poor regions, particularly in Africa, appear at greatest risk from the suggested effects of global warming, while their actual emissions have been negligible compared to the developed world.

At the same time, developing country exemptions from provisions of the Kyoto Protocol have been criticized by the United States and Australia, and have been used as part of their rationale for continued non-ratification. Chinas CO_2 emissions, mainly from automobiles and coal power plants, are expected to exceed those of the United States within the next few years. China has contended that it has less obligation to reduce emissions, since its emissions per capita are about one-fifth those of the United States. The United States contends that if they must bear the costs of reducing emissions, so should China. India will also soon be one of the biggest sources of industrial emissions, and has made assertions similar to Chinas on this issue.

The world's primary body for crafting a response is the Intergovernmental Panel on Climate Change (IPCC), a UN-sponsored activity that holds periodic meetings between national delegations on the problems of global warming, and issues working papers and assessments on the current status of the science of climate change, impacts, and mitigation.

- global warming
- greenhouse gases
- temperature
- emissions

- solar radiation
- infrared radiation
- gases

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- Evaporation Feedbacks
- Greenhouse Effect
- Greenhouse Gases
- Hurricanes and Typhoons
- Kyoto Protocol

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