

Global Climate Change

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Abstract

The global-mean temperature at Earth's surface has increased by about 0.6°C (1.1°F) over the past century. Most of this warming is due to the excess greenhouse gases emitted to the atmosphere by human activities such as fossil fuel use, agriculture practices, and land-use change. Many changes in natural systems have already resulted from this warming, including the melting of glaciers and ice caps, the rising of the sea level, extended growing seasons and changes in precipitation regimes, and changes in the geographical distributions of plant and animal species. Current projections, based on reasonable assumptions of future energy-use practices, indicate that Earth will continue to warm during the 21st century and beyond, in part because parts of Earth's system respond slowly to changes in greenhouse gas levels.

INTRODUCTION

For the past century, Earth's climate has been changing due to human activities. Observations show that Earth's surface warmed by approximately 0.6°C (1.1°F) on average in the 20th century. Much of this warming has been attributed to increasing abundances of greenhouse gases emitted to the atmosphere by human activities, although it is difficult to quantify this contribution against the backdrop of natural variability and climate-forcing uncertainties. Atmospheric abundances of the major anthropogenic greenhouse gases (carbon dioxide; methane; nitrous oxide; halocarbons manufactured by humans, such as chlorofluorocarbons; and tropospheric ozone) reached their highest recorded levels at the end of the 20th century, and all but methane has continued to rise. Major causes of this rise have been fossil fuel use, agriculture, and land-use change.

The emerging impacts of climate change on natural systems include melting glaciers and ice caps, the rising sea level, extended growing seasons and changes in precipitation regimes, and changes in the geographical distributions of plant and animal species. Additional impacts, to which it may be difficult for human and natural systems to adapt, could arise from events whose triggers are poorly understood. Human-induced global warming will continue during the 21st century and beyond, because many parts of the Earth system respond slowly to changes in greenhouse gas levels and because altering established energy-use

practices is difficult. Uncertainties remain about the magnitude and the impacts of future climate change, largely due to gaps in understanding of climate science and the socioeconomic drivers of climate change.

THE CLIMATE SYSTEM AND THE NATURAL GREENHOUSE EFFECT

While climate conventionally has been defined as the long-term statistics of the weather (e.g., temperature, cloudiness, precipitation), improved understanding of the atmosphere's interactions with the oceans, the cryosphere (ice-covered regions of the world), and the terrestrial and marine biospheres has led scientists to expand the definition of climate to encompass the oceanic and terrestrial spheres as well as chemical components of the atmosphere (Fig. 1). Physical processes within the atmosphere are influenced by ocean circulation, the reflectivity of Earth's surface, the chemical composition of the atmosphere, and vegetation patterns, among other factors.

The Sun provides almost all of Earth's energy. Solar radiation intercepted by Earth first encounters the atmosphere, which allows most of it to pass to Earth's surface. The intensity of radiation at the surface depends on the amount of incident radiation and on the orientation of the surface with respect to that radiation. The surface either reflects or absorbs this incoming radiation. Different surfaces reflect different amounts of sunlight. The fraction of solar energy reflected is defined as a surface's albedo. Albedos range from about 10% for open water, dark soil, and asphalt to about 80% for fresh snow.^[1] Earth's average albedo is about 31%.

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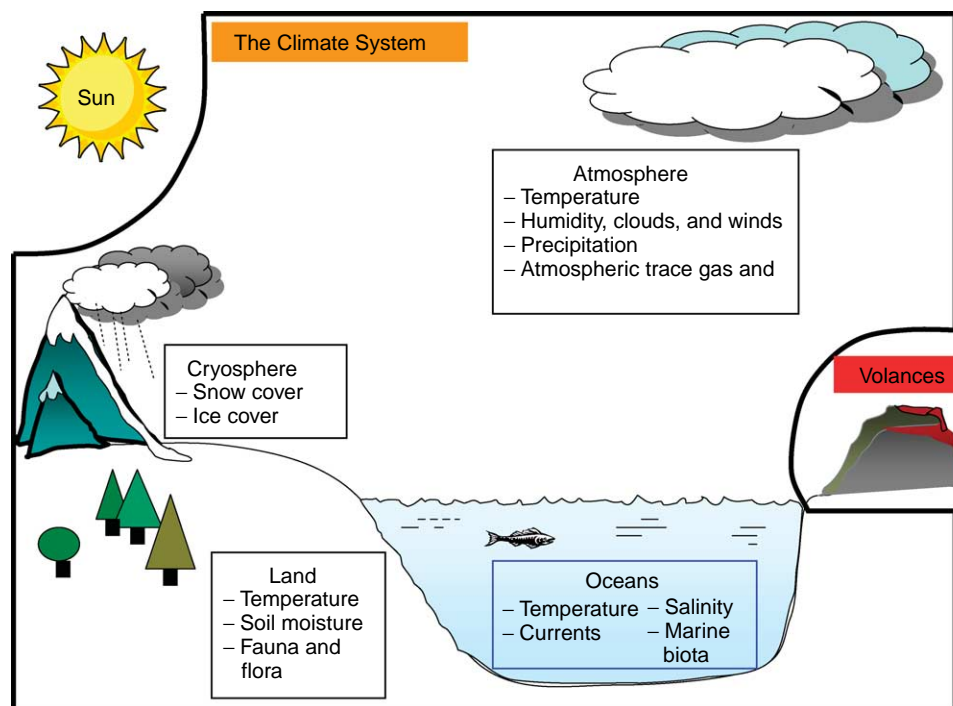


Fig. 1 The climate system.
Source: From National Academies Press (see Ref. 5).

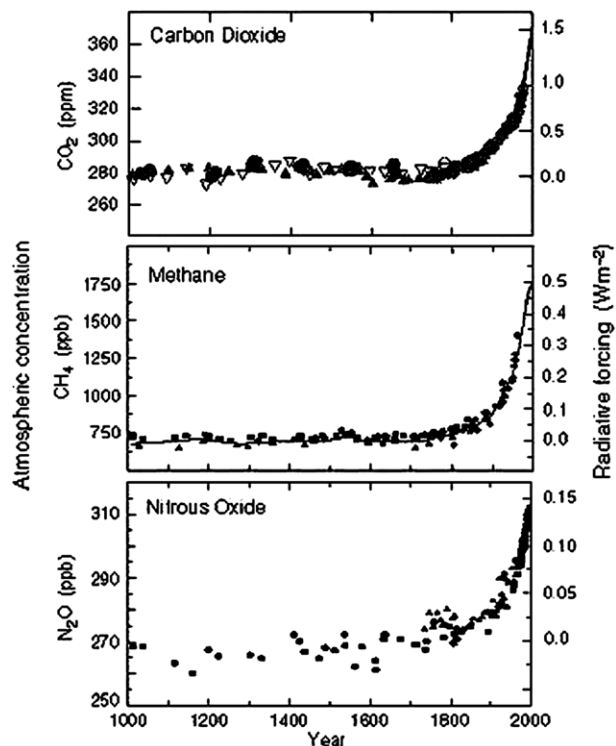


Fig. 2 Concentrations of major greenhouse gases retrieved from gas bubbles trapped in ice cores from Antarctica and Greenland.
Source: From Cambridge University Press (see Ref. 10).

Although we do not normally think of it as a radiative body, Earth—like all bodies with a nonzero temperature—emits electromagnetic radiation. For Earth’s temperature, most of this radiation is in the form of infrared light. In the absence of an atmosphere, all the radiation emitted by Earth would escape to space. The balance of incoming solar radiation and outgoing infrared radiation would result in a global-mean temperature for Earth of 255 K (−18°C/0°F). However, some molecules in Earth’s atmosphere absorb some of this outgoing infrared light, thereby increasing their temperature. These greenhouse gases in the atmosphere emit some energy back toward Earth, warming Earth’s surface. This natural greenhouse effect, which is present in the absence of human activities, raises the global-mean surface temperature from 255 K to a comfortable 288 K (or about 15°C/59°F).^[2]

Greenhouse gases that are present naturally in the atmosphere include water vapor (H₂O), carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and ozone (O₃). The most common greenhouse gas by quantity and the one exerting the greatest influence on the climate is water vapor; however, because water has a very short lifetime in the atmosphere (~1 week), any human perturbation will dissipate quickly. In most cases, the “greenhouse effect” or “climate change” refers not to this natural phenomenon but to additional, anthropogenic enhancements to the atmosphere’s capacity to trap heat. Much higher concentrations of CO₂, CH₄, and N₂O have been observed in the past century than were naturally present for the past 1000 years (Fig. 2) and likely much

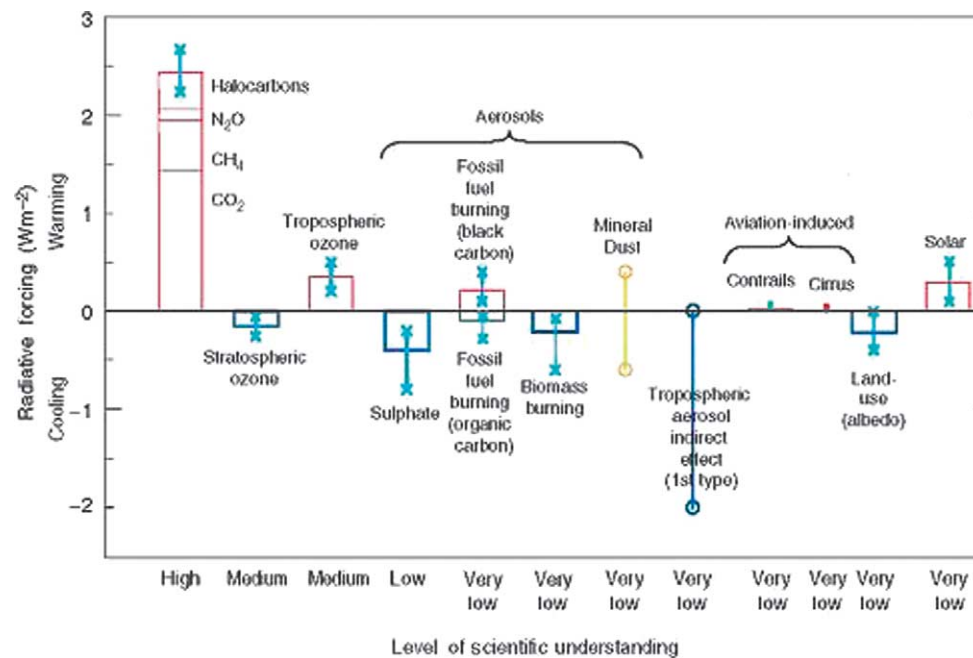


Fig. 3 Estimated radiative forcings since preindustrial times for Earth and the troposphere system. The height of the rectangular bar denotes a central or best estimate of the forcing, while each vertical line is an estimate of the uncertainty range associated with the forcing, guided by the spread in the published record and physical understanding, and with no statistical connotation. Each forcing agent is associated with a level of scientific understanding, which is based on an assessment of the nature of assumptions involved, the uncertainties prevailing about the processes that govern the forcing, and the resulting confidence in the numerical values of the estimate. On the vertical axis, the direction of expected surface temperature change due to each radiative forcing is indicated by the labels “warming” and “cooling.”

Source: From Cambridge University Press (see Ref. 10).

longer.^[3] Earth’s surface is warmer now on average than it was at any time during the past 400 years, and it is likely warmer now than it was at any time in the past 2000 years.^[4]

CLIMATE FORCINGS AND FEEDBACKS

Factors that affect climate change are usefully separated into forcings and feedbacks. Climate forcings are energy imbalances imposed on the climate system either externally or by human activities.^[5] Examples include human-caused emissions of greenhouse gases, as discussed in the preceding section, as well as changes in solar energy output; volcanic emissions; deliberate land modification; or anthropogenic emissions of aerosols, which can absorb and scatter radiation. Climate forcings can be either direct or indirect. Direct radiative forcings are simple changes to the drivers of Earth’s radiative balance. For example, added CO₂ absorbs and emits infrared radiation. Indirect radiative forcings create a radiative imbalance by first altering climate system components that lead to consequent changes in radiative fluxes; an example is the effect of aerosols on the precipitation efficiency of clouds. Fig. 3 provides a summary of the estimated contribution from major climate

forcings. Additional information about specific climate forcings is provided in the discussion below.

Climate feedbacks are internal climate processes that amplify or dampen the climate response to an initial forcing.^[6] An example is the increase in atmospheric water vapor that is triggered by an initial warming due to rising CO₂ concentrations, which then acts to amplify the warming through the greenhouse properties of water vapor (Fig. 4). Other climate feedbacks involve snow and ice cover, biogeochemistry, clouds, and ocean circulation. Some of the uncertainty about how the climate will change in the future stems from unresolved research questions on climate change feedbacks.

Natural Climate Forcings: Solar and Volcanic Variability

Variations in the sun’s activity and in Earth’s orbital parameters cause natural forcing of climate. Radiometers on various spacecraft have been measuring the total solar irradiance since the late 1970s. There is an 11-year cycle in total solar irradiance of peak-to-peak amplitude: ~1 W m⁻² (0.1%) in the past three cycles. Allowing for reflection of 30% of this incident energy (Earth’s albedo) and averaging over the globe, the corresponding climate forcing

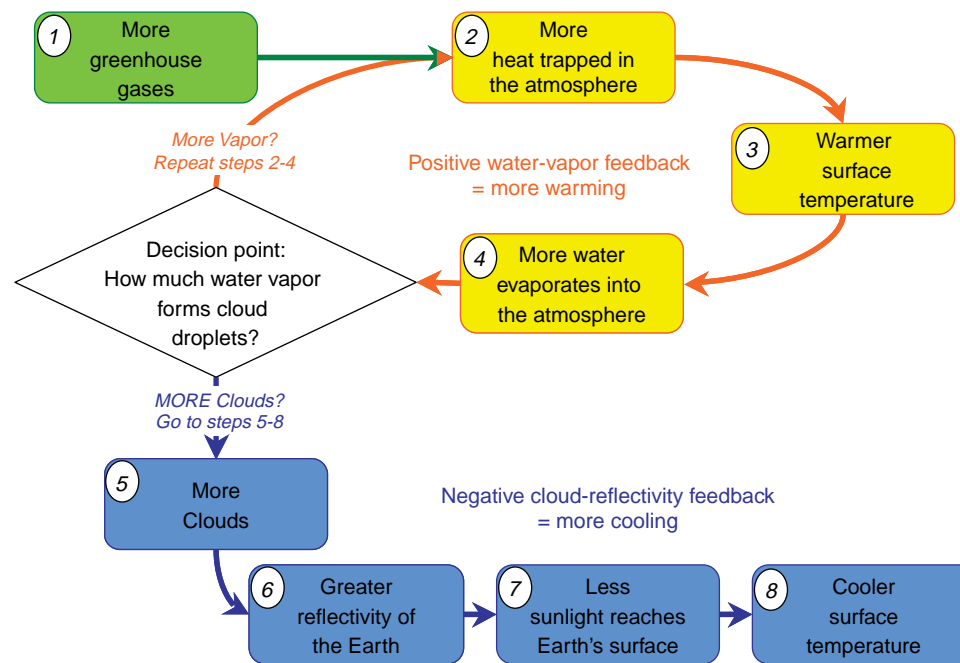


Fig. 4 This schematic illustrates just two out of the dozens of climate feedbacks identified by scientists. The warming created by emitting more greenhouse gases leads to evaporation of water into the atmosphere. But water itself is a greenhouse gas and can cause even more warming via positive water-vapor feedback. On the other hand, if the water vapor leads to more clouds, the result could be to counteract some of the warming because clouds can reflect incoming sunlight back to space. This chain of events is negative cloud-reflectivity feedback. Trying to understand whether water vapor will create more clouds and what kinds of clouds water vapor will create is a major research objective right now. The answer depends on weather patterns, where the evaporation takes place, and the amount of small soot particles suspended in the air.

is of order 0.2 W m^{-2} , although recent analyses have found little secular trend in solar irradiance over the past 30 years.^[7] Knowledge of solar irradiance variations prior to 1979 is less certain, as it relies upon models of how sunspot and facular influences relate to solar irradiance observed since then. These models are used to extrapolate variations back to about 1610, when telescopes were first used to monitor sunspots. The amount of energy Earth receives from the Sun also depends on Earth's distance from the Sun, which does not remain constant. The eccentricity of Earth's orbit (currently 0.0167) and the tilt of its axis relative to the orbital plane result in continual changes to the amount and distribution of energy Earth receives. In modern times, this variation is $\pm 3.5\%$ during the year, with maximum energy and minimum distance in January.

Volcanic forcing has been the dominant source of natural global radiative forcing over the past millennium. Emissions from volcanic eruptions have multiple effects on climate, as listed in Table 1.^[8] The greater prevalence of explosive volcanic activity during both the early and the late 20th century and the dearth of eruptions from 1915 to 1960 represent a significant natural radiative forcing of 20th-century climate.^[9] Similarly, the longer-term volcanic radiative forcing has been associated with a significant long-term forced cooling from 1000 to 1900, resulting

from a general increase in explosive volcanic activity in later centuries.

Greenhouse Gas Forcing

The role of greenhouse gases in the climate system is well understood by scientists because instruments can accurately measure the abundances of these gases in the atmosphere and their radiative properties. The concentrations of CO_2 , CH_4 , N_2O , various halocarbons, and O_3 have increased substantially since preindustrial times, and they are the greatest contributors to total anthropogenic radiative forcing.^[10] Many of these greenhouse gases are emitted primarily as a byproduct of fossil fuel combustion.

For a given gas, the total amount of heat-trapping ability depends on the efficiency of heat trapping for a given unit of gas (i.e., radiative forcing), the number of units present in the atmosphere, and the average length of time a given unit spends in the atmosphere. While these three components are enough to characterize a single gas, the large number of gases has prompted the development of an index called the global warming potential (GWP), which represents the relative impact of a particular greenhouse gas on the atmosphere's radiative balance.^[10] See Table 2 for some GWP calculations. As the standard

Table 1 Effects of large explosive volcanoes on weather and climate

Effect and mechanism	Begins	Duration
Reduction of diurnal cycle	Immediately	1–4 days
Blockage of shortwave and emission of longwave radiation		
Reduced tropical precipitation	1–3 months	3–6 months
Blockage of shortwave radiation, reduced evaporation		
Summer cooling of Northern Hemisphere tropics and subtropics	1–3 months	1–2 years
Blockage of shortwave radiation		
Reduced Sahel precipitation	1–3 months	1–2 years
Blockage of shortwave radiation, reduced land temperature, reduced evaporation		
Stratospheric warming	1–3 months	1–2 years
Stratospheric absorption of shortwave and longwave radiation		
Winter warming of Northern Hemisphere continents	6–18 months	1 or 2 winters
Stratospheric absorption of shortwave and longwave radiation, dynamics		
Global cooling	Immediately	1–3 years
Blockage of shortwave radiation		
Global cooling from multiple eruptions	Immediately	Up to decades
Blockage of shortwave radiation		
Ozone depletion, enhanced UV radiation	1 day	1–2 years
Dilution, heterogeneous chemistry on aerosols		

Source: From American Geophysical Union (see Ref. 8).

reference gas, CO₂ has a GWP of 1, by definition. Over a time horizon of 100 years, CH₄ and N₂O have GWPs of 23 and 296, respectively. In other words, 1 additional kg of CH₄ in the atmosphere absorbs as much radiation as 23 additional kg of CO₂. However, these numbers change if the time horizon shifts.^[10] By allowing greenhouse gases to be compared directly, GWPs enable policies that can reduce total climate impact by addressing the least-cost abatement options first.^[11,12]

Atmospheric Aerosol Forcing

Aerosols are small particles or liquid droplets suspended in the atmosphere. Aerosols both scatter and absorb radiation, representing a direct radiative forcing. Scattering generally dominates (except for black carbon particles) so that the net effect is of cooling. The average global mean of aerosol-direct forcing from fossil fuel combustion and biomass burning is in the range of -0.2 to -2.0 W m^{-2} .^[10] This large range results from uncertainties in aerosol sources, composition, and properties used in different models. Recent advances in modeling and measurements have provided important constraints on the direct effect of aerosols on radiation.^[13–15] Aerosols have several indirect effects on climate, all arising from their interaction with clouds—particularly from their roles as cloud condensation nuclei (CCN) and ice nuclei (Table 3).

Land-Use Change Forcing

Land-use changes include irrigation, urbanization, deforestation, desertification, reforestation, the grazing of domestic animals, and dryland farming. Each of these alterations in landscape produces changes in radiative forcing, both directly and indirectly.^[16,17] Direct effects include the change of albedo and emissivity resulting from the different types of land covers. For example, the development of agriculture in tropical regions typically results in an increase of albedo from a low value of forest canopies (0.05–0.15) to a higher value of agricultural fields, such as pasture (0.15–0.20). The Intergovernmental Panel on Climate Change (IPCC)^[10] reports the globally averaged forcing due to albedo change alone as $-0.25 \pm 0.25 \text{ W m}^{-2}$. Significant uncertainties remain in estimating the effect of land-use change on albedo because of the complexity of land surfaces (e.g., the type of vegetation, phenology, density of coverage, soil color).

Indirect effects of land-cover change on the net radiation include a variety of processes related to (1) the ability of the land cover to use the radiation absorbed at the ground surface for evaporation, transpiration, and sensible heat fluxes (the impact on these heat fluxes caused by changes in land cover is sometimes referred to as thermodynamic forcing); (2) the exchange of greenhouse and other trace gases between the surface and the atmosphere; (3) the emission of aerosols (e.g., from dust); and (4) the distribution and melting of snow and

Table 2 Radiative forcing characteristics of some major greenhouse gases

	Contribution to direct radiative forcing		Global warming potential (GWP) for different time horizons				
	W m ⁻²	%	Concentration in 1998	Lifetime (yrs)	10 yrs	100 yrs	500 yrs
Carbon dioxide (CO ₂)	1.46	60	365 ppm	5–200 ^a	1	1	1
Methane (CH ₄)	0.48	20	1745 ppb	12.0	62	23	7
Nitrous oxide (N ₂ O)	0.15	6	314 ppb	114	275	296	156
Halocarbons and related compounds	0.34	14	—	0.3–3200	40–15100	12–22200	4–16300

Total direct radiative forcing uncertainty is approximately 10%. The abbreviations parts per million (ppm) and parts per billion (ppb) refer to the ratio of greenhouse gas molecules to molecules of dry air.

^a No single lifetime can be defined for CO₂ because it is affected by multiple removal processes with different uptake rates.

Source: From Cambridge University Press (see Ref. 10).

ice.^[5] These effects are not yet well characterized or quantified.

EVIDENCE OF HUMAN-INDUCED CLIMATE CHANGE

Because we do not have a “control Earth” against which to compare the effects of our current changing atmosphere, incontrovertibly linking human activities and observed climate change is difficult. Scientists therefore rely on multiple, overlapping evidence of changes and then compare observed patterns of change with what our scientific understanding indicates should happen under anthropogenic climate change. This two-stage concept of discovering changes in climate and linking them to human activity is called detection and attribution. Evidence used to detect climate change is summarized in this section, and the use of climate models for attribution is discussed in the following section.

One piece of evidence of global warming is an increase in surface temperature since the 1900s, with particularly rapid increases since the late 1970s (Fig. 5). This dataset caused some controversy when researchers discovered that readings taken near the surface of Earth with thermometers appeared to be higher than readings of the lower atmosphere taken by satellites from above. Subsequent studies concluded that the warming trend in global-mean surface temperature observations during the past 30 years is undoubtedly real and is substantially greater than the average rate of warming during the 20th century.^[18] Satellite-and balloon-based observations of middle-troposphere temperatures, after several revisions of the data, now compare reasonably with one another and with observations from surface stations, although some uncertainties remain.^[19,20]

The ocean, which represents the largest reservoir of heat in the climate system, has warmed by about 0.118°C (0.212°F), averaged over the layer extending from the surface down to 700 m, from 1955 to 2003 (Fig. 6).^[21] Approximately 84% of the total heating of Earth’s system (oceans, atmosphere, continents, and cryosphere) over the past 40 years has gone into warming the oceans. Recent studies have shown that the observed heat storage in the oceans is what would be expected by a human-enhanced greenhouse effect. Indeed, increased ocean heat content accounts for most of the planetary energy imbalance (i.e., when Earth absorbs more energy from the Sun than it emits back to space) simulated by climate models.^[22]

Changes in several other climate indicators have been observed over the past decades, providing a growing body of evidence consistent with a human impact on the climate. For example, reductions in snow and ice cover are one important indicator.^[10] Satellite observations indicate that snow cover has decreased by about 10% since the 1960s, while spring and summer sea-ice extent in the

Table 3 Overview of the different aerosol indirect effects associated with clouds

Effect	Cloud type	Description	Sign of top of the atmosphere radiative forcing
First indirect aerosol effect (cloud albedo or Twomey effect)	All clouds	For the same cloud water or ice content more but smaller cloud particles reflect more solar radiation	Negative
Second indirect aerosol effect (cloud lifetime or Albrecht effect)	All clouds	Smaller cloud particles decrease the precipitation efficiency, thereby prolonging cloud lifetime	Negative
Semidirect effect	All clouds	Absorption of solar radiation by soot leads to evaporation of cloud particles	Positive
Glaciation indirect effect	Mixed-phase clouds	An increase in ice nuclei increases the precipitation efficiency	Positive
Thermodynamic effect	Mixed-phase clouds	Smaller cloud droplets inhibit freezing, causing super cooled droplets to extend to colder temperatures	Unknown
Surface energy budget effect	All clouds	The aerosol-induced increase in cloud optical thickness decreases the amount of solar radiation reaching the surface, changing the surface energy budget	Negative

Source: From National Academies Press (see Ref. 5).

Northern Hemisphere has decreased by about 10%–15% since the 1950s. The shrinking of mountain glaciers in many nonpolar regions has also been observed during the 20th century.

ATTRIBUTION OF OBSERVED CLIMATE CHANGE TO HUMAN INFLUENCE

An important question in global climate change is to what extent the observed changes are caused by the emissions of

greenhouse gases and other human activities. Climate models are used to study how the climate operates today, how it may have functioned differently in the past, and how it may evolve in response to forcings. Built using our best scientific knowledge of atmospheric, oceanic, terrestrial, and cryospheric processes, climate models and their components are extensively tested against the full suite of observations of current and past climate to verify that they simulate a realistic version of the climate. Discrepancies between models and observations provide indications that we need to improve understanding of

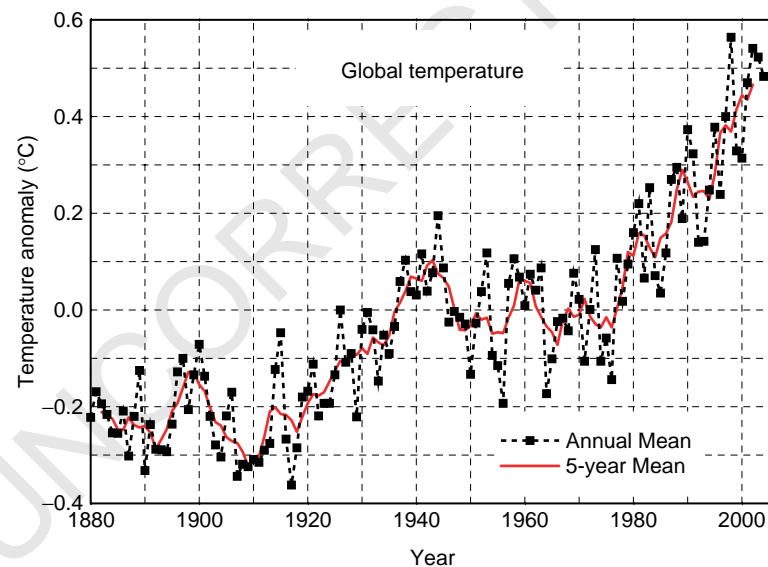


Fig. 5 Global annual-mean surface air temperature change derived from the meteorological station network. Data and plots are available from the Goddard Institute for Space Sciences (GISS) at <http://data.giss.nasa.gov/gistemp/graphs>.

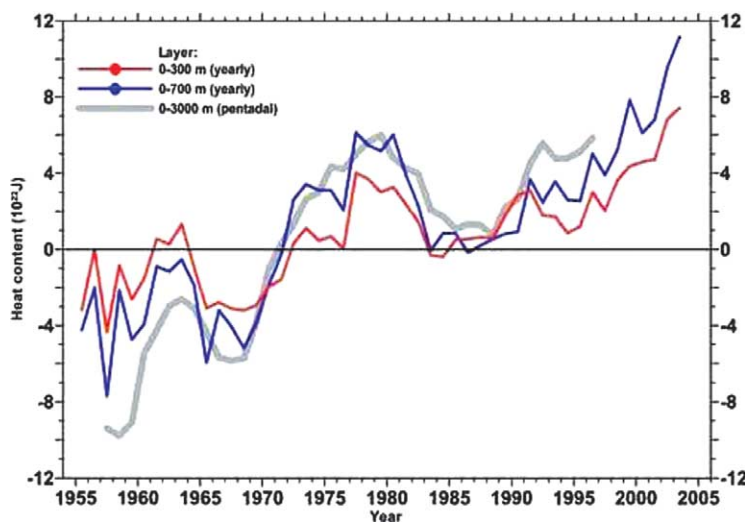


Fig. 6 Time series of (i) yearly ocean heat content (10^{22} J) for the 0–300 m and 0–700 m layers and (ii) 5-year running averages for 1955–1959 through 1994–1998 for the 0–3000 m layer. Source: From American Geophysical Union (see Ref. 21).

physical processes, model representations of the processes, or in some cases the observations themselves. Hence, climate models contain our accumulated wisdom about the underlying scientific processes and can be no better than our observations of the system and our understanding of the climate.

Fig. 7 shows how scientists have used climate models to make the case that human activities have perturbed the

climate since preindustrial times. In this experiment, the model is run with three different sets of climate forcings: (a) natural only, (b) anthropogenic only, and (c) natural and anthropogenic. When the natural or anthropogenic forcings are employed separately, the model is unable to reproduce the global-mean variation of temperature anomalies over the simulated time period. Only when both sets of forcings are used does the model capture the

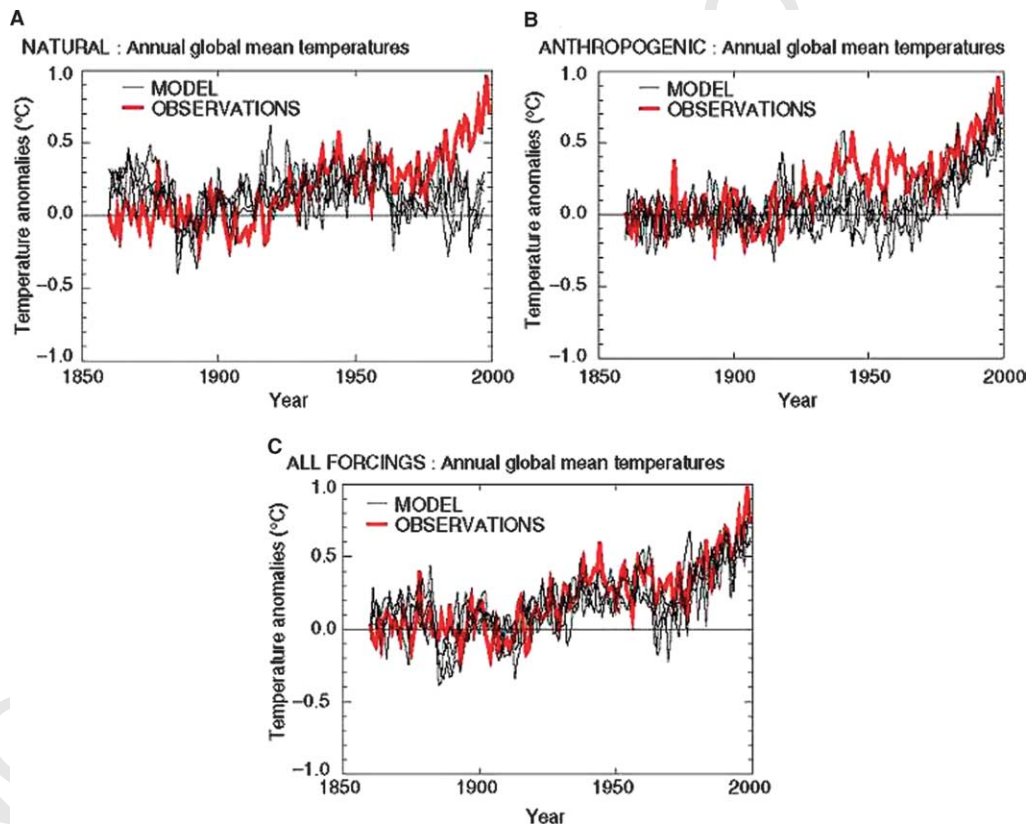


Fig. 7 Climate model results with (A) solar and volcanic forcings only; (B) anthropogenic forcings only; and (C) all forcings, both natural and anthropogenic. Source: From Cambridge University Press (see Ref. 10.).

nature of the variations, providing evidence that human activities have caused a significant fraction of warming in the past 150 years.^[10]

PROJECTIONS FOR FUTURE CLIMATE CHANGE

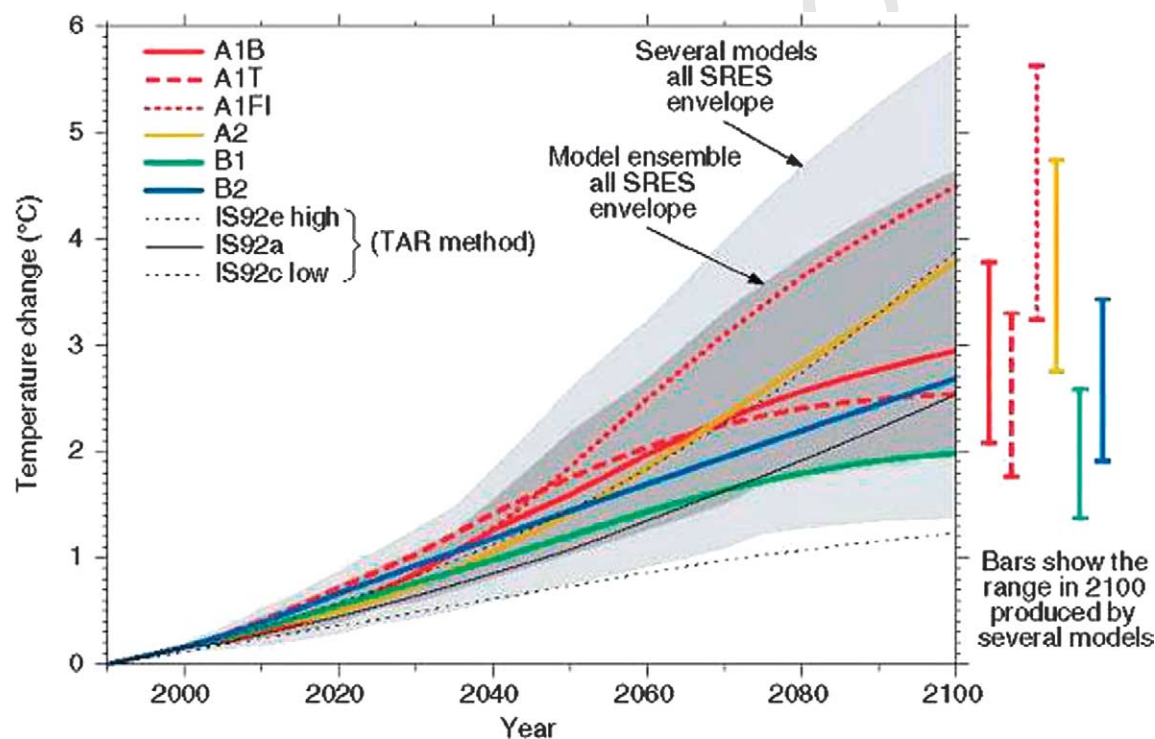
The IPCC has concluded that by 2100, global surface temperatures will likely be from 1.4 to 5.8°C (2.5°F–10.4°F) above 1990 levels (Fig. 8) and that the combined effects of ice melting and seawater expansion from ocean warming will cause the global-mean sea level to rise by between 0.1 and 0.9 m.^[10] Uncertainties remain about the magnitude and impacts of future climate change, largely due to gaps in understanding of climate science and the difficulty of predicting societal choices.

Climate changes in the coming century will not be uniformly distributed; some regions will experience more warming than others. There will be winners and losers from the impacts of climate change, even within a single region, but globally, the losses are expected to far outweigh the benefits. A changed climate will increase the likelihood of extreme heat and drought events.^[23] High

latitudes and polar regions are expected to see comparatively greater increases in average temperatures than lower latitudes, resulting in melting of permafrost and sea ice, which will result in additional costs for residents and in disruption to wildlife and ecosystems.^[24] Precipitation changes, which are of great importance to agriculture, may have even more regional variability that is hard to predict.

Finally, several elements of Earth's system seem to be vulnerable to rapid destabilization. For example, the West Antarctic ice sheet and the Greenland ice sheet may be more prone to rapid melting than previously thought, and the loss of either of these would result in a large sea-level rise greater than 5 m. Moreover, the stability of the oceanic circulation that brings heat to Northern Europe has also been questioned. Because of feedback processes and the large uncertainty in system sensitivity, these outcomes are not easy to model and are usually not included in the gradual climate change projections quoted above. Nevertheless, they are nontrivial threats and represent active areas of current research.

Unfortunately, the regions that will be most severely affected are often the regions that are the least able to adapt. Bangladesh, one of the poorest nations in the world,



Q2 Fig. 8 Climate models are often used to simulate possible future climates to help inform decisions about policy responses to potential climate changes. This figure shows the range of plausible global-mean temperature change over the next 100 years, simulated by a collection of models. The spread in 2100 temperatures from 1.4 to 5.8°C reflects two factors: (1) Each model was run multiple times using different scenarios (indicated by different colors) for future climate forcings, and (2) each model makes different assumptions about how the climate responds to those forcings. The scenarios range from those that assume continued acceleration of greenhouse gas emissions to those that assume more moderate growth or leveling off of emissions rates. SRES refers to the collection of scenarios presented in the Special Report on Emissions Scenarios. (Nac..., 1999) TAR refers to the IPCC Third Assessment Report. Source: From Cambridge University Press (see Ref. 10).

is projected to lose 17.5% of its land if sea level rises about 1 m (40 in.), displacing tens of thousands of people.^[10] Several islands throughout the South Pacific and Indian Oceans will be at similar risk for increased flooding and vulnerability to storm surges. Although wetland and coastal areas of many developed nations—including the United States—are also threatened, wealthy countries may be more able to adapt to sea-level rise and threats to agriculture. Solutions could include building, limiting or changing construction codes in coastal zones, and developing new agricultural technologies.

CONCLUSION

Research conducted to understand how the climate system may be changing—and in turn affecting other natural systems and human society—has led to significant advancement in scientific understanding, but many questions remain. Society faces increasing pressure to decide how best to respond to a changing climate and associated global and regional changes.

One way to address global climate change is to take steps to reduce the amount of greenhouse gases in the atmosphere. Because CO₂ and other greenhouse gases can remain in the atmosphere for many decades, the climate-change impacts from concentrations today will likely continue throughout the 21st century and beyond. Failure to implement significant reductions in net greenhouse gas emissions now will make the job much harder in the future—both in terms of stabilizing CO₂ concentrations and in terms of experiencing more significant impacts. While no single solution can eliminate all future warming, many potentially cost-effective technological options could contribute to stabilizing greenhouse gas concentrations. These options range from personal choices such as driving less to national choices such as regulating emissions or seeking technologies to remove greenhouse gases from the atmosphere to international choices such as sharing energy technologies.

At the same time, it will be necessary to seek ways to adapt to the potential impacts of climate change. Climate is becoming increasingly important to public and private decision-making in various fields such as emergency management, water-quality assurance, insurance, irrigation and power production, and construction. For example, developing practical, “no regrets” strategies that could be used to reduce economic and ecological systems’ vulnerabilities to change could provide benefits whether a significant climate change ultimately occurs or not. No-regrets measures could include low-cost steps to improve climate forecasting; to slow biodiversity loss; to improve water, land, and air quality; and to make institutions—such as the health care enterprise, financial markets, and transportation systems—more resilient to major disruptions.

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Author Queries

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Q1 Please provide better quality for figures 2,3,6,7 and 8.

Q2 Please check the edit of the sentence.

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