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Climate Change The Biggest Science Fraud In Our Life Time
By Al Whore

Global warming and now the PC term climate change since global warming has be proven as a fraud is nothing more than a political front to cramdown enviornmental policies that will bankrupt America along with illegal immigration.

Climate change is any long-term significant change in the expected patterns of average weather of a specific region (or, more relevantly to contemporary socio-political concerns, of the Earth as a whole) over an appropriately significant period of time. Climate change reflects abnormal variations to the expected climate within the Earth's atmosphere and subsequent effects on other parts of the Earth, such as in the ice caps over durations ranging from decades to millions of years.

U.S. President George W. Bush promoted improved energy technology as a means to combat climate change,[101] while various state and city governments within the United States have begun their own initiatives to indicate support and compliance with the Kyoto Protocol on a local basis, such as the Regional Greenhouse Gas Initiative.[102]

The IPCC's Working Group III is responsible for crafting reports that deal with the mitigation of global warming and analyzing the costs and benefits of different approaches. In the 2007 IPCC Fourth Assessment Report, they conclude that no one technology or sector can be completely responsible for mitigating future warming. They find there are key practices and technologies in various sectors, such as energy supply, transportation, industry, and agriculture, that should be implemented to reduced global emissions. They estimate that stabilization of carbon dioxide equivalent between 445 and 710 ppm by 2030 will result in between a 0.6 percent increase and three percent decrease in global gross domestic product.[103] According to Working Group III, to limit temperature rise to 2 degrees Celsius, "developed countries as a group would need to reduce their emissions to below 1990 levels in 2020 (on the order of -10 percent to 40 percent below 1990 levels for most of the considered regimes) and to still lower levels by 2050 (40 percent (Sic. 80 percent in Box 13.7, p776) to 95 percent below 1990 levels), even if developing countries make substantial reductions." [104]

In recent usage, especially in the context of environmental policy, climate change usually refers to changes in modern climate (see global warming). For information on temperature measurements over various periods, and the data sources available, see temperature record. For attribution of climate change over the past century, see attribution of recent climate change.

Global warming is the increase in the average temperature of the Earth's near-surface air and the oceans since the mid-twentieth century and its projected continuation. Global surface temperature increased 0.74 ± 0.18 °C (1.33 ± 0.32 °F) during the 100 years ending in 2005.[1][A] The Intergovernmental Panel on Climate Change (IPCC) concludes that anthropogenic greenhouse gases are responsible for most of the observed temperature increase since the middle of the twentieth century,[1] and natural phenomena such as solar variation and

volcanoes probably had a small warming effect from pre-industrial times to 1950 and a small cooling effect from 1950 onward.[2][3] These basic conclusions have been endorsed by 30 scientific societies and academies of science,[B] including all of the national academies of science of the major industrialized countries.[4][5]

Climate model projections summarized in the latest IPCC report indicate that global surface temperature will likely rise a further 1.1 to 6.4 °C (2.0 to 11.5 °F) during the twenty-first century.[1] The uncertainty in this estimate arises from the use of models with differing climate sensitivity, and the use of differing estimates of future greenhouse gas emissions. Some other uncertainties include how warming and related changes will vary from region to region around the globe. Although most studies focus on the period up to 2100, warming is expected to continue beyond 2100, even if emissions have stopped, because of the large heat capacity of the oceans and the lifespan of CO₂ in the atmosphere.[6][7]

Increasing global temperature will cause sea levels to rise and will change the amount and pattern of precipitation, likely including an expanse of the subtropical desert regions.[8] Other likely effects include Arctic shrinkage and resulting Arctic methane release, shrinkage of the Amazon rainforest, increases in the intensity of extreme weather events, changes in agricultural yields, modifications of trade routes, glacier retreat, species extinctions and changes in the ranges of disease vectors.

Political and public debate continues regarding the appropriate response to global warming. The available options are mitigation to reduce further emissions; adaptation to reduce the damage caused by warming; and, more speculatively, geoengineering to reverse global warming. Most national governments have signed and ratified the Kyoto Protocol aimed at reducing greenhouse gas emissions.

The causes of the recent warming are an active field of research. The scientific consensus[9][10] is that the increase in atmospheric greenhouse gases due to human activity has caused most of the warming observed since the start of the industrial era, and the observed warming cannot be satisfactorily explained by natural causes alone.[11] This attribution is clearest for the most recent 50 years, which is the period when most of the increase in greenhouse gas concentrations took place and for which the most complete measurements exist.

The greenhouse effect was discovered by Joseph Fourier in 1824[12] and first investigated quantitatively by Svante Arrhenius in 1896. It is the process by which absorption and emission of infrared radiation by atmospheric gases warm a planet's lower atmosphere and surface. Existence of the greenhouse effect as such is not disputed. The question is instead how the strength of the greenhouse effect changes when human activity increases the atmospheric concentrations of particular greenhouse gases.

Recent increases in atmospheric carbon dioxide (CO₂). The monthly CO₂ measurements display small seasonal oscillations in an overall yearly uptrend; each year's maximum is reached during the Northern Hemisphere's late spring, and declines during the Northern Hemisphere growing season as plants remove some CO₂ from the atmosphere. Naturally occurring greenhouse gases have a mean warming effect of about 33 °C (59 °F), without which Earth would be uninhabitable.[13][C] On Earth the major greenhouse gases are water vapor, which causes about 36–70 percent of the greenhouse effect (not including clouds);

carbon dioxide (CO₂), which causes 9-26 percent; methane (CH₄), which causes 4-9 percent; and ozone, which causes 3-7 percent.[14][15]

Human activity since the industrial revolution has increased the atmospheric concentration of various greenhouse gases, leading to increased radiative forcing from CO₂, methane, tropospheric ozone, CFCs and nitrous oxide. The atmospheric concentrations of CO₂ and methane have increased by 36% and 148% respectively since the beginning of the industrial revolution in the mid-1700s.[16] These levels are considerably higher than at any time during the last 650,000 years, the period for which reliable data has been extracted from ice cores.[17] Less direct geological evidence indicates that CO₂ values this high were last seen approximately 20 million years ago.[18] Fossil fuel burning has produced approximately three-quarters of the increase in CO₂ from human activity over the past 20 years. Most of the rest is due to land-use change, in particular deforestation.[19]

CO₂ concentrations are expected to continue to rise due to ongoing burning of fossil fuels and land-use change. The rate of rise will depend on uncertain economic, sociological, technological, and natural developments. The IPCC Special Report on Emissions Scenarios gives a wide range of future CO₂ scenarios, ranging from 541 to 970 ppm by the year 2100.[20] Fossil fuel reserves are sufficient to reach this level and continue emissions past 2100 if coal, tar sands or methane clathrates are extensively exploited.[21]

Forcing and feedback

Components of the current radiative forcing as estimated by the IPCC Fourth Assessment Report. The Earth's climate changes in response to external forcings, including those related to greenhouse gases, variations in its orbit around the Sun (orbital forcing),[22][23][24] changes in solar luminosity, and volcanic eruptions[25] which are all examples of the Earth's own variation in temperatures, for which the UNFCCC uses the term climate variability. There are also positive and negative feedbacks which determine how the climate will respond to external forcing.

None of the effects of forcing are instantaneous. The thermal inertia of the Earth's oceans and slow responses of other indirect effects mean that the Earth's current climate is not in equilibrium with the forcing imposed. Climate commitment studies indicate that even if greenhouse gases were stabilized at 2000 levels, a further warming of about 0.5 °C (0.9 °F) would still occur.[26]

Solar variation

Main article: Solar variation

One alternative hypothesis to the consensus view that anthropogenic forcing has caused most of the recent temperature increase is that recent warming may be the result of variations in solar activity.[27][28][29]

A paper by Peter Stott and colleagues suggests that climate models overestimate the relative effect of greenhouse gases compared to solar forcing; they also suggest that the cooling effects of volcanic dust and sulfate aerosols have been underestimated.[30] They nevertheless conclude that even with an enhanced climate sensitivity to solar forcing, most of the warming since the mid-20th century is likely attributable to the increases in greenhouse gases. Another paper suggests that the Sun may have contributed about 45-50 percent of the

increase in the average global surface temperature over the period 1900–2000, and about 25–35 percent between 1980 and 2000.[31]

Solar variation over the last thirty years. A different hypothesis is that variations in solar output, possibly amplified by cloud seeding via galactic cosmic rays, may have contributed to recent warming.[32] It suggests magnetic activity of the sun is a crucial factor which deflects cosmic rays that may influence the generation of cloud condensation nuclei and thereby affect the climate.[33]

One predicted effect of an increase in solar activity would be a warming of most of the stratosphere, whereas an increase in greenhouse gases should produce cooling there.[34] The observed trend since at least 1960 has been a cooling of the lower stratosphere.[35] Reduction of stratospheric ozone also has a cooling influence, but substantial ozone depletion did not occur until the late 1970s.[36] Solar variation combined with changes in volcanic activity probably did have a warming effect from pre-industrial times to 1950, but a cooling effect since.[1] In 2006, Peter Foukal and colleagues found no net increase of solar brightness over the last 1,000 years. Solar cycles led to a small increase of 0.07 percent in brightness over the last 30 years. This effect is too small to contribute significantly to global warming.[37][38] One paper by Mike Lockwood and Claus Fröhlich found no relation between global warming and solar radiation since 1985, whether through variations in solar output or variations in cosmic rays.[39] Henrik Svensmark and Eigil Friis-Christensen, the main proponents of cloud seeding by galactic cosmic rays, disputed this criticism of their hypothesis.[40] A 2007 paper found that in the last 20 years there has been no significant link between changes in cosmic rays coming to Earth and cloudiness and temperature.[41][42]

Feedback

Main article: Effects of global warming

When a warming trend results in effects that induce further warming, the process is referred to as a positive feedback; when the effects induce cooling, the process is referred to as a negative feedback. The primary positive feedback involves water vapor. The primary negative feedback is the effect of temperature on emission of infrared radiation: as the temperature of a body increases, the emitted radiation increases with the fourth power of its absolute temperature.[43] This provides a powerful negative feedback which stabilizes the climate system over time.

One of the most pronounced positive feedback effects relates to the evaporation of water. If the atmosphere is warmed, the saturation vapour pressure increases, and the quantity of water vapor in the atmosphere will tend to increase. Since water vapor is a greenhouse gas, the increase in water vapor content makes the atmosphere warm further; this warming causes the atmosphere to hold still more water vapor (a positive feedback), and so on until other processes stop the feedback loop. The result is a much larger greenhouse effect than that due to CO₂ alone. Although this feedback process causes an increase in the absolute moisture content of the air, the relative humidity stays nearly constant or even decreases slightly because the air is warmer.[44]

Feedback effects due to clouds are an area of ongoing research. Seen from below, clouds emit infrared radiation back to the surface, and so exert a warming effect; seen from above, clouds reflect sunlight and emit infrared radiation to space, and so exert a cooling effect. Whether the net effect is warming or

cooling depends on details such as the type and altitude of the cloud, details that have been difficult to represent in climate models.[44]

A subtler feedback process relates to changes in the lapse rate as the atmosphere warms. The atmosphere's temperature decreases with height in the troposphere. Since emission of infrared radiation varies with the fourth power of temperature, longwave radiation emitted from the upper atmosphere is less than that emitted from the lower atmosphere. Most of the radiation emitted from the upper atmosphere escapes to space, while most of the radiation emitted from the lower atmosphere is re-absorbed by the surface or the atmosphere. Thus, the strength of the greenhouse effect depends on the atmosphere's rate of temperature decrease with height: if the rate of temperature decrease is greater the greenhouse effect will be stronger, and if the rate of temperature decrease is smaller then the greenhouse effect will be weaker. Both theory and climate models indicate that with increased greenhouse gas content the rate of temperature decrease with height will be reduced, producing a negative lapse rate feedback that weakens the greenhouse effect. Measurements of the rate of temperature change with height are very sensitive to small errors in observations, making it difficult to establish whether the models agree with observations.[45]

Aerial photograph showing a section of sea ice. The lighter blue areas are melt ponds and the darkest areas are open water, both have a lower albedo than the white sea ice. The melting ice contributes to the ice-albedo feedback. Another important feedback process is ice-albedo feedback.[46] When global temperatures increase, ice near the poles melts at an increasing rate. As the ice melts, land or open water takes its place. Both 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. Rapid Arctic shrinkage is already occurring, with 2007 being the lowest ever recorded sea ice area.

Warming is also the triggering variable for the release of methane from sources both on land and on the deep ocean floor, making both of these possible feedback effects. Thawing permafrost, such as the frozen peat bogs in Siberia, creates a positive feedback due to release of CO₂ and CH₄. [47] Methane discharge from permafrost is presently under intensive study. Warmer deep ocean temperatures, likewise, could release the greenhouse gas methane from the 'frozen' state of the vast deep ocean deposits of methane clathrate/methane hydrate, according to the Clathrate Gun Hypothesis,

Ocean ecosystems' ability to sequester carbon are expected to decline as it warms. This is because the resulting low nutrient levels of the mesopelagic zone (about 200 to 1000 m depth) limits the growth of diatoms in favor of smaller phytoplankton that are poorer biological pumps of carbon.[48]

Temperature changes

Main article: Temperature record

Recent

Two millennia of mean surface temperatures according to different reconstructions, each smoothed on a decadal scale. The unsmoothed, annual value for 2004 is also plotted for reference. Global temperatures have increased by 0.75 °C (1.35 °F) relative to the period 1860–1900, according to the

instrumental temperature record. This measured temperature increase is not significantly affected by the urban heat island effect.[49] Since 1979, land temperatures have increased about twice as fast as ocean temperatures (0.25 °C per decade against 0.13 °C per decade).[50] Temperatures in the lower troposphere have increased between 0.12 and 0.22 °C (0.22 and 0.4 °F) per decade since 1979, according to satellite temperature measurements. Temperature is believed to have been relatively stable over the one or two thousand years before 1850, with possibly regional fluctuations such as the Medieval Warm Period or the Little Ice Age.[citation needed]

Sea temperatures increase more slowly than those on land both because of the larger effective heat capacity of the oceans and because the ocean can lose heat by evaporation more readily than the land.[51] The Northern Hemisphere has more land than the Southern Hemisphere, so it warms faster. The Northern Hemisphere also has extensive areas of seasonal snow and sea-ice cover subject to the ice-albedo feedback. More greenhouse gases are emitted in the Northern than Southern Hemisphere, but this does not contribute to the difference in warming because the major greenhouse gases persist long enough to mix between hemispheres.[52]

Based on estimates by NASA's Goddard Institute for Space Studies, 2005 was the warmest year since reliable, widespread instrumental measurements became available in the late 1800s, exceeding the previous record set in 1998 by a few hundredths of a degree.[53] Estimates prepared by the World Meteorological Organization and the Climatic Research Unit concluded that 2005 was the second warmest year, behind 1998.[54][55] Temperatures in 1998 were unusually warm because the strongest El Niño-Southern Oscillation in the past century occurred during that year.[56]

Anthropogenic emissions of other pollutants—notably sulfate aerosols—can exert a cooling effect by increasing the reflection of incoming sunlight. This partially accounts for the cooling seen in the temperature record in the middle of the twentieth century,[57] though the cooling may also be due in part to natural variability. James Hansen and colleagues have proposed that the effects of the products of fossil fuel combustion—CO₂ and aerosols—have, for the short term, largely offset one another, so that net warming in recent decades has been driven mainly by non-CO₂ greenhouse gases.[58]

Paleoclimatologist William Ruddiman has argued that human influence on the global climate began around 8,000 years ago with the start of forest clearing to provide land for agriculture and 5,000 years ago with the start of Asian rice irrigation.[59][60] Ruddiman's interpretation of the historical record, with respect to the methane data, has been disputed.[61]

Pre-human climate variations

Further information: Paleoclimatology

See also: Snowball Earth and Paleocene-Eocene thermal maximum

Curves of reconstructed temperature at two locations in Antarctica and a global record of variations in glacial ice volume. Today's date is on the left side of the graph. Earth has experienced warming and cooling many times in the past. The recent Antarctic EPICA ice core spans 800,000 years, including eight glacial cycles timed by orbital variations with interglacial warm periods comparable to present temperatures.[62]

A rapid buildup of greenhouse gases amplified warming in the early Jurassic period (about 180 million years ago), with average temperatures rising by 5 °C

(9 °F). Research by the Open University indicates that the warming caused the rate of rock weathering to increase by 400%. As such weathering locks away carbon in calcite and dolomite, CO₂ levels dropped back to normal over roughly the next 150,000 years.[63]

Sudden releases of methane from clathrate compounds (the clathrate gun hypothesis) have been hypothesized as both a cause for and an effect of other warming events in the distant past, including the Permian-Triassic extinction event (about 251 million years ago) and the Paleocene-Eocene Thermal Maximum (about 55 million years ago).

Related climatic issues

Main articles: Ocean acidification, global cooling, global dimming, and ozone depletion

A variety of issues are often raised in relation to global warming. One is ocean acidification. Increased atmospheric CO₂ increases the amount of CO₂ dissolved in the oceans.[124] CO₂ dissolved in the ocean reacts with water to form carbonic acid, resulting in acidification. Ocean surface pH is estimated to have decreased from 8.25 near the beginning of the industrial era to 8.14 by 2004,[125] and is projected to decrease by a further 0.14 to 0.5 units by 2100 as the ocean absorbs more CO₂. [1][126] Since organisms and ecosystems are adapted to a narrow range of pH, this raises extinction concerns, directly driven by increased atmospheric CO₂, that could disrupt food webs and impact human societies that depend on marine ecosystem services.[127]

Global dimming, the gradual reduction in the amount of global direct irradiance at the Earth's surface, may have partially mitigated global warming in the late 20th century. From 1960 to 1990 human-caused aerosols likely precipitated this effect. Scientists have stated with 66-90% confidence that the effects of human-caused aerosols, along with volcanic activity, have offset some of the global warming, and that greenhouse gases would have resulted in more warming than observed if not for these dimming agents.[1]

Ozone depletion, the steady decline in the total amount of ozone in Earth's stratosphere, is frequently cited in relation to global warming. Although there are areas of linkage, the relationship between the two is not strong.

Climate models

Main article: Global climate model

Calculations of global warming prepared in or before 2001 from a range of climate models under the SRES A2 emissions scenario, which assumes no action is taken to reduce emissions.

The geographic distribution of surface warming during the 21st century calculated by the HadCM3 climate model if a business as usual scenario is assumed for economic growth and greenhouse gas emissions. In this figure, the globally averaged warming corresponds to 3.0 °C (5.4 °F). Scientists have studied global warming with computer models of the climate. These models are based on physical principles including fluid dynamics and radiative transfer and are designed to be simplifications of the actual climate system. All modern climate models include an atmospheric model that is coupled to an ocean model and models for ice cover on land and sea. Some models also include treatments of chemical and biological processes.[64] These models project a warmer climate due to

increasing levels of greenhouse gases.[65] Although a large amount of the variation in model outcomes depends on the greenhouse gas emissions used as inputs, the temperature effect of a specific greenhouse gas concentration (climate sensitivity) varies depending on the model used.

Global climate model projections of future climate depend on estimates of greenhouse gas emissions, most often those from the IPCC Special Report on Emissions Scenarios (SRES). In addition to human-caused emissions, some models also include a simulation of the carbon cycle; this generally shows a positive feedback, though this response is uncertain. Some observational studies also show a positive feedback.[66][67][68] The representation of clouds is one of the main sources of uncertainty in present-generation models, though progress is being made on this problem.[69]

Including uncertainties in future greenhouse gas concentrations and climate sensitivity, the IPCC anticipates a warming of 1.1 °C to 6.4 °C (2.0 °F to 11.5 °F) by the end of the 21st century, relative to 1980–1999.[1] A 2008 paper predicts that the global temperature will not increase during the next decade because of short-term natural climate cycles.[70]

Models are also used to help investigate the causes of recent climate change by comparing the observed changes to those that the models project from various natural and human-derived causes. Although these models do not unambiguously attribute the warming that occurred from approximately 1910 to 1945 to either natural variation or human effects, they do suggest that the warming since 1975 is dominated by man-made greenhouse gas emissions.

Current climate models produce a good match to observations of global temperature changes over the last century, but do not simulate all aspects of climate.[71] Comparing model predictions with current climate is a good way to test the predictive power of models. While a 2007 study by David Douglass and colleagues found that the models did not accurately predict observed changes in the tropical troposphere,[72] a 2008 paper published by a 17-member team led by Ben Santer noted errors in the Douglass study, and found instead that the models and observations were not statistically different.[73]

Attributed and expected effects

Environmental

Main article: Effects of global warming

Sparse records indicate that glaciers have been retreating since the early 1800s. In the 1950s measurements began that allow the monitoring of glacial mass balance, reported to the WGMS and the NSIDC. Although it is difficult to connect specific weather events to global warming, an increase in global temperatures may in turn cause broader changes, including glacial retreat, Arctic shrinkage, 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. These changes are not likely to be reversible on timescales shorter than a thousand years.[74] Other effects may include changes in agricultural yields, addition of new trade routes,[75] reduced summer streamflows, species extinctions,[76] 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. A 2001 report by the IPCC

suggests that glacier retreat, ice shelf disruption such as that of the Larsen Ice Shelf, sea level rise, changes in rainfall patterns, and increased intensity and frequency of extreme weather events are attributable in part to global warming.[77] Other expected effects include water scarcity in some regions and increased precipitation in others, changes in mountain snowpack, and adverse health effects from warmer temperatures.[78]

Social and economic effects of global warming may be exacerbated by growing population densities in affected areas. Temperate regions are projected to experience some benefits, such as fewer deaths due to cold exposure.[79] A summary of probable effects and recent understanding can be found in the report made for the IPCC Third Assessment Report by Working Group II.[77] The newer IPCC Fourth Assessment Report summary reports that there is observational evidence for an increase in intense tropical cyclone activity in the North Atlantic Ocean since about 1970, in correlation with the increase in sea surface temperature (see Atlantic Multidecadal Oscillation), but that the detection of long-term trends is complicated by the quality of records prior to routine satellite observations. The summary also states that there is no clear trend in the annual worldwide number of tropical cyclones.[1]

Additional anticipated effects include sea level rise of 0.18 to 0.59 meters (0.59 to 1.9 ft) in 2090-2100 relative to 1980-1999, [1] repercussions to agriculture, possible slowing of the thermohaline circulation, reductions in the ozone layer, increasingly intense (but less frequent)[80] hurricanes and extreme weather events, lowering of ocean pH, oxygen depletion in the oceans,[81] and the spread of diseases such as malaria and dengue fever,[82][83] as well as Lyme disease, hantavirus infections, bubonic plague, and cholera.[84] One study predicts 18% to 35% of a sample of 1,103 animal and plant species would be extinct by 2050, based on future climate projections.[85] However, few mechanistic studies have documented extinctions due to recent climate change[86] and one study suggests that projected rates of extinction are uncertain.[87]

Economic

Main articles: Economics of global warming and Low-carbon economy

The projected temperature increase for a range of stabilization scenarios (the colored bands). The black line in middle of the shaded area indicates 'best estimates'; the red and the blue lines the likely limits. From the work of IPCC AR4. Some economists have tried to estimate the aggregate net economic costs of damages from climate change across the globe. Such estimates have so far yielded no conclusive findings; in a survey of 100 estimates, the values ran from US\$-10 per tonne of carbon (tC) (US\$-3 per tonne of carbon dioxide) up to US\$350/tC (US\$95 per tonne of carbon dioxide), with a mean of US\$43 per tonne of carbon (US\$12 per tonne of carbon dioxide).[79]

One widely publicized report on potential economic impact is the Stern Review. It suggests that extreme weather might reduce global gross domestic product by up to one percent, and that in a worst-case scenario global per capita consumption could fall 20 percent.[88] The report's methodology, advocacy and conclusions have been criticized by many economists, primarily around the Review's assumptions of discounting and its choices of scenarios.[89] Others have supported the general attempt to quantify economic risk, even if not the specific numbers.[90][91]

Preliminary studies suggest that costs and benefits of mitigating global warming are broadly comparable in magnitude.[92]

According to United Nations Environment Programme (UNEP), economic sectors likely to face difficulties related to climate change include banks, agriculture, transport and others.[93] Developing countries dependent upon agriculture will be particularly harmed by global warming.[94]

Adaptation and mitigation

Main articles: Adaptation to global warming, Mitigation of global warming, Kyoto Protocol, and Geoengineering

The broad agreement among climate scientists that global temperatures will continue to increase has led some nations, states, corporations and individuals to implement responses. These responses to global warming divide broadly between adapting to the effects of global warming and reducing or even reversing global warming itself. The latter is referred to as mitigation and includes emission reduction, carbon sequestration, and certain geoengineering techniques which seek to directly remove greenhouse gases from the atmosphere.

The slow pace of action to reduce greenhouse gas emissions have led some scientists, such as Ken Caldeira and the Nobel Prize winning Paul Crutzen[95] to suggest geoengineering techniques. Geoengineering can be divided into mitigation techniques which remove greenhouse gases (e.g. carbon dioxide air capture), and adaptation techniques (e.g. the creation of stratospheric sulfur aerosols).

Mitigation

Many environmental groups encourage individual action against global warming, often by the consumer, but also by community and regional organizations. Others have suggested a quota on worldwide fossil fuel production, citing a direct link between fossil fuel production and CO2 emissions.[96][97]

There has also been business action on climate change, including efforts at increased energy efficiency and limited moves towards use of alternative fuels. In January 2005 the European Union introduced its European Union Emission Trading Scheme, a greenhouse gas emissions trading scheme through which companies, in conjunction with government, agree to cap their emissions or to purchase credits from those below their allowances. Australia announced its Carbon Pollution Reduction Scheme in 2008. United States President Barack Obama has announced he will introduce an economy wide cap and trade scheme.[98]

The world's primary international agreement on combating global warming is the Kyoto Protocol, an amendment to the UNFCCC negotiated in 1997. The Protocol now covers more than 160 countries globally and over 55 percent of global greenhouse gas emissions.[99] Only the United States and Kazakhstan have not ratified the treaty, with the United States historically being the world's largest emitter of greenhouse gas. This treaty expires in 2012, and international talks began in May 2007 on a future treaty to succeed the current one.[100]

Economic and political debate

Main articles: Global warming controversy, Politics of global warming, and Economics of global warming

See also: Scientific opinion on climate change, Climate change denial, List of countries by greenhouse gas emissions per capita, List of countries by carbon dioxide emissions per capita, List of countries by carbon dioxide emissions, and List of countries by ratio of GDP to carbon dioxide emissions

Per capita greenhouse gas emissions in 2000, including land-use change.

Per country greenhouse gas emissions in 2000, including land-use change. Increased publicity of the scientific findings surrounding global warming has resulted in political and economic debate.[105] Poor regions, particularly Africa, appear at greatest risk from the projected effects of global warming, while their emissions have been small compared to the developed world.[106] At the same time, developing country exemptions from provisions of the Kyoto Protocol have been criticized by the United States and Australia, and used as part of a rationale for continued non-ratification by the U.S.[107] In the Western world, the idea of human influence on climate has gained wider public acceptance in Europe than in the United States.[108][109]

The issue of climate change has sparked debate weighing the benefits of limiting industrial emissions of greenhouse gases against the costs that such changes would entail. There has been discussion in several countries about the cost and benefits of adopting alternative energy sources in order to reduce carbon emissions.[110] Business-centered organizations, conservative commentators, and companies such as the Competitive Enterprise Institute and ExxonMobil have downplayed IPCC climate change scenarios, funded scientists who disagree with the scientific consensus, and provided their own projections of the economic cost of stricter controls.[111][112][113][114] Likewise, environmental organizations and a number of public figures have emphasized the potential risks of climate change and promote the implementation of GHG emissions reduction measures. Some fossil fuel companies have scaled back their efforts in recent years,[115] or called for policies to reduce global warming.[116]

Another point of contention is the degree to which emerging economies such as India and China should be expected to constrain their emissions. According to recent reports, China's gross national CO₂ emissions may now exceed those of the U.S.[117][118][119][120] China has contended that it has less of an obligation to reduce emissions since its per capita emissions are roughly one-fifth that of the United States.[121] India, also exempt from Kyoto restrictions and another of the biggest sources of industrial emissions, has made similar assertions.[122] The U.S. contends that if it must bear the cost of reducing emissions, then China should do the same.[123]

Climate change factors

Climate Change is the result of a great many factors including the dynamic processes of the Earth itself, external forces including variations in sunlight intensity, and more recently by human activities, which might in future be deliberate geoengineering. External factors that can shape climate are often called climate forcings and include such processes as variations in solar radiation, deviations in the Earth's orbit, and the level of greenhouse gas concentrations.

Glaciation

Percentage of advancing glaciers in the Alps in the last 80 years
Glaciers are recognized as being among the most sensitive indicators of climate change [1], advancing during climate cooling (for example, during the period known as the

Little Ice Age) and retreating during climate warming on moderate time scales. Glaciers grow and shrink, both contributing to natural variability and amplifying externally forced changes. A world glacier inventory has been compiled since the 1970s. Initially based mainly on aerial photographs and maps, this compilation has resulted in a detailed inventory of more than 100,000 glaciers covering a total area of approximately 240,000 km² and, in preliminary estimates, for the recording of the remaining ice cover estimated to be around 445,000 km². The World Glacier Monitoring Service collects data annually on glacier retreat and glacier mass balance. From this data, glaciers worldwide have been shown to be shrinking significantly, with strong glacier retreats in the 1940s, stable or growing conditions during the 1920s and 1970s, and again increasing rates of ice loss from the mid 1980s to present.[2]. Mass balance data indicate 17 consecutive years of negative glacier mass balance.

The most significant climate processes of the last several million years are the glacial and interglacial cycles of the present age. The present interglaciation (often termed the Holocene) has lasted about 10,000 years.[3] Shaped by orbital variations, earth-based responses such as the rise and fall of continental ice sheets and significant sea-level changes helped create the climate. Other changes, including Heinrich events, Dansgaard-Oeschger events and the Younger Dryas, however, illustrate how glacial variations may also influence climate without the forcing effect of orbital changes.

Ocean variability

A schematic of modern thermohaline circulation
Main article: Thermohaline circulation

On a timescale often measured in decades or more, climate changes can also result from the interaction between the atmosphere and the oceans. Many climate fluctuations, including the El Niño Southern oscillation, the Pacific decadal oscillation, the North Atlantic oscillation, and the Arctic oscillation, owe their existence at least in part to the different ways that heat may be stored in the oceans and also to the way it moves between various 'reservoirs'. On longer time scales (with a complete cycle often taking up to a thousand years to complete), ocean processes such as thermohaline circulation also play a key role in redistributing heat by carrying out a very slow and extremely deep movement of water, and the long-term redistribution of heat in the oceans.

Hysteresis

More generally, most forms of internal variability in the climate system can be recognized as a form of hysteresis, where the current state of climate does not immediately reflect the inputs. Because the Earth's climate system is so large, it moves slowly and has time-lags in its reaction to inputs. For example, a year of dry conditions may do no more than to cause lakes to shrink slightly or plains to dry marginally. In the following year however, these conditions may result in less rainfall, possibly leading to a drier year the next. When a critical point is reached after "x" number of years, the entire system may be altered inexorably. In this case, resulting in no rainfall at all. It is this hysteresis that has been mooted to be the possible progenitor of rapid and irreversible climate change [4]

Effects of CO₂ on climate change

Main article: Greenhouse gas

Carbon dioxide variations during the last 500 million years Increased carbon dioxide levels are thought to exacerbate the heating effects of the Greenhouse Effect by reducing the re-radiation of heat from the sun and, therefore, increasing the temperature contained in the atmosphere. As the ability of the atmosphere to capture and recycle energy emitted by the Earth's surface is essential to a stable climate, this heightened temperature may introduce a destabilising influence and potentially affect global weather patterns and, eventually, long-term climate change.

Other factors driving climate change

Plate tectonics

On the longest time scales, plate tectonics will reposition continents, shape oceans, build and tear down mountains and generally serve to define the stage upon which climate exists. During the Carboniferous period, plate tectonics may have triggered the large-scale storage of Carbon and increased glaciation.[5] More recently, plate motions have been implicated in the intensification of the present ice age when, approximately 3 million years ago, the North and South American plates collided to form the Isthmus of Panama and shut off direct mixing between the Atlantic and Pacific Oceans.[6]

Solar variation

Main article: Solar variation

Variations in solar activity during the last several centuries based on observations of sunspots and beryllium isotopes. The sun is the source of a large percentage of the heat energy input to the climate system. Lesser amounts of energy is provided by the gravitational pull of the Moon (manifested as tidal power), and geothermal energy. The energy output of the sun, which is converted to heat at the Earth's surface, is an integral part of the Earth's climate. Early in Earth's history, according to one theory, the sun was too cold to support liquid water at the Earth's surface, leading to what is known as the Faint young sun paradox.[7] Over the coming millenia, the sun will continue to brighten and produce a correspondingly higher energy output; as it continues through what is known as its "main sequence", and the Earth's atmosphere will be affected accordingly.

On more contemporary time scales, there are also a variety of forms of solar variation, including the 11-year solar cycle and longer-term modulations. However, the 11-year sunspot cycle does not appear to manifest itself clearly in the climatological data. Solar intensity variations are considered to have been influential in triggering the Little Ice Age, and for some of the warming observed from 1900 to 1950. The cyclical nature of the sun's energy output is not yet fully understood; it differs from the very slow change that is happening within the sun as it ages and evolves, with some studies pointing toward solar radiation increases from cyclical sunspot activity affecting Global Warming[8]

Orbital variations

In their effect on climate, orbital variations are in some sense an extension of solar variability, because slight variations in the Earth's orbit lead to changes in the distribution and abundance of sunlight reaching the Earth's surface. These orbital variations, known as Milankovitch cycles, directly affect glacial activity. Eccentricity, axial tilt, and precession comprise the three dominant cycles that make up the variations in Earth's orbit. The combined

effect of the variations in these three cycles creates changes in the seasonal reception of solar radiation on the Earth's surface. As such, Milankovitch Cycles affecting the increase or decrease of received solar radiation directly influence the Earth's climate system, and influence the advance and retreat of Earth's glaciers. Subtler variations are also present, such as the repeated advance and retreat of the Sahara desert in response to orbital precession.[9]

Volcanism

Volcanism is the process of conveying material from the depths of the Earth to the surface, as part of the process by which the planet removes excess heat and pressure from its interior. Volcanic eruptions, geysers and hot springs are all part of the volcanic process and all release varying levels of particulates into the atmosphere.

A single eruption of the kind that occurs several times per century can affect climate, causing cooling for a period of a few years or more. The eruption of Mount Pinatubo in 1991, for example, produced the second largest terrestrial eruption of the 20th century (after the 1912 eruption of Novarupta) and affected the climate substantially, with global temperatures dropping by about 0.5 °C (0.9 °F), and ozone depletion being temporarily substantially increased. Much larger eruptions, known as large igneous provinces, occur only a few times every hundred million years, but can reshape climate for millions of years and cause mass extinctions. Initially, it was thought that the dust ejected into the atmosphere from large volcanic eruptions was responsible for longer-term cooling by partially blocking the transmission of solar radiation to the Earth's surface. However, measurements indicate that most of the dust hurled into the atmosphere may return to the Earth's surface within as little as six months, given the right conditions.[10]

Volcanoes are also part of the extended carbon cycle. Over very long (geological) time periods, they release carbon dioxide from the earth's interior, counteracting the uptake by sedimentary rocks and other geological carbon dioxide sinks. According to the US Geological Survey, however, estimates are that human activities generate more than 130 times the amount of carbon dioxide emitted by volcanoes.[11]

Human influences

Attribution of recent climate change Anthropogenic factors are human activities that change the environment. In some cases the chain of causality of human influence on the climate is direct and unambiguous (for example, the effects of irrigation on local humidity), whilst in other instances it is less clear. Various hypotheses for human-induced climate change have been argued for many years though, generally, the scientific debate has moved on from scepticism to a scientific consensus on climate change that human activity is the probable cause for the rapid changes in world climate in the past several decades.[12] Consequently, the debate has largely shifted onto ways to reduce further human impact and to find ways to adapt to change that has already occurred. [13]

Of most concern in these anthropogenic factors is the increase in CO₂ levels due to emissions from fossil fuel combustion, followed by aerosols (particulate matter in the atmosphere) and cement manufacture. Other factors, including land use, ozone depletion, animal agriculture [14] and deforestation, are also of concern in the roles they play - both separately and in conjunction with other factors - in affecting climate.

Fossil fuels

Carbon dioxide variations over the last 400,000 years, showing a rise since the industrial revolution. Carbon dioxide levels are substantially higher now than at any time in the last 750,000 years.[15] Beginning with the industrial revolution in the 19th Century and accelerating since, the human consumption of fossil fuels has elevated CO₂ levels from a concentration of approximately 280 ppm in pre-industrial times [16] to around 387 ppm today.[17] The concentrations are increasing at a rate of about 2-3 ppm/year. [18] If current rates of emission continue, these increasing concentrations are projected to reach a range of between 535 to 983 ppm by the end of the 21st century.[19] Along with rising methane levels, it is suggested that these changes may possibly cause an increase of 1.4-5.6°C between 1990 and 2100 (see global warming). Proposals by some scientists and international coalitions, aimed at attempting to prevent drastic climate change, have suggested setting goals to try to limit concentrations to 450 or 500 ppm.[20]

Aerosols

Anthropogenic aerosols, particularly sulphate aerosols from fossil fuel combustion, exert a cooling influence[21]. This, together with natural variability (such as Orbital Precession), may account for the relative "plateau" in the temperature of the middle part of the 20th-century [22].

Cement manufacture

Cement manufacture contributes CO₂ to the atmosphere when calcium carbonate is heated, producing lime and carbon dioxide, and also as a result of burning fossil fuels in the process. It is estimated that the cement industry produces around 5% of global man-made CO₂ emissions, of which 50% is produced from the chemical process itself, and 40% from burning fuel to power that process. The amount of CO₂ emitted by the cement industry is more than 900 kg of CO₂ for every 1000 kg of cement produced. [23]

Land use

Prior to widespread fossil fuel use, humanity's largest effect on local climate was land use; irrigation, deforestation, and agriculture - on large scales - may fundamentally change the environment. For example, through the redirection of natural water courses or the destruction of animal habitats. Land use may also alter the local albedo by reducing ground cover and, therefore, altering the way sunlight is absorbed or reflected. There is evidence to suggest that the climate of Greece and other Mediterranean countries was permanently changed by widespread deforestation between 700 BC and 1 AD (the wood being used for shipbuilding, construction and fuel), with the result that the modern climate in the region is significantly hotter and drier, and the species of trees that were used for shipbuilding in the ancient world can no longer be found in the area.[24] Similarly, large tracts of land in Australia were permanently altered shortly after humans arrived some 40,000+ years ago when vast areas of temperate rainforest were burned down to produce grasslands that favoured game that the new inhabitants preferred to eat. [25] In more modern times, an assessment of conterminous U.S. biomass burning speculated that the approximate 8 fold reduction in Wildland Fire Emissions (aerosols) from the pre-industrial era to present caused by land use changes and land management decisions may have had a

regional warming affect if not for fossil fuel burning emission increases occurring concurrently [26].

A controversial hypothesis by William Ruddiman - the early anthropocene hypothesis [27] - suggests that the rise of agriculture and its accompanying deforestation may have led to significant increases in carbon dioxide and methane levels during the period 5000-8000 years ago. These increases, which apparently reversed previous declines, may have been responsible for delaying the onset of the next Ice Age.

More recently, a 2007 Jet Propulsion Laboratory study [28] found that the average mean temperature of California has risen approximately 2 degrees over the past 50 years. The change has been attributed mostly to extensive human development of the landscape. [29]

Livestock

According to a 2006 United Nations report, *Livestock's Long Shadow*, livestock is responsible for some 18% of the world's greenhouse gas emissions as measured in CO2 equivalents (this, however, also includes the net effect of deforestation in order to create grazing land, as well as livestock natural methane gas emissions), as well as 65% of human-induced nitrous oxide (which has 296 times the global warming potential of CO2) and 37% of all human-induced methane (which has 23 times the global warming potential of CO2).[14] In the Amazon Rainforest, 70% of deforestation is specifically carried out to make way for grazing land, and so is a major factor in the 2006 UN FAO report; the first agricultural report to factor in land usage change and radiative forcing in regard to the influence of livestock production.

Interplay of factors

In a cybernetic system (as is the climate of the Earth), there exist feedback mechanisms that act to amplify or reduce the effects of positive or negative forces acting upon it. In the case of the climate, these positive and negative feedback mechanisms maintain the stasis of the climate system. Without these mechanisms, the climate system would tend one way or another - too hot or too cold. Too much additional energy fed into a system with over-stressed feedback mechanisms may result in that system breaking down and a disastrous climate change occurring through thermal runaway. Ordinarily, a large part of the reason that this does not occur is the existence of a powerful negative feedback between generated temperature and emitted radiation: with radiation increasing as the fourth power of absolute temperature.

However, a number of important positive feedback mechanisms do exist; the glacial and interglacial cycles of the recent epoch being an important example. It is mooted that orbital variations directly influence the timing for the retreat of ice sheets in proportion to the radiant heat (or insolation) arriving on the Earth's surface. However, as the ice sheets themselves reflect sunlight back into space the increased insolation may actually result in a cooling effect and the growth in the ice through what is known as the albedo feedback effect. Similarly, falling sea levels and expanding ice may decrease plant growth and indirectly lead to declines in carbon dioxide and methane, which may then lead to further cooling. Conversely, rising temperatures caused, for example, by anthropogenic emissions of greenhouse gases could lead to decreased snow and ice cover, revealing darker ground underneath and, consequently, result in more absorption of sunlight and a retreat of glacial ice.[30] Either way, it is

feared that these changes may overload the system sufficiently to produce the runaway feedback described and lead to sudden and disastrous climate change.

Water vapor, methane, and carbon dioxide can also act as significant influences on positive feedback, with their levels rising in response to a warming trend and, as a result, possibly accelerating that trend. Water vapor acts strictly as a feedback mechanism (excepting small amounts in the stratosphere), unlike the other major greenhouse gases, which may also act as forcings. More complex climate feedback influences include heat movement from the equatorial regions to the northern latitudes and involve the possibility of altered water currents with in the oceans or air currents within the atmosphere. A significant concern is that melting glacial ice from Greenland may interfere with (and possibly change) the thermohaline circulation of water in the North Atlantic, affecting the Gulf Stream that conveys warmer water in to replace sinking colder water. Alterations in these flows may affect the distribution of heat to the coast of Europe and the east coast of the United States, with a possible resulting change in climate.

Monitoring the current status of climate

Testing for spatial dependence between independently measured values in an ordered set is based on applying Fisher's F-test to the variance of a set and the first variance term of the ordered set. Charting statistically significant variance terms gives a sampling variogram that shows where spatial dependence in our sample space of time dissipates into randomness. The lag of a sampling variogram is a statistically robust measure for a change in a climate statistic.

Scientists use "Indicator time series" that represent the many aspects of climate and ecosystem status. The time history provides a historical context. Current status of the climate is also monitored with climate indices.[31][32][33][34]

Physical Evidence for Climatic Change

Evidence for climatic change is taken from a variety of sources that can be used to reconstruct past climates. Most of the evidence is indirect—climatic changes are inferred from changes in indicators that reflect climate, such as vegetation, ice cores[35], dendrochronology, sea level change, and glacial geology.

Variations in CO₂, temperature and dust from the Vostok ice core over the last 450,000 yearsAtmospheric sciences [cat.]

Meteorology [cat.]

weather [cat.]

tropical cyclones [cat.]

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Vegetation

A change in the type, distribution and coverage of vegetation may occur given a change in the climate; this much is obvious. However, to what extent particular plant life changes, dies or thrives, depends largely on the model of prediction used. In any given scenario, a mild change in climate may result in increased precipitation and warmth, resulting in improved plant growth and the subsequent sequestration of airborne CO₂. Larger, faster or more radical changes, however, may well[weasel words] result in vegetation stress, rapid plant loss and desertification in certain circumstances.[36]

Ice Cores

Analysis of ice in a core drilled from a permafrost area, such as the Antarctic, can be used to show a link between temperature and global sea level variations. The air trapped in bubbles in the ice can also reveal the CO₂ variations of the atmosphere from the distant past, well before modern environmental influences. The study of these ice cores has been a significant indicator of the changes in CO₂ over many millennia, and continue to provide valuable information about the differences between ancient and modern atmospheric conditions.

Dendrochronology

Basically, Dendochronology is the analysis of tree ring growth patterns to determine the age of a tree. From a climate change viewpoint, however, Dendochronology can also indicate the climatic conditions for a given number of years. Wide and thick rings indicate a fertile, well-watered growing period, whilst thin, narrow rings indicate a time of lower rainfall and less-than-ideal growing conditions.

Pollen analysis

Palynology is the science that studies contemporary and fossil palynomorphs, including pollen. Palynology is used to infer the geographical distribution of plant species, which vary under different climate conditions. Different groups of plants have pollen with distinctive shapes and surface textures, and since the outer surface of pollen is composed of a very resilient material, they resist decay. Changes in the type of pollen found in different sedimentation levels in lakes, bogs or river deltas indicate changes in plant communities; which are dependent on climate conditions[37][38].

Insects

Remains of beetles are common in freshwater and land sediments. Different species of beetles tend to be found under different climatic conditions. Given the extensive lineage of beetles whose genetic makeup has not altered significantly over the millenia, knowledge of the present climatic range of the different species, and the age of the sediments in which remains are found, past climatic conditions may be inferred.[39]

Sea Level Change

Main article: Current sea level rise

Climate models for the substantiation of theories regarding global warming rely heavily on the measurement of long-term changes in global average sea level. Global sea level change for much of the last century has generally been estimated using tide gauge measurements collated over long periods of time to give a long-term average. More recently, altimeter measurements – in combination

with accurately determined satellite orbits – have provided an improved measurement of global sea level change.[40]

Glacial geology

Main article: [Glaciers](#)

Advancing glaciers leave behind moraines that contain a wealth of material - including organic matter that may be accurately dated - recording the periods in which a glacier advanced and retreated. Similarly, by tephrochronological techniques, the lack of glacier cover can be identified by the presence of soil or volcanic tephra horizons whose date of deposit may also be precisely ascertained. Glaciers are considered one of the most sensitive climate indicators by the IPCC, and their recent observed variations are considered a prominent indicator of impending climate change. See also [Retreat of glaciers since 1850](#). [citation needed]

Examples of climate change

Climate change has continued throughout the entire history of Earth. The field of paleoclimatology has provided information of climate change in the ancient past, supplementing modern observations of climate.

Climate of the deep past

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[Snowball earth](#)

[Oxygen Catastrophe](#)

[Climate of the last 500 million years](#)

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