Global warming

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Global warming is the increase in the average temperature of Earth's near-surface air and oceans since the mid-20th century and its projected continuation. According to the 2007 Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC), global surface temperature increased 0.74 ± 0.18 °C (1.33 ± 0.32 °F) during the 20th century.[2][A] Most of the observed temperature increase since the middle of the 20th century was caused by increasing concentrations of greenhouse gases, which results from human activity such as fossil fuel burning and deforestation.[3] Global dimming, a result of increasing concentrations of atmospheric aerosols that block sunlight from reaching the surface, has partially countered the effects of greenhouse gas induced warming.

Climate model projections summarized in the latest IPCC report indicate that the global surface temperature is likely to rise a further 1.1 to 6.4 °C (2.0 to 11.5 °F) during the 21st century.[2] The uncertainty in this estimate arises from the use of models with differing sensitivity to greenhouse gas concentrations and the use of differing estimates of future greenhouse gas emissions. An increase in global temperature will cause sea levels to rise and will change the amount and pattern of precipitation, probably including expansion of subtropical deserts.[4] Warming is expected to be strongest in the Arctic and would be associated with continuing retreat of glaciers, permafrost and sea ice. Other likely effects include changes in the frequency and intensity of extreme weather events, species extinctions, and changes in agricultural yields. Warming and related changes will vary from region to region around the globe, though the nature of these regional variations is uncertain.[5]

The scientific consensus is that anthropogenic global warming is occurring.[6][7][8][B] Nevertheless, political and public debate continues. The Kyoto Protocol is aimed at stabilizing greenhouse gas concentration to prevent a "dangerous anthropogenic interference".[9] As of November 2009, 187 states have signed and ratified the protocol.[10]

Temperature changes

Evidence for warming of the climate system includes observed increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.[11][12][13][14][15] The most common measure of global warming is the trend in globally averaged temperature near the Earth's surface. Expressed as a linear trend, this temperature rose by 0.74 ± 0.18 °C over the period 1906–2005. The rate of warming over the last half of that period was almost double that for the period as a whole (0.13 ± 0.03 °C per decade, versus 0.07 °C ± 0.02 °C per decade). The urban heat island effect is estimated to account for about 0.002 °C of warming per decade since 1900.[16] Temperatures in the lower troposphere have increased between 0.13 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 regionally varying fluctuations such as the Medieval Warm Period and the Little Ice Age.[17]

Estimates by NASA's Goddard Institute for Space Studies (GISS) and the National Climatic Data Center show that 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.[18][19] Estimates prepared by the World Meteorological Organization and the Climatic Research Unit show 2005 as the second warmest year, behind 1998.[20][21] Temperatures in 1998 were unusually warm because the strongest El Niño in the past century occurred during that year.[22] Global temperature is subject to short-term fluctuations that overlay long term trends and can temporarily mask them. The relative stability in temperature from 2002 to 2009 is consistent with such an episode.[23][24]

Temperature changes vary over the globe. Since 1979, land temperatures have increased about twice as fast as ocean temperatures (0.25 °C per decade against 0.13 °C per decade).[25] Ocean temperatures increase more slowly than land temperatures because of the larger effective heat capacity of the oceans and because the ocean loses more heat by evaporation.[26] The Northern Hemisphere warms faster than the Southern Hemisphere because it has more land and because it has extensive areas of seasonal snow and sea-ice cover subject to ice-albedo feedback. Although more greenhouse gases are emitted in the Northern than Southern Hemisphere this does not contribute to the difference in warming because the major greenhouse gases persist long enough to mix between hemispheres.[27]

The thermal inertia of the oceans and slow responses of other indirect effects mean that climate can take centuries or longer to adjust to changes in forcing. 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.[28]

External forcings

External forcing refers to processes external to the climate system (though not necessarily external to Earth) that influence climate. Climate responds to several types of external forcing, such as radiative forcing due to changes in atmospheric composition (mainly greenhouse gas concentrations), changes in solar luminosity, volcanic eruptions, and variations in Earth's orbit around the Sun.[29] Attribution of recent climate change focuses on the first three types of forcing. Orbital cycles vary slowly over tens of thousands of years and thus are too gradual to have caused the temperature changes observed in the past century.

Greenhouse gases

The greenhouse effect is the process by which absorption and emission of infrared radiation by gases in the atmosphere warm a planet's lower atmosphere and surface. It was proposed by Joseph Fourier in 1824 and was first investigated quantitatively by Svante Arrhenius in 1896.[30] The question in terms of global warming is how the strength of the presumed greenhouse effect changes when human activity increases the concentrations of greenhouse gases in the atmosphere.

Naturally occurring greenhouse gases have a mean warming effect of about 33 °C (59 °F).[31][C] The major greenhouse gases are water vapor, which causes about 36–70 percent of the greenhouse effect; carbon dioxide (CO2), which causes 9–26 percent; methane (CH4), which causes 4–9 percent; and ozone (O3), which causes 3–7 percent.[32][33][34] Clouds also affect the radiation balance, but they are composed of liquid water or ice and so have different effects on radiation from water vapor.

Human activity since the Industrial Revolution has increased the amount of greenhouse gases in the atmosphere, leading to increased radiative forcing from CO2, methane, tropospheric ozone, CFCs and nitrous oxide. The concentrations of CO2 and methane have increased by 36% and 148% respectively since 1750.[35] These levels are much higher than at any time during the last 650,000 years, the period for which reliable data has been extracted from ice cores.[36][37][38] Less direct geological evidence indicates that CO2 values higher than this were last seen about 20 million years ago.[39] Fossil fuel burning has produced about 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, particularly deforestation.[40]

CO2 emissions are continuing to rise due to the burning of fossil fuels and land-use change.[41][42] Emissions scenarios, estimates of changes in future emission levels of greenhouse gases, have been projected that depend upon uncertain economic, sociological, technological, and natural developments.[43] In most scenarios, emissions continue to rise over the century, while in a few, emissions are reduced.[44][45] These emission scenarios, combined with carbon cycle modelling, have been used to produce estimates of how atmospheric concentrations of greenhouse gases will change in the future. Using the six IPCC SRES "marker" scenarios, models suggest that by the year 2100, the atmospheric concentration of CO2 could range between 541 and 970 ppm.[46] This is an increase of 90-250% above the concentration in the year 1750. Fossil fuel reserves are sufficient to reach these levels and continue emissions past 2100 if coal, tar sands or methane clathrates are extensively exploited.[47]

The destruction of stratospheric ozone by chlorofluorocarbons is sometimes mentioned in relation to global warming. Although there are a few areas of linkage, the relationship between the two is not strong. Reduction of stratospheric ozone has a cooling influence on the entire troposphere, but a warming influence on the surface.[48] Substantial ozone depletion did not occur until the late 1970s.[49] Ozone in the troposphere (the lowest part of the Earth's atmosphere) does contribute to surface warming.[50]

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