



Frequently Asked Question 7.1

Are the Increases in Atmospheric Carbon Dioxide and Other Greenhouse Gases During the Industrial Era Caused by Human Activities?

Yes, the increases in atmospheric carbon dioxide (CO₂) and other greenhouse gases during the industrial era are caused by human activities. In fact, the observed increase in atmospheric CO₂ concentrations does not reveal the full extent of human emissions in that it accounts for only 55% of the CO₂ released by human activity since 1959. The rest has been taken up by plants on land and by the oceans. In all cases, atmospheric concentrations of greenhouse gases, and their increases, are determined by the balance between sources (emissions of the gas from human activities and natural systems) and sinks (the removal of the gas from the atmosphere by conversion to a different chemical compound). Fossil fuel combustion (plus a smaller contribution from cement manufacture) is responsible for more than 75% of human-caused CO₂ emissions. Land use change (primarily deforestation) is responsible for the remainder. For methane, another important greenhouse gas, emissions generated by human activities exceeded natural emissions over the last 25 years. For nitrous oxide, emissions generated by human activities are equal to natural emissions to the atmosphere. Most of the long-lived halogen-containing gases (such as chloro-fluorocarbons) are manufactured by humans, and were not present in the atmosphere before the industrial era. On average, present-day tropospheric ozone has increased 38% since pre-industrial times, and the increase results from atmospheric reactions of short-lived pollutants emitted by human activity. The concentration of CO₂ is now 379 parts per million (ppm) and methane is greater than 1,774 parts per billion (ppb), both very likely much higher than any time in at least 650 kyr (during which CO₂ remained between 180 and 300 ppm and methane between 320 and 790 ppb). The recent rate of change is dramatic and unprecedented; increases in CO₂ never exceeded 30 ppm in 1 kyr – yet now CO₂ has risen by 30 ppm in just the last 17 years.

Carbon Dioxide

Emissions of CO₂ (Figure 1a) from fossil fuel combustion, with contributions from cement manufacture, are responsible for more than 75% of the increase in atmospheric CO₂ concentration since pre-industrial times. The remainder of the increase comes from land use changes dominated by deforestation (and associated biomass burning) with contributions from changing agricultural practices. All these increases are caused by human activity. The natural carbon

for thousands of years. Concentrations of several important halogen-containing gases, including CFCs, are now stabilising or decreasing at the Earth's surface as a result of the Montreal Protocol on Substances that Deplete the Ozone Layer and its Amendments. Concentrations of HCFCs, production of which is to be phased out by 2030, and of the Kyoto Protocol gases HFCs and PFCs, are currently increasing.

Methane

Methane (CH₄) sources to the atmosphere generated by human activities exceed CH₄ sources from natural systems (Figure 1c). Between 1960 and 1999, CH₄ concentrations grew an average of at least six times faster than over any 40-year period of the two millennia before 1800, despite a near-zero growth rate since 1980. The main natural source of CH₄ to the atmosphere is wetlands. Additional natural sources include termites, oceans, vegetation and CH₄ hydrates. The human activities that produce CH₄ include energy production from coal and natural gas, waste disposal in landfills, raising ruminant animals (e.g., cattle and sheep), rice agriculture and biomass burning. Once emitted, CH₄ remains in the atmosphere for approximately 8.4 years before removal, mainly by chemical oxidation in the troposphere. Minor sinks for CH₄ include uptake by soils and eventual destruction in the stratosphere.

Nitrous Oxide

Nitrous oxide (N₂O) sources to the atmosphere from human activities are approximately equal to N₂O sources from natural systems (Figure 1d). Between 1960 and 1999, N₂O concentrations grew an average of at least two times faster than over any 40-year period of the two millennia before 1800. Natural sources of N₂O include oceans, chemical oxidation of ammonia in the atmosphere, and soils. Tropical soils are a particularly important source of N₂O to the atmosphere. Human activities that emit N₂O include transformation of fertilizer nitrogen into N₂O and its subsequent emission from agricultural soils, biomass burning, raising cattle and some industrial activities, including nylon manufacture. Once emitted, N₂O remains in the atmosphere for approximately 114 years before removal, mainly by destruction in the stratosphere.

cycle cannot explain the observed atmospheric increase of 3.2 to 4.1 GtC yr⁻¹ in the form of CO₂ over the last 25 years. (One GtC equals 10¹⁵ grams of carbon, i.e., one billion tonnes.)

Natural processes such as photosynthesis, respiration, decay and sea surface gas exchange lead to massive exchanges, sources and sinks of CO₂ between the land and atmosphere (estimated at ~120 GtC yr⁻¹) and the ocean and atmosphere (estimated at ~90 GtC yr⁻¹; see figure 7.3). The natural sinks of carbon produce a small net uptake of CO₂ of approximately 3.3 GtC yr⁻¹ over the last 15 years, partially offsetting the human-caused emissions. Were it not for the natural sinks taking up nearly half the human-produced CO₂ over the past 15 years, atmospheric concentrations would have grown even more dramatically.

The increase in atmospheric CO₂ concentration is known to be caused by human activities because the character of CO₂ in the atmosphere, in particular the ratio of its heavy to light carbon atoms, has changed in a way that can be attributed to

addition of fossil fuel carbon. In addition, the ratio of oxygen to nitrogen in the atmosphere has declined as CO₂ has increased; this is as expected because oxygen is depleted when fossil fuels are burned. A heavy form of carbon, the carbon-13 isotope, is less abundant in vegetation and in fossil fuels that were formed from past vegetation, and is more abundant in carbon in the oceans and in volcanic or geothermal emissions. The relative amount of the carbon-13 isotope in the atmosphere has been declining, showing that the added carbon comes from fossil fuels and vegetation. Carbon also has a rare radioactive isotope, carbon-14, which is present in atmospheric CO₂ but absent in fossil fuels. Prior to atmospheric testing of nuclear weapons, decreases in the relative amount of carbon-14 showed that fossil fuel carbon was being added to the atmosphere.

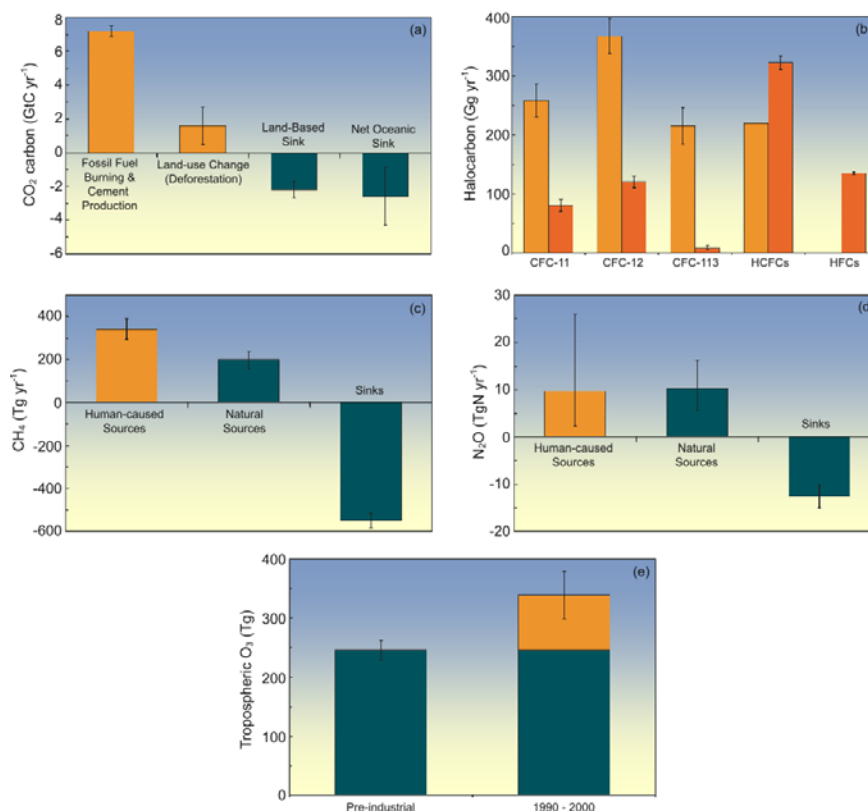
Halogen-Containing Gases

Human activities are responsible for the bulk of long-lived atmospheric halogen-containing gas concentrations. Before industrialisation, there were only a few naturally occurring halogen-containing gases, for example, methyl bromide and methyl chloride. The development of new techniques for chemical synthesis resulted in a proliferation of chemically manufactured halogen-containing gases during the last 50 years of the 20th century.

Tropospheric Ozone

Tropospheric ozone is produced by photochemical reactions in the atmosphere involving forerunner chemicals such as carbon monoxide, CH₄, volatile organic compounds and nitrogen oxides. These chemicals are emitted by natural biological processes and by human activities including land use change and fuel combustion. Because tropospheric ozone is relatively short-lived, lasting for a few days to weeks in the atmosphere, its distributions are highly variable and tied to the abundance of its forerunner compounds, water vapour and sunlight. Tropospheric ozone concentrations are significantly higher in urban air, downwind of urban areas and in regions of biomass burning. The increase of 38% (20–50%) in tropospheric ozone since the pre-industrial era (Figure 1e) is human-caused.

It is very likely that the increase in the combined radiative forcing from CO₂, CH₄ and N₂O was at least six times faster between 1960 and 1999 than over any 40-year period during the two millennia prior to the year 1800.



FAQ 7.1, Figure 1. Breakdown of contributions to the changes in atmospheric greenhouse gas concentrations, based on information detailed in Chapters 4 and 7. In (a) through (d), human-caused sources are shown in orange, while natural sources and sinks are shown in teal. In (e), human-caused tropospheric ozone amounts are in orange while natural ozone amounts are in green. (a) Sources and sinks of CO₂ (GtC). Each year CO₂ is released to the atmosphere from human activities including fossil fuel combustion and land use change. Only 57 to 60% of the CO₂ emitted from human activity remains in the atmosphere. Some is dissolved into the oceans and some is incorporated into plants as they grow. Land-related fluxes are for the 1990s; fossil fuel and cement fluxes and net ocean uptake are for the period 2000 to 2005. All values and uncertainty ranges are from Table 7.1. (b) Global emissions of CFCs and other halogen-containing compounds for 1990 (light orange) and 2002 (dark orange). These chemicals are exclusively human-produced. Here, 'HCFCs' comprise HCFC-22, -141b and -142b, while 'HFCs' comprise HFC-23, -125, -134a and -152a. One Gg = 10⁹ g (1,000 tonnes). Most data are from reports listed in Chapter 2. (c) Sources and sinks of CH₄ for the period 1983 to 2004. Human-caused sources of CH₄ include energy production, landfills, ruminant animals (e.g., cattle and sheep), rice agriculture and biomass burning. One Tg = 10¹² g (1 million tonnes). Values and uncertainties are the

Emissions of key halogen-containing gases produced by humans are shown in Figure 1b. Atmospheric lifetimes range from 45 to 100 years for the chlorofluorocarbons (CFCs) plotted here, from 1 to 18 years for the hydrochlorofluorocarbons (HCFCs), and from 1 to 270 years for the hydrofluorocarbons (HFCs). The perfluorocarbons (PFCs, not plotted) persist in the atmosphere

means and standard deviations for CH₄ of the corresponding aggregate values from Table 7.6. (d) Sources and sinks of N₂O. Human-caused sources of N₂O include the transformation of fertilizer nitrogen into N₂O and its subsequent emission from agricultural soils, biomass burning, cattle and some industrial activities including nylon manufacture. Source values and uncertainties are the midpoints and range limits from Table 7.7. N₂O losses are from Chapter 7.4. (e) Tropospheric ozone in the 19th and early 20th centuries and the 1990 to 2000 period. The increase in tropospheric ozone formation is human-induced, resulting from atmospheric chemical reactions of pollutants emitted by burning of fossil fuels or biofuels. The pre-industrial value and uncertainty range are from Table 4.9 of the IPCC Third Assessment Report (TAR), estimated from reconstructed observations. The present-day total and its uncertainty range are the average and standard deviation of model results quoted in Table 7.9 of this report, excluding those from the TAR.

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Updated: 27-Mar-2008 8:59

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