

## Frequently Asked Question 2.1

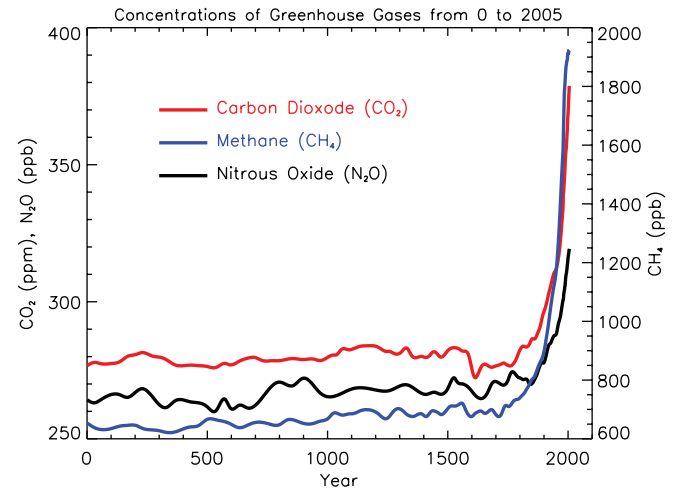
# How do Human Activities Contribute to Climate Change and How do They Compare with Natural Influences?

Human activities contribute to climate change by causing changes in Earth's atmosphere in the amounts of greenhouse gases, aerosols (small particles), and cloudiness. The largest known contribution comes from the burning of fossil fuels, which releases carbon dioxide gas to the atmosphere. Greenhouse gases and aerosols affect climate by altering incoming solar radiation and outgoing infrared (thermal) radiation that are part of Earth's energy balance. Changing the atmospheric abundance or properties of these gases and particles can lead to a warming or cooling of the climate system. Since the start of the industrial era (about 1750), the overall effect of human activities on climate has been a warming influence. The human impact on climate during this era greatly exceeds that due to known changes in natural processes, such as solar changes and volcanic eruptions.

### Greenhouse Gases

Human activities result in emissions of four principal greenhouse gases: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and the halocarbons (a group of gases containing fluorine, chlorine and bromine). These gases accumulate in the atmosphere, causing concentrations to increase with time. Significant increases in all of these gases have occurred in the industrial era (see Figure 1). All of these increases are attributable to human activities.

- Carbon dioxide has increased from fossil fuel use in transportation, building heating and cooling and the manufacture of cement and other goods. Deforestation releases CO<sub>2</sub> and reduces its uptake by plants. Carbon dioxide is also released in natural processes such as the decay of plant matter.
- Methane has increased as a result of human activities related to agriculture, natural gas distribution and landfills. Methane is also released from natural processes that occur, for example, in wetlands. Methane concentrations are not currently increasing in the atmosphere because growth rates decreased over the last two decades.
- Nitrous oxide is also emitted by human activities such as fertilizer use and fossil fuel burning. Natural processes in soils and the oceans also release N<sub>2</sub>O.
- Halocarbon gas concentrations have increased primarily due to human activities. Natural processes are also a small source. Principal halocarbons include the chlorofluorocarbons (e.g., CFC-11 and CFC-12), which were used extensively as refrigeration agents and in other industrial processes before their presence in the atmosphere was found to cause stratospheric ozone depletion. The abundance of chlorofluorocarbon gases is decreasing as a result of international regulations designed to protect the ozone layer.



**FAQ 2.1, Figure 1.** Atmospheric concentrations of important long-lived greenhouse gases over the last 2,000 years. Increases since about 1750 are attributed to human activities in the industrial era. Concentration units are parts per million (ppm) or parts per billion (ppb), indicating the number of molecules of the greenhouse gas per million or billion air molecules, respectively, in an atmospheric sample. (Data combined and simplified from Chapters 6 and 2 of this report.)

- Ozone is a greenhouse gas that is continually produced and destroyed in the atmosphere by chemical reactions. In the troposphere, human activities have increased ozone through the release of gases such as carbon monoxide, hydrocarbons and nitrogen oxide, which chemically react to produce ozone. As mentioned above, halocarbons released by human activities destroy ozone in the stratosphere and have caused the ozone hole over Antarctica.
  - Water vapour is the most abundant and important greenhouse gas in the atmosphere. However, human activities have only a small direct influence on the amount of atmospheric water vapour. Indirectly, humans have the potential to affect water vapour substantially by changing climate. For example, a warmer atmosphere contains more water vapour. Human activities also influence water vapour through CH<sub>4</sub> emissions, because CH<sub>4</sub> undergoes chemical destruction in the stratosphere, producing a small amount of water vapour.
  - Aerosols are small particles present in the atmosphere with widely varying size, concentration and chemical composition. Some aerosols are emitted directly into the atmosphere while others are formed from emitted compounds. Aerosols contain both naturally occurring compounds and those emitted as a result of human activities. Fossil fuel and biomass burning have increased aerosols containing sulphur compounds, organic compounds and black carbon (soot). Human activities such as
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surface mining and industrial processes have increased dust in the atmosphere. Natural aerosols include mineral dust released from the surface, sea salt aerosols, biogenic emissions from the land and oceans and sulphate and dust aerosols produced by volcanic eruptions.

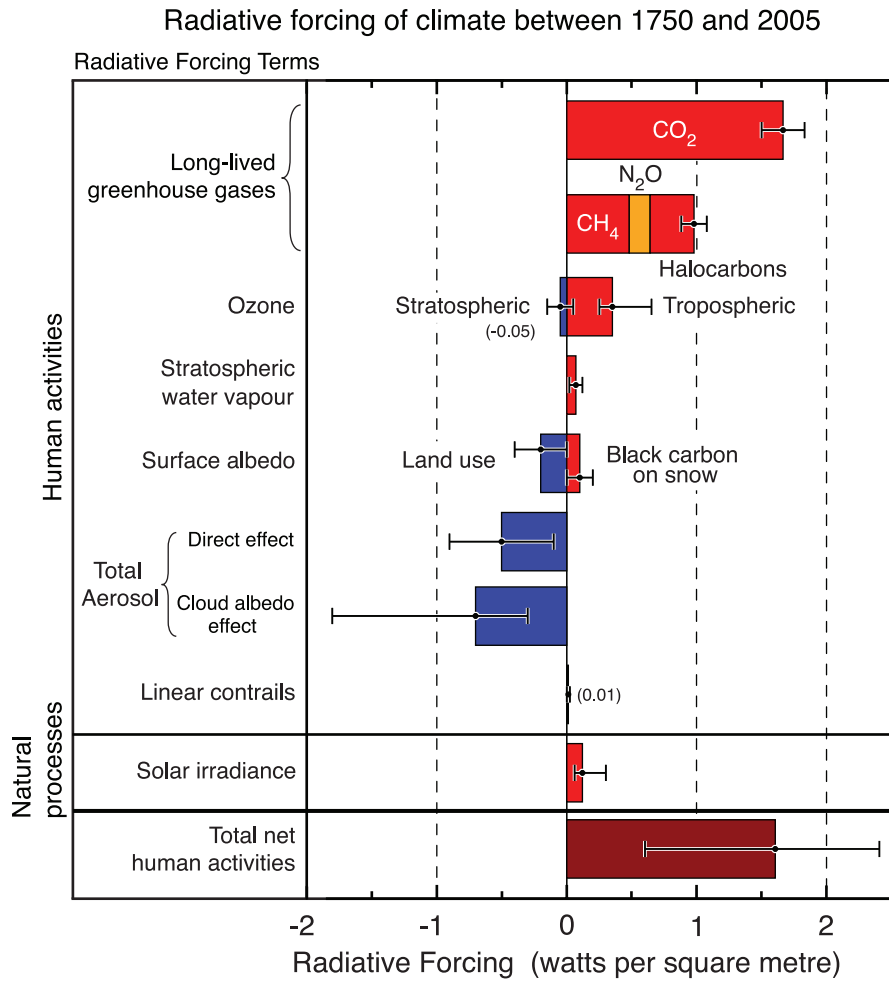
**Radiative Forcing of Factors Affected by Human Activities**

The contributions to radiative forcing from some of the factors influenced by human activities are shown in Figure 2. The values reflect the total forcing relative to the start of the industrial era (about 1750). The forcings for all greenhouse gas increases, which are the best understood of those due to human activities, are positive because each gas absorbs outgoing infrared radiation in the atmosphere. Among the greenhouse gases, CO<sub>2</sub> increases have caused the largest forcing over this period. Tropospheric ozone increases have also contributed to warming, while stratospheric ozone decreases have contributed to cooling.

Aerosol particles influence radiative forcing directly through reflection and absorption of solar and infrared radiation in the atmosphere. Some aerosols cause a positive forcing while others cause a negative forcing. The direct radiative forcing summed over all aerosol types is negative. Aerosols also cause a negative radiative forcing indirectly through the changes they cause in cloud properties.

Human activities since the industrial era have altered the nature of land cover over the globe, principally through changes in

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**FAQ 2.1, Figure 2.** Summary of the principal components of the radiative forcing of climate change. All these radiative forcings result from one or more factors that affect climate and are associated with human activities or natural processes as discussed in the text. The values represent the forcings in 2005 relative to the start of the industrial era (about 1750). Human activities cause significant changes in long-lived gases, ozone, water vapour, surface albedo, aerosols and contrails. The only increase in natural forcing of any significance between 1750 and 2005 occurred in solar irradiance. Positive forcings lead to warming of climate and negative forcings lead to a cooling. The thin black line attached to each coloured bar represents the range of uncertainty for the respective value. (Figure adapted from Figure 2.20 of this report.)

**FAQ 2.1, Box 1: What is Radiative Forcing?**

What is radiative forcing? The influence of a factor that can cause climate change, such as a greenhouse gas, is often evaluated in terms of its radiative forcing. Radiative forcing is a measure of how the energy balance of the Earth-atmosphere system is influenced when factors that affect climate are altered. The word radiative arises because these factors change the balance between incoming solar radiation and outgoing infrared radiation within the Earth’s atmosphere. This radiative balance controls the Earth’s surface temperature. The term forcing is used to indicate that Earth’s radiative balance is being pushed away from its normal state.

Radiative forcing is usually quantified as the ‘rate of energy change per unit area of the globe as measured at the top of the atmosphere’, and is expressed in units of ‘Watts per square metre’ (see Figure 2). When radiative forcing from a factor or group of factors is evaluated as positive, the energy of the Earth-atmosphere system will ultimately increase, leading to a warming of the system. In contrast, for a negative radiative forcing, the energy will ultimately decrease, leading to a cooling of the system. Important challenges for climate scientists are to identify all the factors that affect climate and the mechanisms by which they exert a forcing, to quantify the radiative forcing of each factor and to evaluate the total radiative forcing from the group of factors.

croplands, pastures and forests. They have also modified the reflective properties of ice and snow. Overall, it is likely that more solar radiation is now being reflected from Earth's surface as a result of human activities. This change results in a negative forcing.

Aircraft produce persistent linear trails of condensation ('contrails') in regions that have suitably low temperatures and high humidity. Contrails are a form of cirrus cloud that reflect solar radiation and absorb infrared radiation. Linear contrails from global aircraft operations have increased Earth's cloudiness and are estimated to cause a small positive radiative forcing.

### **Radiative Forcing from Natural Changes**

Natural forcings arise due to solar changes and explosive volcanic eruptions. Solar output has increased gradually in the industrial era, causing a small positive radiative forcing (see Figure 2). This is in addition to the cyclic changes in solar radiation that

follow an 11-year cycle. Solar energy directly heats the climate system and can also affect the atmospheric abundance of some greenhouse gases, such as stratospheric ozone. Explosive volcanic eruptions can create a short-lived (2 to 3 years) negative forcing through the temporary increases that occur in sulphate aerosol in the stratosphere. The stratosphere is currently free of volcanic aerosol, since the last major eruption was in 1991 (Mt. Pinatubo).

The differences in radiative forcing estimates between the present day and the start of the industrial era for solar irradiance changes and volcanoes are both very small compared to the differences in radiative forcing estimated to have resulted from human activities. As a result, in today's atmosphere, the radiative forcing from human activities is much more important for current and future climate change than the estimated radiative forcing from changes in natural processes.