Greenhouse Gas Concentrations

Energy from the sun drives the Earth's weather and climate. The Earth absorbs some of the energy it receives from the sun and radiates the rest back toward space. However, certain gases in the atmosphere, called greenhouse gases (GHGs), absorb some of the energy radiated from the Earth and trap it in the atmosphere. These gases essentially act as a blanket, making the Earth's surface warmer than it otherwise would be. This "greenhouse effect" occurs naturally, making life as we know it possible. Since the Industrial Revolution began in the late 1700s, however, people have added GHGs into the atmosphere by burning fossil fuels, cutting down forests, and conducting other activities (e.g., agriculture). The resulting substantial increase in GHG concentrations is causing the atmosphere to trap more heat and leading to changes in the Earth's climate.

The major GHGs emitted into the atmosphere through human activities are carbon dioxide, methane, nitrous oxide, and halogenated gases (a group of gases containing chlorine, fluorine, or bromine). Some of these gases are produced almost entirely by human activities; others come from a combination of natural sources and human activities.

When GHGs are emitted into the atmosphere, many remain there for long time periods ranging from a decade to many millennia (see Major Greenhouse Gases Associated With Human Activities Table). Over time, these gases are removed from the atmosphere by emissions sinks, such as oceans, vegetation, or chemical reactions. Emissions sinks are the opposite of emissions sources, and they absorb and store emissions or cause the gases to break down. However, if these gases enter the atmosphere more quickly than they can be removed, their concentrations increase.

This indicator describes how concentrations of carbon dioxide, methane, nitrous oxide, and selected halogenated gases in the atmosphere have changed over time. All of these gases become well mixed throughout the entire global atmosphere because of their long lifetimes and because of transport by winds. Thus, measurements at individual locations are globally representative. Concentrations of other GHGs such as tropospheric ozone, which has an atmospheric lifetime of hours to days, often vary regionally and are not included in this indicator.

To provide context for modern-day observations, this indicator shows concentrations of GHGs over thousands of years. Recent measurements come from monitoring stations around the world, while older measurements come from air bubbles trapped in layers of ice from Antarctica and Greenland. By determining the age of the ice layers and the concentrations of gases trapped inside, scientists can learn what the atmosphere was like thousands of years ago.

Concentrations of GHGs are measured in parts per million (ppm), parts per billion (ppb), or parts per trillion (ppt) by volume. In other words, a concentration of 1 ppb for a given gas means there is one part of that gas in 1 billion parts of a given amount of air. For some GHGs, even changes as small as a few parts per trillion can make a difference in global climate.

What the Data Show

Exhibits 1, 2, and 3 show how concentrations of carbon dioxide, methane, and nitrous oxide have evolved over time. The underlying data come from research sites spread around the world and use multiple measuring methods, but nevertheless demonstrate a high level of consistency—indicating that the gases are well-mixed and that the sampling can be considered spatially representative. The exhibits show cyclical glacial-interglacial patterns over geological time scales, and they also depict substantial increases in concentrations since the start of the industrial era that continue today.

The concentration of carbon dioxide, the most important anthropogenic GHG, has varied considerably over geological time (Exhibit 1). Over the past 650,000 years, concentrations have generally cycled over several-thousand-year periods from highs around 285-300 ppm to lows around 180-185 ppm. Before the industrial era began in the late 1700s, carbon dioxide concentrations measured approximately 280 ppm. Concentrations have risen steadily since then, reaching an annual average of 394 ppm in 2012—a 41 percent increase. Almost all of this increase is due to human activities (IPCC, 2007), and current global concentrations are unprecedented compared with the past 650,000 years.

Methane concentrations have cycled widely over the past 650,000 years, but peaks remained below 800 ppb prior to 1800 AD (Exhibit 2). The concentration of methane in the atmosphere has more than doubled since then, reaching about 1,826 ppb at Mauna Loa, Hawaii, in 2012. It is very likely that this increase is predominantly due to agriculture and fossil fuel use (IPCC, 2007). Methane concentration measurements since 1950 demonstrate a pattern of higher values from research sites located in northern latitudes—a result of the higher number of methane sources in the northern hemisphere and methane's relatively short lifetime compared with other long-lived GHGs. Despite the latitudinal differences, however, the pattern over the past two centuries shows a common trend in all locations, and concentrations everywhere on Earth today are unprecedented compared with the past 650,000 years.

Over geological time, concentrations of nitrous oxide in the atmosphere generally ranged between 180 and 280 ppb (Exhibit 3). Levels have risen since the 1920s, however, reaching a new high of 325 ppb in 2012. This increase is primarily due to recent agricultural emissions (IPCC, 2007).

Concentrations of many of the halogenated gases shown in Exhibit 4 were essentially zero a few decades ago but have increased rapidly as they have been incorporated into industrial products and processes. Some of these chemicals are now being phased out of use because they are ozone-depleting substances, meaning they also cause harm to the Earth's ozone layer. As a result, concentrations of some ozone-depleting gases have begun to stabilize or decline. Concentrations of other halogenated gases have continued to rise, however, especially where the gases have emerged as substitutes for ozone-depleting chemicals. Some of these halogenated gases are considered major greenhouse gases due to their very high global warming potentials and long atmospheric lifetimes.

Limitations

- This indicator does not include concentrations of water vapor. Although water vapor is the most abundant GHG in the atmosphere, human activities have only a small direct influence on it, primarily through irrigation and deforestation. However, the surface warming caused by human production of other GHGs leads to an increase in atmospheric water vapor, because a warmer climate increases evaporation. This creates a positive "feedback loop" where warming leads to more warming.
- This indicator includes several of the most important halogenated gases, but some others are not shown. Many other halogenated gases are also GHGs, but Exhibit 4 is limited to a set of common examples that represent most of the major types of these gases.
- The indicator does not address certain other pollutants that can affect climate by either reflecting or absorbing energy. For example, sulfate particles can reflect sunlight away from the Earth, while black carbon aerosols (soot) absorb energy.

Data Sources

Global atmospheric concentration measurements for carbon dioxide (Exhibit 1), methane (Exhibit 2), and nitrous oxide (Exhibit 3) come from a variety of monitoring programs and studies published in peer-reviewed literature. References for the underlying data are noted below the corresponding exhibits. Global atmospheric concentration data for selected halogenated gases (Exhibit 4) were compiled by the Advanced Global Atmospheric Gases Experiment (AGAGE, 2013), the National Oceanic and Atmospheric Administration (NOAA, 2013b), and a peer-reviewed study on nitrogen trifluoride (Arnold, 2013). A similar figure with many of these gases appears in the Intergovernmental Panel on Climate Change's Fifth Assessment Report (IPCC, 2013).

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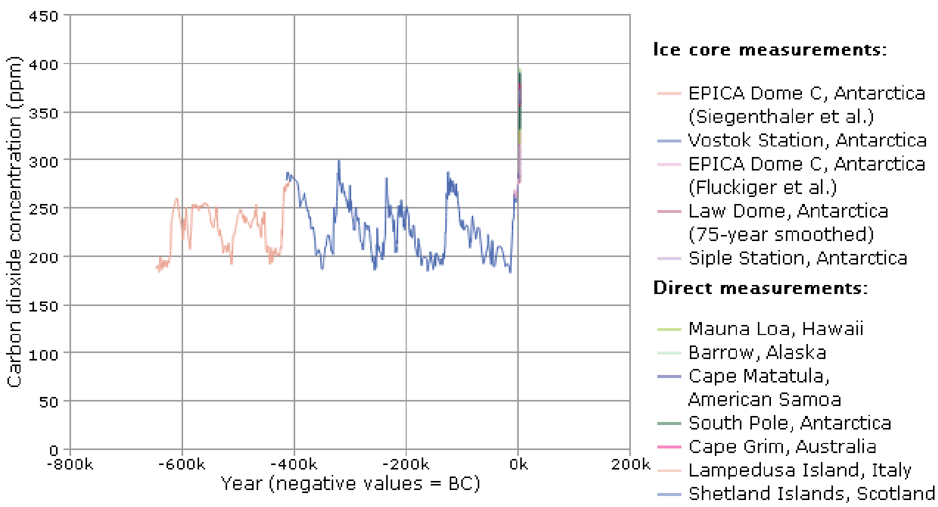
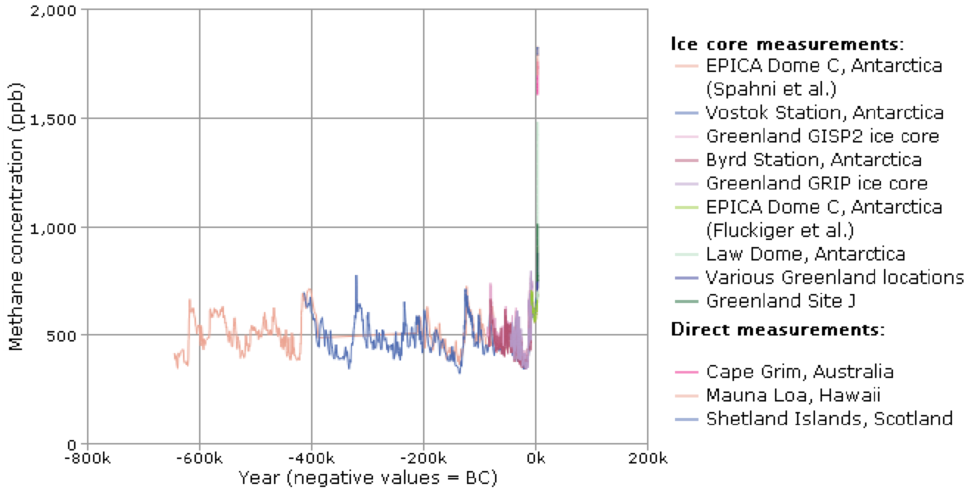
Exhibit 1. Global atmospheric concentrations of carbon dioxide over geological time and in recent years



Authoritative scientific assessments have concluded that concentrations of carbon dioxide now substantially exceed the highest concentrations recorded in ice cores during the past 800,000 years. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: Barnola et al., 2003; Chamard et al., 2001; Etheridge et al., 1998; Fluckiger et al., 2002; Neftel et al., 1994; NOAA, 2012, 2013a; Siegenthaler et al., 2005; Steele et al., 2007

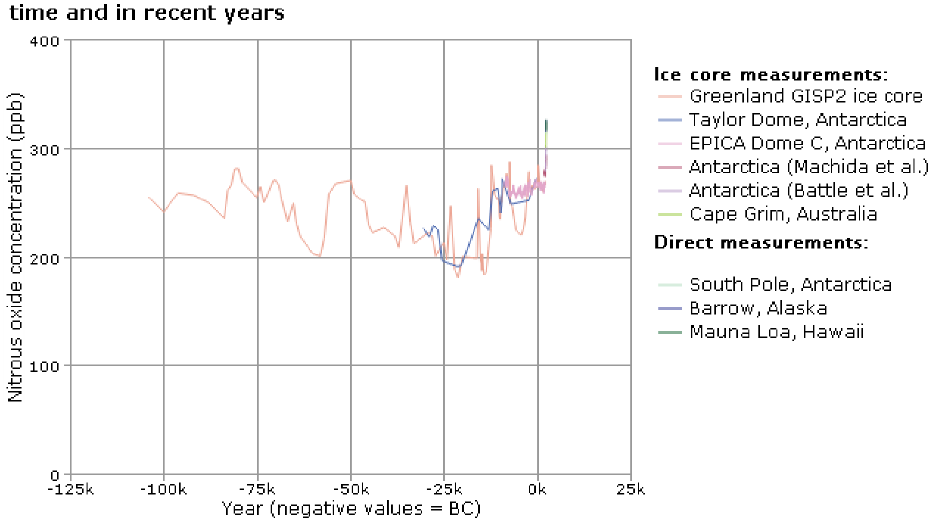
Exhibit 2. Global atmospheric concentrations of methane over geological time and in recent years



Authoritative scientific assessments have concluded that concentrations of methane now substantially exceed the highest concentrations recorded in ice cores during the past 800,000 years. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: Blunier and Brook, 2001; Etheridge et al., 2002; Fluckiger et al., 2002; NOAA, 2013c, d; Petit et al., 1999; Spahni et al., 2005; Steele et al., 2002; WDCGG, 2006

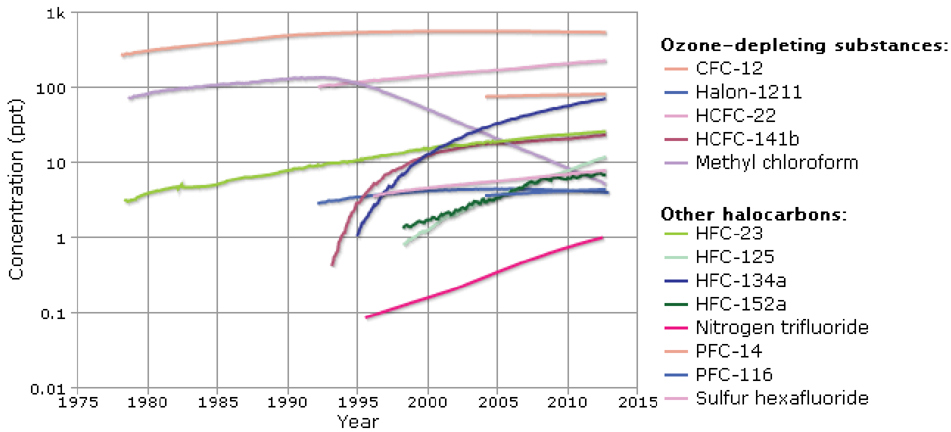
Exhibit 3. Global atmospheric concentrations of nitrous oxide over geological time and in recent years



Authoritative scientific assessments have concluded that concentrations of nitrous oxide now substantially exceed the highest concentrations recorded in ice cores during the past 800,000 years. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: AGAGE, 2012; Battle et al., 1996; Fluckiger et al., 2002; Machida et al., 1995; NOAA, 2013e; Sowers et al., 2003

Exhibit 4. Global atmospheric concentrations of selected halogenated gases, 1978-2012



Trends are presented for selected halogenated gases with sufficient data to support long-term trend analysis.

Authoritative scientific assessments have concluded that concentrations of HCFCs, HFCs, PFCs, sulfur hexafluoride, and certain other halogenated gases are increasing, while concentrations of major chlorofluorocarbons (CFCs) increased over the last several decades but are now decreasing. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: AGAGE, 2013; Arnold, 2013; NOAA, 2013b