# THE ATMOSPHERE, CLIMATE, AND GLOBAL WARMING

First observation: The average surface temperature of the Earth from 1850 to the present. the increase was about 0.2°C per decade.

The second kind of key observation is the measurement of carbon dioxide concentrations in the atmosphere.

the best-known $CO_2$ observation were made on Mauna Loa Mountain, Hawaii, by Charles Keeling and are now known as the Keeling Curve. Taken at 3,500 m on an island far from most human activities, these measurements provide an excellent estimate of the background condition of the atmosphere.

## The fundamental questions about global warming:

- What is the origin of known periods of rapid warming in the geologic record? This fundamental question is the subject of intense ongoing research and is not yet solved.
- Is the present rapid warming unprecedented or at least so rare that many living things will not be able to respond successfully to it?
- To what extent, have people caused it?
- What are likely to be the effects on people?
- What are likely to be the effects on all life on Earth?
- How can we make forecasts about it and other kinds of climate change?
- What can we do to minimize potential negative effects?

# Weather and Climate

- **Weather** is what's happening now or over some short time period—this hour, today, this week—in the atmosphere near the ground: its temperature, pressure, cloudiness, precipitation, winds.
- **Climate** is the average weather and usually refers to average weather conditions over long  periods, at least seasons, but more often years or decades.

Since climates are characteristic of certain latitudes, they are classified mainly by latitude—tropical, subtropical, midlatitudinal (continental), sub-Arctic (continental), and Arctic—but also by wetness/dryness, such as humid continental, Mediterranean, monsoon, desert, and tropical wet–dry.

# The Climate Is Always Changing at a Variety of Time Scales

- The climate is always changing and this has been happening as far back in Earth's history as scientists have been able to study.
- The Precambrian Era, around 550 million years ago, averaged a relatively cool 12°C.
- the Cambrian Period heating up to about 22°C in,
- got very cool in the Ordovician/Silurian transition,
- warmed again in the Devonian,
- cooled a lot again at the end of the Carboniferous,
- and warmed again in the Triassic.

# The Origin of the Global Warming Issue

- Burning fossil fuels might enhance the levels of greenhouse
- It was first proposed in the early 19th century, about half a century after the discovery of carbon dioxide, oxygen, and the other gases that make up the atmosphere.
- But in 20th century most scientists did not take the idea of global warming seriously. It just seemed impossible that people could be affecting the entire planet.

# The Atmosphere

- The thin layer of gases that envelop Earth. Atmosphere is a dynamic system, changing continuously.
- Major gases in the atmosphere include nitrogen (78%), oxygen (21%), argon (0.9%), carbon dioxide (0.03%), and water vapor in varying concentrations in the lower few kilometers. The atmosphere also contains trace amounts of methane ozone, hydrogen sulfide, carbon  monoxide, oxides of nitrogen and sulfur, and a number of small hydrocarbons, as well as synthetic chemicals, such as chlorofluorocarbons (CFCs).
- It is a chemically active system, fueled by sunlight, affected by high-energy compounds emitted by living things and by our industrial and agricultural activities.
- Many complex chemical reactions take place in the atmosphere, changing from day to night and with the chemical elements available.

# Structure of the Atmosphere

# Atmospheric Processes: Temperature, Pressure, and Global Zones of High and Low Pressure

- Two important qualities of the atmosphere are **pressure** and **temperature**.
- **Pressure** is force per unit area. Atmospheric pressure is caused by the weight of overlying atmospheric gases on those below and therefore decreases with altitude.
- At sea level, atmospheric pressure is 105 N/m2 (newtons per square meter) (14.7 lb/in).
- When the air pressure is low, air tends to rise, cooling as it rises and condensing its water vapor; it is therefore characterized by clouds and precipitation.
- When air pressure is high, it is moving downward, which warms the air, changing the condensed water drops in clouds to vapor; therefore high-pressure systems are clear and sunny.

- **Temperature** is a measure of thermal energy, which is the kinetic energy—the motion of atoms and molecules in a substance.
- **Water vapor** content is another important characteristic of the lower atmosphere. It varies from less than 1% to about 4% by volume, depending on air temperature, air pressure, and availability of water vapor from the surface.

The atmosphere moves because of the Earth’s rotation and differential heating of Earth’s surface and atmosphere.

# Energy and the Atmosphere: What Makes the Earth Warm

- Almost all the energy the Earth receives is from the sun (a small amount comes from the interior of the Earth and an even smaller amount from frictional forces due to the moon revolving around the Earth).
- Sunlight comes in a wide range of electromagnetic radiation, from very long radio waves to much shorter infrared waves, then shorter wavelengths of visible light, even shorter wavelengths of ultraviolet, and then on to shorter and shorter wavelengths .

**Under typical conditions, the Earth’s atmosphere reflects about 30% of the electromagnetic energy that comes in from the sun and absorbs about 25%. The remaining 45% gets to the surface. As the surface warms up, it radiates more energy back to the atmosphere, which absorbs some of it. The warmed atmosphere radiates some of its energy upward into outer space and some downward to the Earth’s surface**

# How we study climate

- **The Instrumental Record:** The use of instruments to make climate measurements began around 1860. Since then, temperatures have been measured at various places on land and in the oceans.
- **The Historical Record:** A variety of documents are available from the historical records, which in some cases go back several centuries. Included here would be people's written recollections in books, newspapers, journal articles, personal journals, ships' logs, travelers' diaries, and farmers' logs, along with dates of wine harvests and small-grain harvests. Although these are mostly recorded as qualitative data, we can sometimes get quantitative information from them.

## The Paleo-Proxy Record

- The term proxy data refers to scientific data that are not strictly climatic in nature but can be correlated with climate data, such as temperature of the land or sea. Proxy data provides important insights into climate change. Information gathered as proxy data includes natural records of climate variability as indicated by tree rings, sediments, ice cores, fossil pollen, corals, and carbon-14 (14C).

- **Ice Cores:** Polar ice caps and mountain glaciers have an accumulation record of snow that has been transformed into glacial ice over hundreds to thousands of years. Ice cores often contain small bubbles of air deposited at the time of the snow, and we can measure the atmospheric gases in these.
- **Tree Rings:** The growth of trees is influenced by climate, both temperature and precipitation.
- **Sediments:** Biological material, including pollen from plants, is deposited on the land and stored for very long periods in lake, bog, and pond sediments and, once transported downstream to the coast, in the oceans.

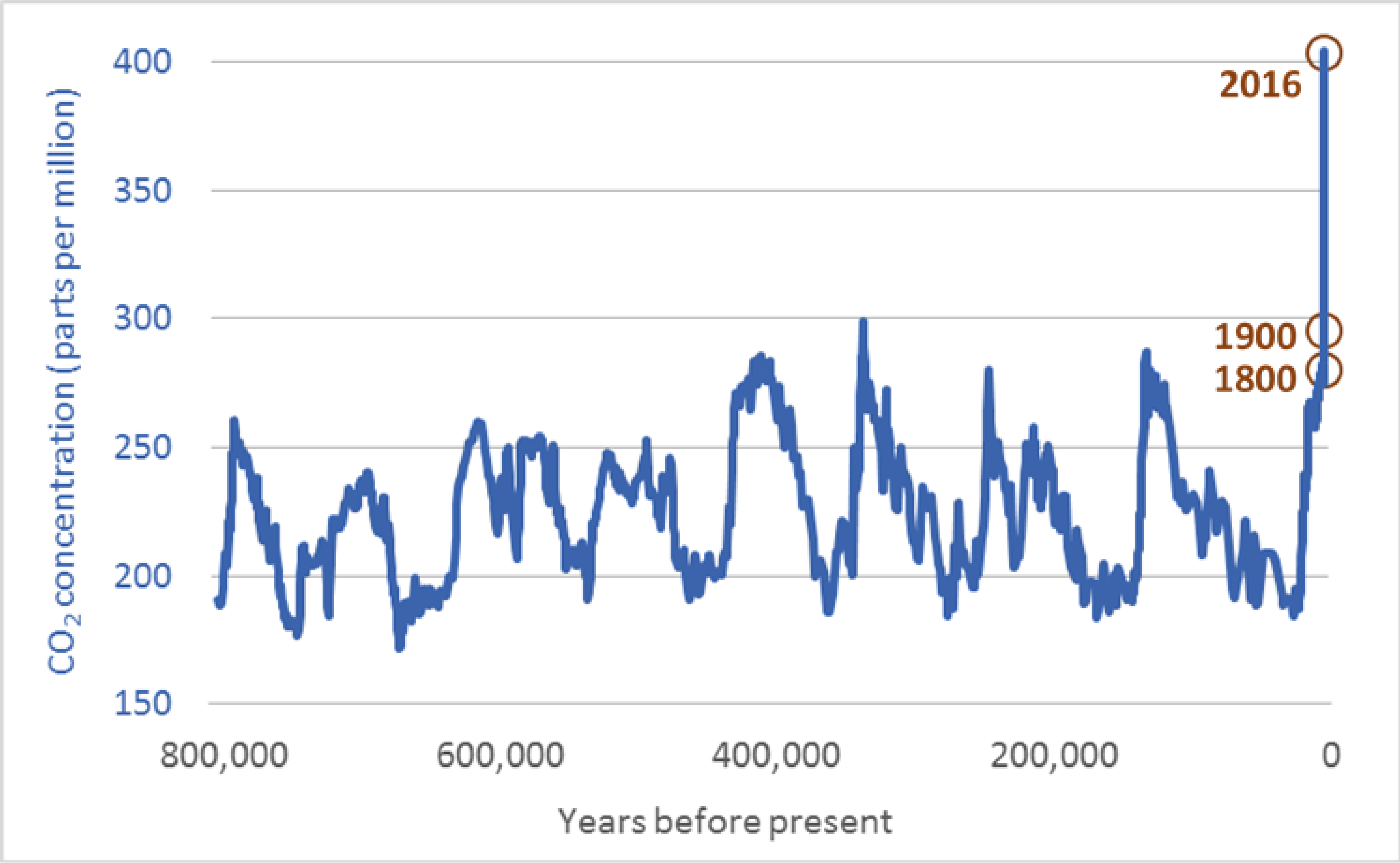
- **Corals**: Corals have hard skeletons composed of calcium carbonate ($CaCO_3$), a mineral extracted by the corals from seawater. The carbonate contains isotopes of oxygen, as well as a variety of trace metals, which have been used to determine the temperature of the water in which the coral grew. The growth of corals has been dated directly with a variety of dating techniques over short time periods of coral growth thereby revealing the chronology of climate change over variable time periods.

- **Carbon-14:** Radioactive carbon-14 (14C) is produced in the upper atmosphere by the collision of cosmic rays and nitrogen-14 (14N). Cosmic rays come from outer space; those the Earth receives are predominantly from the sun. The abundance of cosmic rays varies with the number of sunspots, so called because they appear as dark areas on the sun.

# The Greenhouse Effect

- Each gas in the atmosphere has its own absorption spectrum— which wavelengths it absorbs and which it transmits.
- Certain gases in Earth's atmosphere are especially strong absorbers in the infrared and therefore absorb radiation emitted by the warmed surfaces of the Earth. Warmed by this, the gases re-emit this radiation. Some of it reaches back to the surface, making Earth warmer than it otherwise would be. The process by which the heat is trapped is not the same as in a greenhouse.
- The major greenhouse gases are **water vapor, carbon dioxide, methane, some oxides of nitrogen, and chlorofluorocarbons (CFCs)**.
- The greenhouse effect is a natural phenomenon that occurs on Earth and on other planets in our solar system. Most natural greenhouse warming is due to water in the atmosphere—water vapor and small particles of water in the atmosphere produce about 85% and 12%, respectively, of the total greenhouse warming.

The **atmospheric window**, centered on a wavelength of 10 μm , is a region of wavelengths (8–12 μm ) where outgoing radiation from Earth is not absorbed well by natural greenhouse gases (water vapor and carbon dioxide). Anthropogenic CFCs do absorb in this region, however, and CFCs significantly contribute to the greenhouse effect in this way.




[For detailed information about CO2 levels at aspecific year: https://www.co2levels.org/](https://www.co2levels.org/)

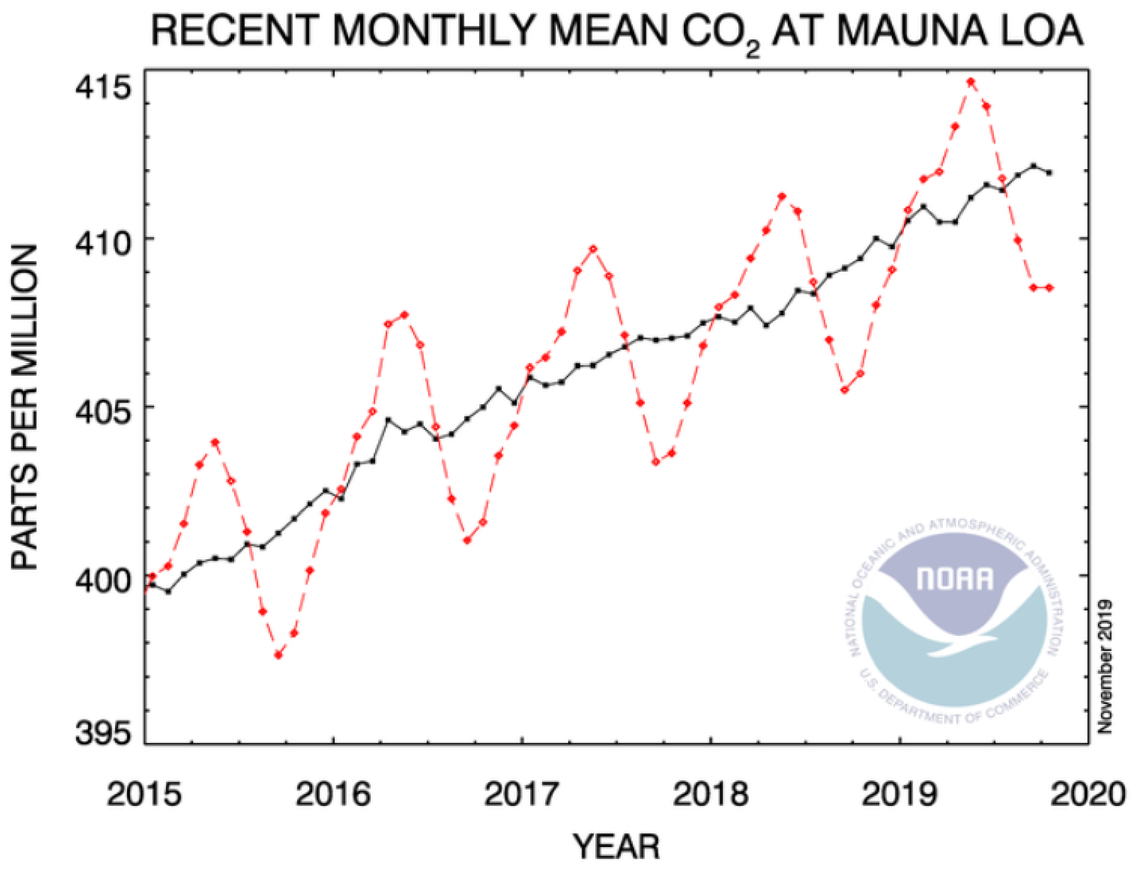
# The Major Greenhouse Gases

## CARBON DIOXIDE

- approximately 200 billion metric tons of carbon in the form of carbon dioxide ($CO_2$) enter and leave Earth's atmosphere each year as a result of a number of biological and physical processes: **50 to 60%** of the anthropogenic greenhouse effect is attributed to this gas.
- Measurements of carbon dioxide trapped in air bubbles in the Antarctic ice sheet suggest that 160,000 years before the Industrial Revolution the atmospheric concentration of carbon dioxide varied from approximately **200 to 300 ppm**.
- **About 140 years ago**, just before the major use of fossil fuels began as part of the Industrial Revolution, the atmospheric concentration of carbon dioxide was approximately **280 ppm**.
- Especially in the past few decades, the concentration of $CO_2$ in the atmosphere has grown rapidly. Today, the $CO_2$ concentration is about **410 ppm**, and at its current rate of increase of about 0.5% per year, the level may rise to approximately 450 ppm by the year 2050—more than 1.5 times the preindustrial level.

https://www.co2.earth/daily-co2

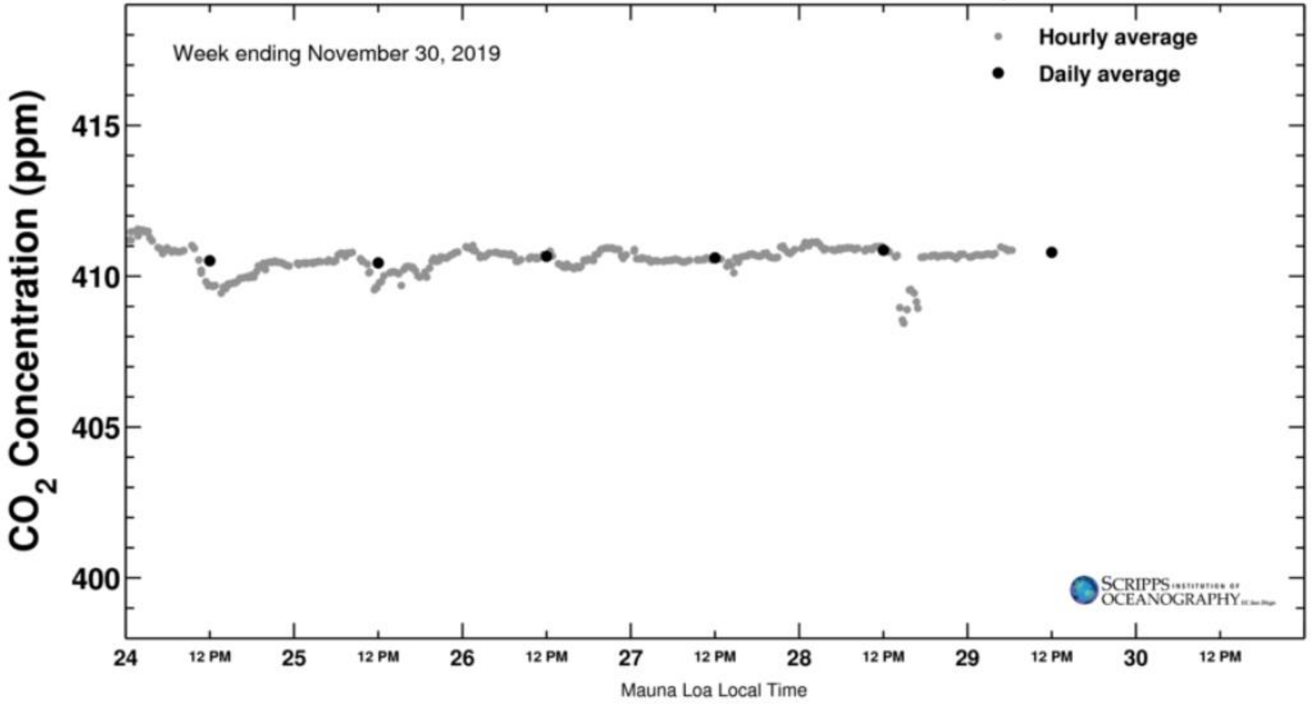
**Recent Monthly Average Mauna Loa CO2**
**October 2018: 406 ppm**
**October 2019: 408.53 ppm**
**Last updated: November 5, 2019**



# Latest $CO_2$ reading: 410.79 ppm

November 29, 2019

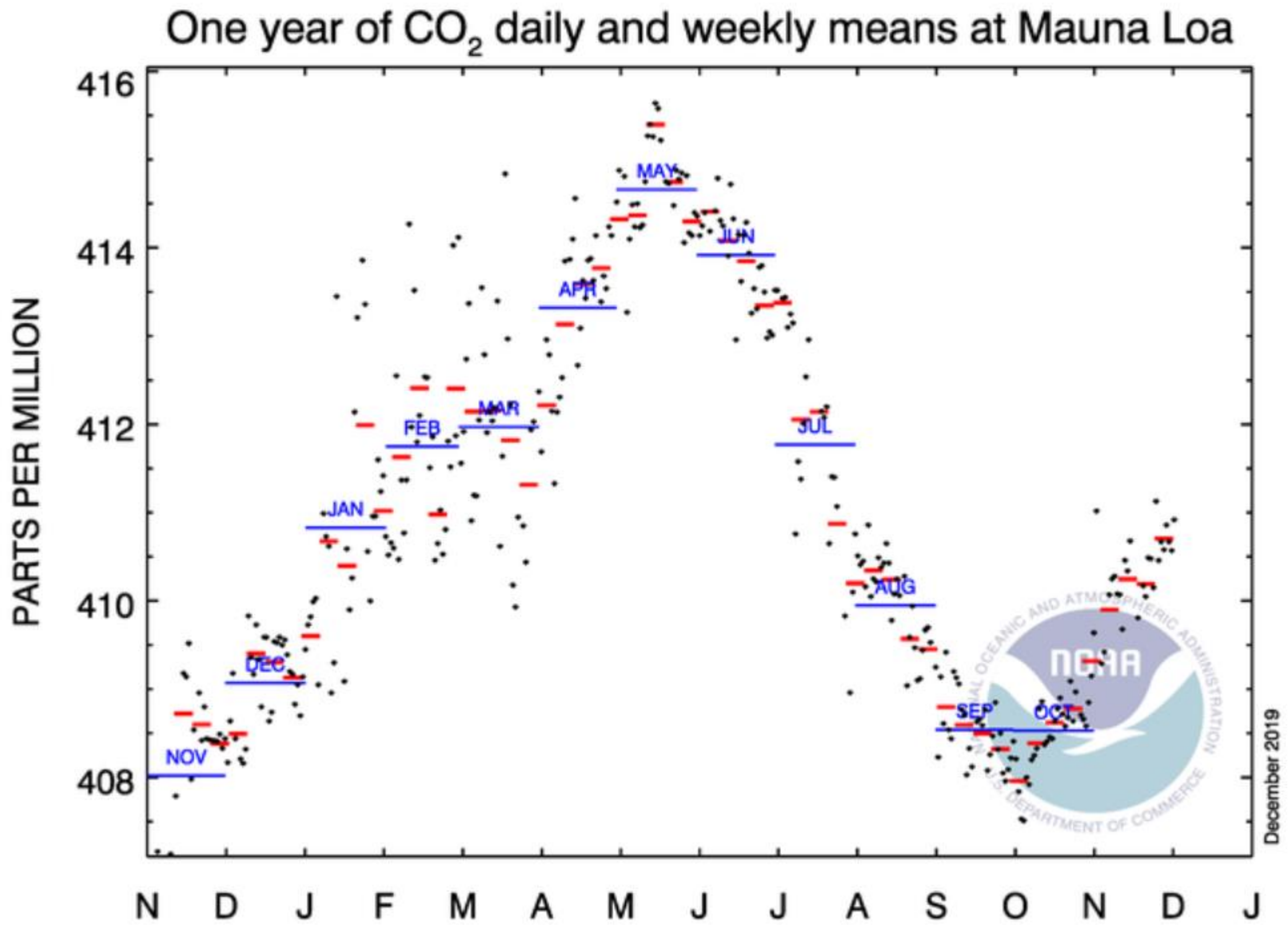
**Carbon dioxide concentration at Mauna Loa Observatory**




One Week | One Month | Six Months | One Year | Two Years | Full Record | 1700-present

Source: https://scripps.ucsd.edu/programs/keelingcurve/

**Week beginning on November 24, 2019: 410.71 ppm**
**Weekly value from 1 year ago: 408.42 ppm**
**Weekly value from 10 years ago: 386.51 ppm**
*Last updated: December 2, 2019*



## Methane

The concentration of methane ($CH_4$) in the atmosphere more than doubled in the past 200 years and is thought to contribute approximately 12 to 20% of the anthropogenic greenhouse effect.

Certain bacteria that can live only in oxygen less atmospheres produce methane and release it. These bacteria live in the guts of termites and the intestines of ruminant mammals, such as cows, which produce methane as they digest woody plants.

Methane is also released with seepage from oil fields and seepage from methane hydrates.

Our activities also release methane; landfills, the burning of biofuels, production of coal and natural gas, and agriculture, such as raising cattle and cultivating rice.

## For more information about methane hydrates

- https://www.nature.com/scitable/knowledge/library/methane-hydrates-and-contemporary-climate-change-24314790/

## Chlorofluorocarbons

- Chlorofluorocarbons (CFCs) are inert, stable compounds that have been used in spray cans as aerosol propellants and in refrigerators.
- The rate of increase of CFCs in the atmosphere in the recent past was about 5% per year, and it has been estimated that approximately **15 to 25% of the anthropogenic greenhouse effect may be related to CFCs**. Because they affect the stratospheric ozone layer and also play a role in the greenhouse effect, the United States banned their use as propellants in 1978.
- In 1987, 46 countries signed the Montreal Protocol to reduce and eventually eliminate production of CFCs and accelerate the development of alternative chemicals.
- As a result of the treaty, production of CFCs was nearly phased out by 2000.

- Potential global warming from CFCs is considerable because they absorb in the **atmospheric window**, and each CFC molecule may absorb hundreds or even thousands of times more infrared radiation emitted from Earth than is absorbed by a molecule of carbon dioxide. Furthermore, because CFCs are highly stable, their residence time in the atmosphere is long. Even though their production was drastically reduced, their concentrations in the atmosphere will remain significant (although lower than today's) for many years, perhaps for as long as a century.

For information about Montreal Protocol:

https://www.unenvironment.org/ozonaction/who-we-are/about-montreal-protocol/

https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-2-a&chapter=27&clang=_en

## Nitrous Oxide

- Nitrous oxide ($N_2O$) is increasing in the atmosphere and probably contributes as much as 5% of the anthropogenic greenhouse effect.
- Anthropogenic sources of nitrous oxide include agricultural application of fertilizers and the burning of fossil fuels.
- has a long residence time; even if emissions were stabilized or reduced, elevated concentrations of nitrous oxide would persist for at least several decades.