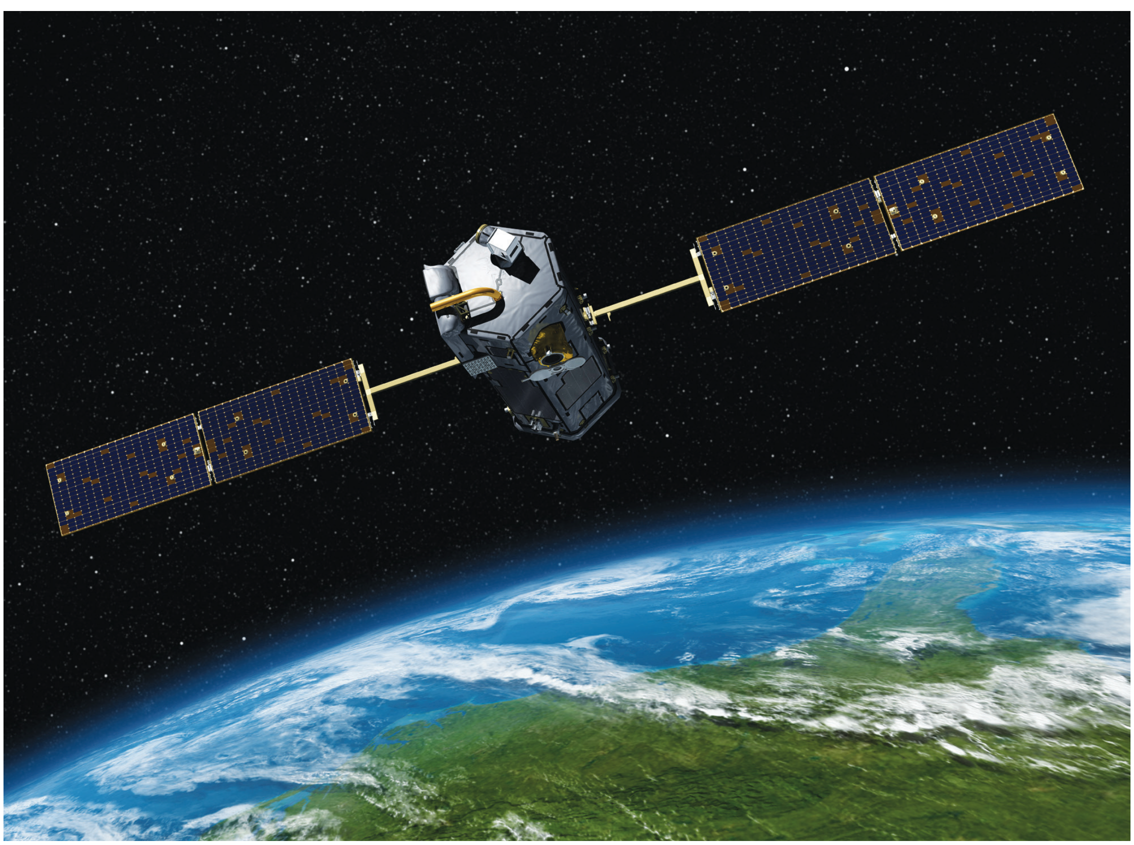
NASAfacts

Orbiting Carbon Observatory-2

Carbon: it's the chemical foundation of all living things and the fourth most abundant element in the universe. When it bonds with oxygen, it primarily forms carbon dioxide, a colorless, odorless gas that is produced both naturally and through human activities. Carbon dioxide is the most significant of the human-produced greenhouse gases (gases that warm Earth's atmosphere by absorbing radiation emitted from Earth's surface) and is the principal human-produced driver of changes to Earth's climate.

To improve our understanding of this important greenhouse gas, NASA will launch the Orbiting Carbon Observatory-2 satellite in July 2014. The latest in NASA's ongoing studies of the global carbon cycle, the Orbiting Carbon Observatory-2 will be NASA's first remote sensing mission dedicated to studying atmospheric carbon dioxide. This experimental NASA Earth System Science Pathfinder mission will provide a key new measurement that will be combined with other ground and aircraft measurements and satellite data to answer important questions about the processes that regulate atmospheric carbon dioxide and its role in the carbon cycle and climate. This information could help policymakers and business leaders make better decisions to ensure climate stability and retain our quality of life. The mission will also serve as a pathfinder for future long-term carbon dioxide monitoring satellites.

The Orbiting Carbon Observatory-2 is based on the original Orbiting Carbon Observatory mission that launched from Vandenberg Air Force Base, Calif., on an Orbital Sciences Corporation Taurus XL launch vehicle on Feb. 24, 2009.



Before the observatory separated, an anomaly with the launch vehicle's payload fairing occurred that prevented the spacecraft from reaching orbit, resulting in the loss of the mission. To produce the Orbiting Carbon Observatory-2 mission with minimum impacts on cost, schedule and performance, every effort has been made to duplicate the original mission's design using identical hardware, drawings, documents, procedures and software wherever possible and practical.

Carbon Dioxide Sources and Sinks

The concentration of atmospheric carbon dioxide is determined by the balance between its sources (emissions due to human activities and natural processes) and its sinks (places where carbon dioxide is pulled out of the atmosphere and stored in the Earth system). Natural processes, including respiration, decay, forest fires and emissions from the ocean, release huge amounts of carbon dioxide into the atmosphere. These natural sources are roughly balanced by photosynthesis, absorption of carbon dioxide by the ocean and other natural sinks that remove this greenhouse gas from the atmosphere. Human activities, however, particularly the burning of fossil fuels and deforestation, constitute a net source of carbon to the atmosphere.

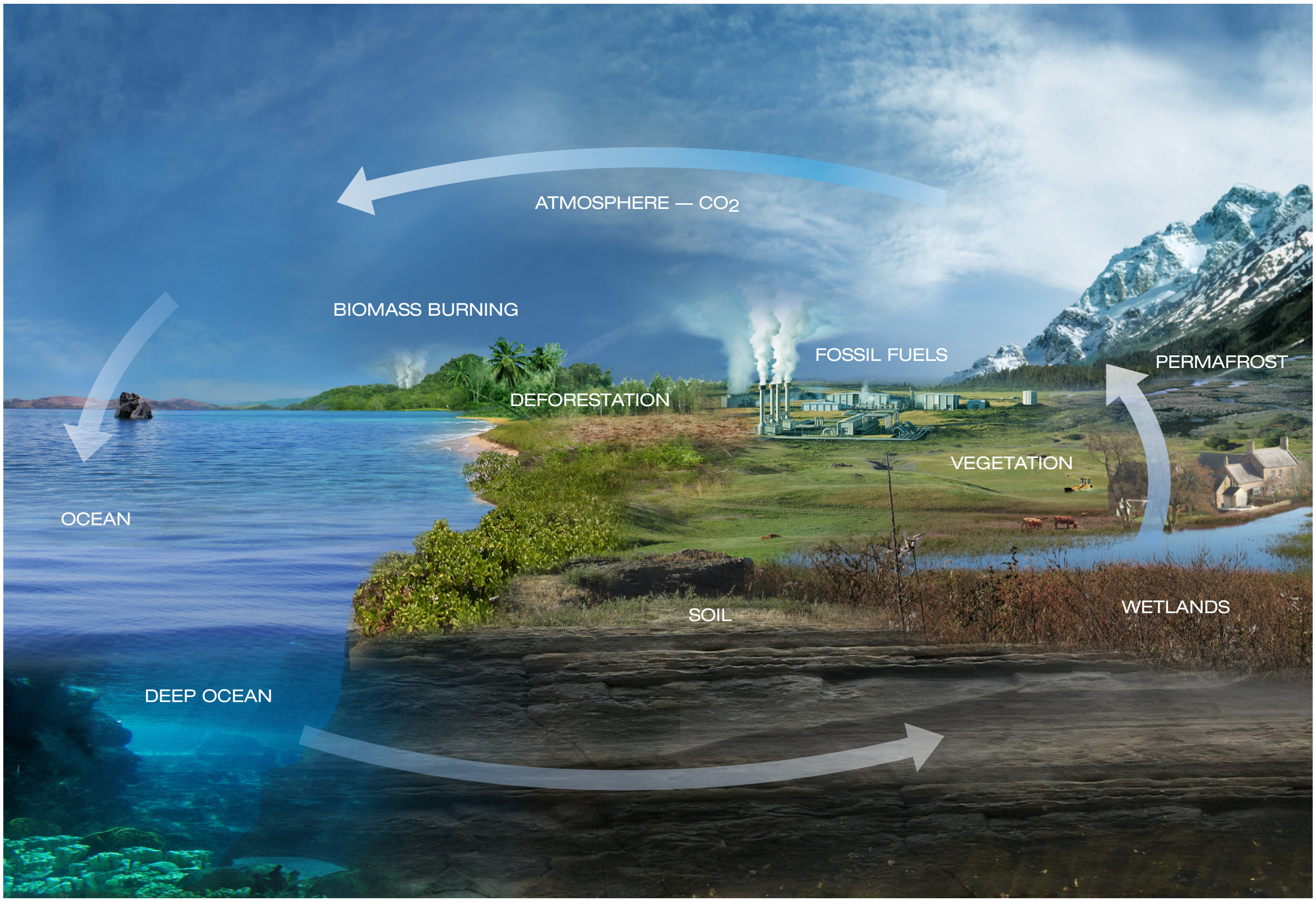
Since the beginning of the Industrial Revolution in the late 1700s, the concentration of carbon dioxide in Earth's atmosphere has increased from about 280 parts per million to more than 400 parts per million, and it continues to rise at an ever-increasing rate. We know these increases are caused primarily by human activities because fossil fuel carbon has its own telltale "fingerprint" — a different ratio of heavy to light carbon atoms.

During the 20th century, temperatures around the world increased on average by about 1 degree Fahrenheit (0.6 degree Celsius). This warming has had profound effects on our climate, such as changes in weather patterns, the retreat of glaciers, changes in Arctic sea ice, rise in sea level, and changes in ocean circulation, to name just a few. Climate models indicate that increased levels of atmospheric carbon dioxide and other greenhouse gases have been the primary cause of these observed increases in Earth's surface temperature. These models also predict that doubling the atmospheric carbon dioxide concentration will raise the average global temperature by 2 degrees Celsius (about 3.5 degrees Fahrenheit). Therefore, to accurately estimate the rate of global warming, we have to better understand the processes that are controlling the rate at which carbon dioxide is building up in the atmosphere.

When scientists try to account for sources and sinks of atmospheric carbon dioxide, they uncover a major mystery. Between 1751 and 2003, human activities added between 306 and 626 billion tons of carbon to the atmosphere as carbon dioxide. Fossil fuel combustion and cement manufacturing account for 65 percent of this emission. Most of the rest has been attributed to land use changes. Meanwhile, only about 182 to 192 billion tons of the carbon emitted into the atmosphere by human activities over this period has remained there. The remaining 60 percent was apparently absorbed (at least temporarily) by the ocean and continents. Recent inventories of the ocean can account for about half of the missing carbon. The rest must have been absorbed somewhere on land, but scientists don't know where most of the land sinks are located or what controls their efficiency over time. Scientists refer to this mystery as the "missing" carbon sink.

Unanswered Questions

Scientists have numerous other unanswered questions about carbon dioxide. Among them: what are the processes controlling the rate at which carbon dioxide is building up in Earth's atmosphere? What is the geographic distribution and quantity of carbon dioxide emitted through both fossil fuel combustion and less well-understood sources, such as ocean outgassing, deforestation, fires and biomass burning? How does this distribution change over time? What natural processes absorb carbon dioxide from human emissions? Will those processes continue to limit increases in atmospheric carbon dioxide in the future, as they do now? Or will they stop or even reverse and accelerate the atmospheric increases? Is the missing carbon dioxide being absorbed primarily by land or the ocean, and in what proportions? Which continents absorb more carbon dioxide than others? Why does the increase in atmospheric carbon dioxide vary from one year to the next while emission rates increase uniformly? How will carbon dioxide sinks respond to changes in Earth's climate or changes in land use? Characterizing and better quantifying these missing sinks, especially their geographical distribution, is crucial to predicting future carbon dioxide increases and to assist policymakers in developing and evaluating carbon management strategies.



The main reservoirs of global carbon are interconnected by pathways of exchange. Over the past century, human activities have released large amounts of carbon dioxide and other greenhouse gases into the atmosphere.

Mission Overview

The mission's primary science objective is to substantially increase our understanding of how carbon dioxide sources and sinks are geographically distributed on regional scales and study how their efficiency changes over time. The Orbiting Carbon Observatory-2 will do this by making space-based measurements of atmospheric carbon dioxide with the precision, resolution and coverage needed to characterize its distribution around the globe.

Precise concentration measurements are needed because carbon dioxide is a long-lived gas that is well mixed by the prevailing winds. Existing measurements and modeling studies indicate that carbon dioxide concentrations only vary by 2 to 5 percent on regional to continental scales. To clearly resolve these small differences, the Orbiting Carbon Observatory-2 will make measurements with about 10 times greater accuracy on those scales.

Since the late 1950s, scientists have measured carbon-dioxide directly using instruments on the ground, on tall towers and in aircraft. The current monitoring network includes about 100 sites, with large parts of the world having few, if any, monitoring stations. The Orbiting Carbon Observatory-2 mission will dramatically improve carbon dioxide measurement coverage and resolution. While thick clouds and other factors will hinder measurements in some regions, the Orbiting Carbon Observatory-2 is expected to return between 100,000 and 200,000 measurements of carbon dioxide over Earth's sunlit hemisphere every day for at least two years.

To locate sources and sinks of carbon dioxide, the Orbiting Carbon Observatory-2 measurements will be used as input to global transport models, similar to those used to predict the weather. These models work by first making an initial guess of locations and intensities of suspected carbon dioxide sources and sinks. Then, the models adjust absorption and emission by these sources and sinks to reproduce the actual carbon dioxide concentration variations observed in the presence of the prevailing winds. Through this process, the mission will provide a much more complete picture of the geographic distribution of human and natural sources and sinks of carbon dioxide emissions everywhere on Earth, on scales comparable to the size of the state of Colorado. It will also determine how these sources and sinks vary from month to month, season to season and year to year.

The carbon dioxide estimates retrieved from Orbiting Carbon Observatory-2 measurements will be used by the atmospheric and carbon cycle science communities to improve global carbon cycle models. Those models will then be incorporated into improved climate models to reduce uncertainties in forecasts of how much carbon dioxide is in the atmosphere, and to make more accurate predictions of global climate change.

Instrument Overview

The Orbiting Carbon Observatory-2 can measure carbon dioxide from space because this gas, like many others in Earth's atmosphere, absorbs specific colors of sunlight in the near-infrared part of the electromagnetic spectrum, which is invisible to the human eye. The amount of carbon dioxide over a given location can be determined by measuring the amount of absorption of each of these specific colors of light. To collect these measurements, the Orbiting Carbon Observatory-2 carries a single science instrument consisting of three high-resolution spectrometers, integrated into a common structure and illuminated by a common telescope. The spectrometers make simultaneous measurements of the amount of reflected sunlight absorbed by carbon dioxide and molecular oxygen. By analyzing these spectra, scientists can measure the relative concentrations of those chemicals in the sampled columns of Earth's atmosphere. The ratio of measured carbon dioxide to molecular oxygen is used to determine the concentration of atmospheric carbon dioxide to a precision of 0.3 to 0.5 percent.

Launch and Orbit

The observatory will be launched on a United Launch Alliance Delta II launch vehicle from California's Vandenberg Air Force Base. The spacecraft will fly at an altitude of 705 kilometers (438 miles), completing one near-polar Earth orbit every 99 minutes and repeating the same ground track every 16 days. It will fly in a loose formation with the other five Earth-observing satellites of NASA's Afternoon Constellation, or "A-Train," each of which monitors various aspects of the same region of Earth's surface or atmosphere at about the same time. Flying as part of the A-Train will complement the mission's science return and facilitate observatory calibration and validation.

Mission Duration

The Orbiting Carbon Observatory-2 is designed to operate for at least two years, long enough to validate a novel, space-based measurement approach and analysis concept that could be applied to future long-term, space-based carbon dioxide monitoring missions. The spacecraft could continue to fly well beyond its nominal two-year lifetime, however.

Partners

The Orbiting Carbon Observatory-2 is managed by NASA's Jet Propulsion Laboratory, Pasadena, Calif., for NASA's Science Mission Directorate, Washington. The science instrument was built by JPL, based on the instrument design co-developed for the original Orbiting Carbon Observatory mission by Hamilton Sundstrand, Pomona, Calif., and JPL. The spacecraft was built by Orbital Sciences Corporation at its Gilbert, Ariz., facility. Orbital Sciences also integrated the instrument with the spacecraft and tested the completed observatory at this facility, and provides mission operations from its headquarters in Dulles, Va., under JPL's leadership. United Launch Alliance, Centennial, Colo., built the Delta II launch vehicle. NASA's Launch Services Program at NASA's Kennedy Space Center in Florida is responsible for launch management.

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