Orbiting Carbon Observatory

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 satellite in early 2009. The latest in NASA's ongoing studies of the global carbon cycle, the Orbiting Carbon Observatory 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 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 adding carbon to the atmosphere.

Since the beginning of the Industrial Revolution in 1750, the concentration of carbon dioxide in Earth's atmosphere has increased from about 280 parts per million to more than 385 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 one degree Fahrenheit (0.6 degrees 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 two 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.

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.

Mission Overview

To address the missing carbon sinks and other unanswered carbon dioxide questions, NASA will launch the Orbiting Carbon Observatory satellite in early 2009. 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 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 two to five percent on regional to continental scales. To clearly resolve these small differences, the Orbiting Carbon Observatory 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 mission will dramatically improve measurements of carbon dioxide over space and time, uniformly sampling Earth’s land and ocean and collecting about 8,000,000 measurements of atmospheric carbon dioxide concentration over Earth’s entire sunlit hemisphere every 16 days for at least two years.

To locate sources and sinks of carbon dioxide, the Orbiting Carbon Observatory 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 the first 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.

Mission data 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 carries a single science instrument consisting of three parallel, high-resolution spectrometers, integrated into a common structure and fed by a common telescope. The spectrometers will make simultaneous measurements of how carbon dioxide and molecular oxygen absorb sunlight reflected off Earth’s surface when viewed in the near-infrared part of the electromagnetic spectrum, which is invisible to the human eye. Each spectrometer focuses on a different, narrow range of colors to detect light with the specific colors 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 an Orbital Sciences Corporation Taurus XL 3110 launch vehicle from Launch Complex 576-E at 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 six Earth-observing satellites of NASA's Afternoon Constellation, or "A-Train," each of which monitors various aspects of the same region of the 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 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 is capable of flying well beyond its nominal two-year lifetime, however.

Partners

The Orbiting Carbon Observatory is managed by NASA's Jet Propulsion Laboratory, Pasadena, Calif., for NASA's Science Mission Directorate, Washington. Orbital Sciences Corporation, Dulles, Va., built the spacecraft and launch vehicle and provides mission operations under JPL's leadership. Hamilton Sundstrand, Pomona, Calif., designed and built the observatory's science instrument. NASA's Launch Services Program at NASA's Kennedy Space Center in Florida is responsible for launch management.

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