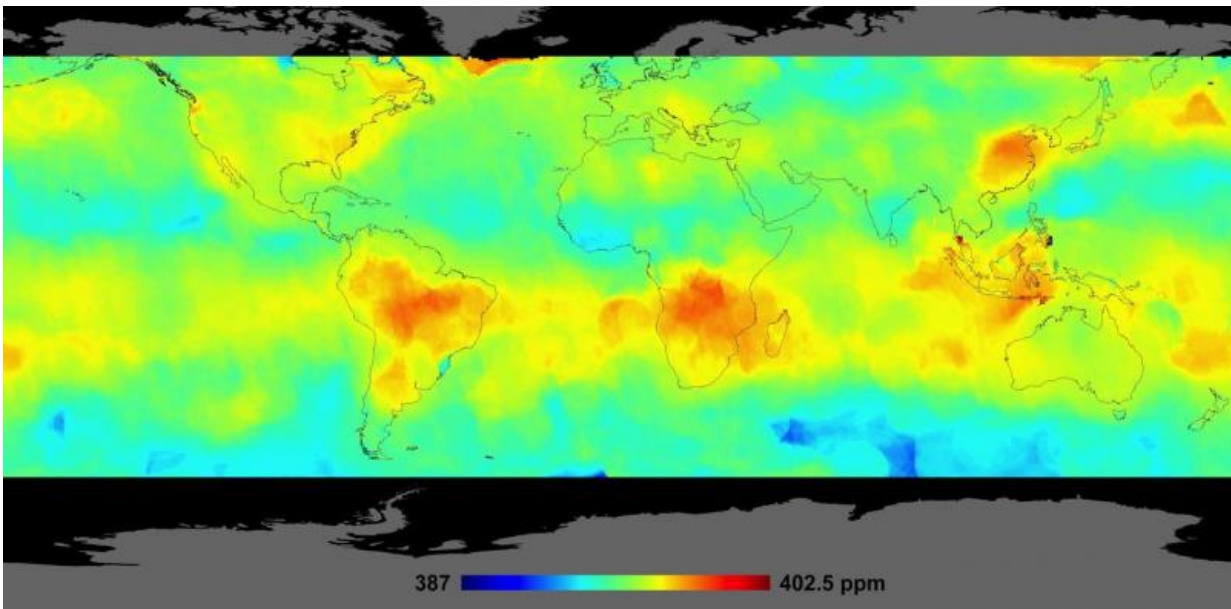


Watching the planet breathe—studying Earth's carbon cycle from space

April 12 2017, by Berrien Moore Iii And Sean Crowell



Average carbon dioxide concentrations, Oct. 1 - Nov. 11, 2014, measured by the Orbiting Carbon Observatory-2 satellite. Credit: NASA

Carbon is a building block of life on our planet. It is stored in reservoirs on Earth – in rocks, plants and soil – in the oceans, and in the atmosphere. And it [cycles](#) constantly between these reservoirs.

Understanding the [carbon cycle](#) is crucially important for many reasons. It provides us with energy, stored as fossil fuel. Carbon gases in the

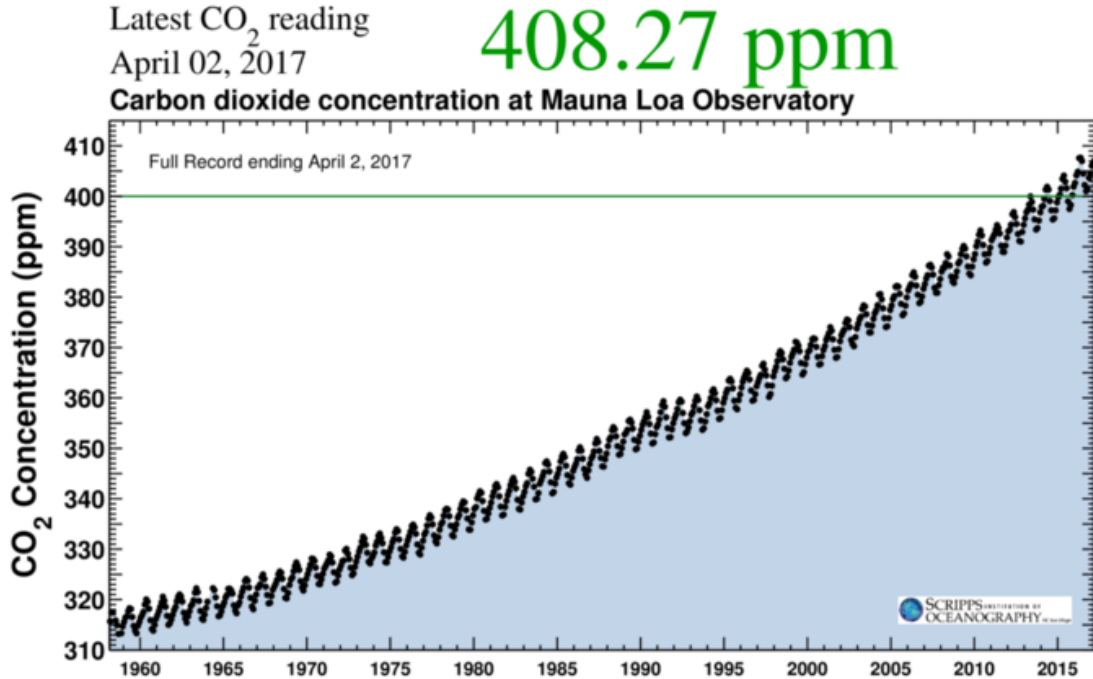
atmosphere help regulate Earth's temperature and are essential to the growth of plants. Carbon passing from the atmosphere to the ocean supports photosynthesis of marine phytoplankton and the development of reefs. These processes and myriad others are all interwoven with Earth's climate, but the manner in which the processes respond to variability and change in climate is not well-quantified.

Our research group at the [University of Oklahoma](#) is leading NASA's latest Earth Venture Mission, the Geostationary Carbon Observatory, or [GeoCarb](#). This mission will place an advanced payload on a satellite to study the Earth from more than 22,000 miles above the Earth's equator. Observing changes in concentrations of three key carbon gases – [carbon dioxide](#) (CO₂), methane (CH₄) and carbon monoxide (CO) – from day to day and year to year will help us to make a major leap forward in understanding natural and human changes in the carbon cycle.

GeoCarb is also an innovative collaboration between NASA, a public university, a commercial technology development firm ([Lockheed Martin Advanced Technology Center](#)) and a commercial communications launch and hosting firm ([SES](#)). Our "hosted payload" approach will place a scientific observatory on a commercial communications satellite, paving the way for future low-cost, commercially enabled Earth observations.

Observing the carbon cycle

The famous "[Keeling curve](#)," which tracks CO₂ concentrations in Earth's atmosphere, is based on daily measurements at Mauna Loa Observatory on Hawaii. It shows that global CO₂ levels are rising over time, but also change seasonally due to biological processes. CO₂ [decreases during the Northern Hemisphere's spring and summer months](#), as plants grow and take CO₂ out of the air. It rises again in fall and winter when plants go relatively dormant and ecosystems "exhale" CO₂.



Recorded starting in 1958 by the late geochemist Charles David Keeling, the Keeling curve measures atmospheric carbon dioxide concentrations. Credit: Scripps Institution of Oceanography

A closer look shows that every year's cycle is slightly different. In some years the biosphere takes more CO₂ out of the atmosphere; in others it releases more to the atmosphere. We want to know more about what causes the year-to-year differences because that contains clues on how the carbon cycle works.

For example, during the El Niño of 1997-1998, a sharp rise in CO₂ was largely driven by fires in Indonesia. The most recent El Niño in 2015-2016 also led to a rise in CO₂, but the cause was probably a complex mixture of effects across the tropics – including reduced

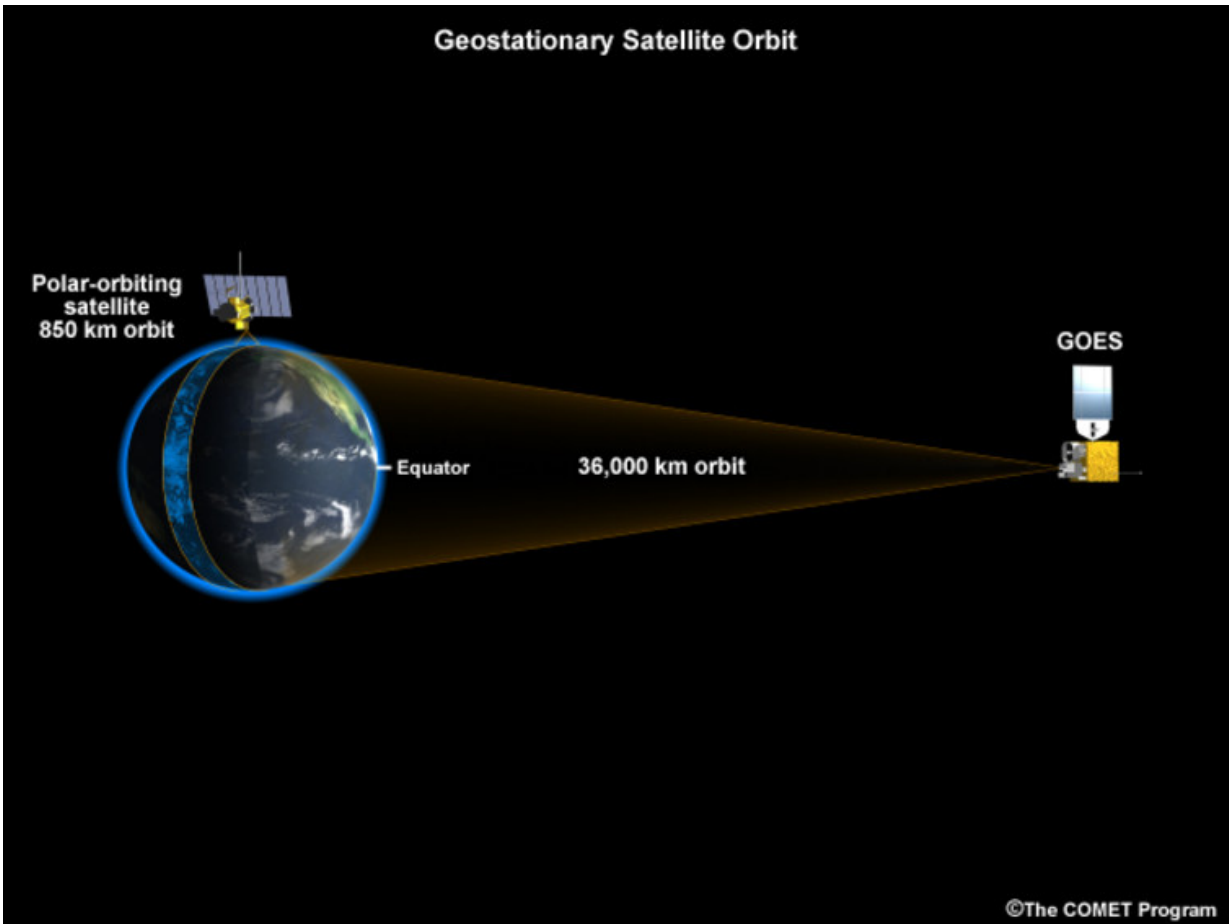
photosynthesis in Amazonia, temperature-driven soil release of CO₂ in Africa and fires in tropical Asia.

These two examples of year-to-year variability in the carbon cycle, both globally and regionally, reflect what we now believe – namely, that variability is largely driven by [terrestrial ecosystems](#). The ability to probe the climate-carbon interaction will require a much more quantitative understanding of the causes of this variability at the process level of various ecosystems.

Why study terrestrial emissions from space?

GeoCarb will be launched into [geostationary orbit](#) at roughly 85 degrees west longitude, where it will rotate in tandem with the Earth. From this vantage point, the major urban and industrial regions in the Americas from Saskatoon to Punta Arenas will be in view, as will the large agricultural areas and the expansive South American tropical forests and wetlands. Measurements of carbon dioxide, methane and [carbon monoxide](#) once or twice daily over much of the terrestrial Americas will help resolve flux variability for CO₂ and CH₄.

GeoCarb also will measure [solar induced fluorescence](#) (SIF) – plants emitting light that they cannot use back out into space. This "flashing" by the biosphere is strongly tied to the rate of photosynthesis, and so provides a measure of how much CO₂ plants take in.



Geostationary satellites like Geo-Carb and the GOES weather satellites (shown here) are positioned over the equator at an altitude of about 36,000 km (or 22,300 miles) above Earth's surface and orbit at the same speed as the Earth's rotation, making them appear to stand still. OCO-2, like the Low Earth satellite shown here, samples a much narrower area. Credit: UCAR

NASA pioneered the technology that GeoCarb will carry on an earlier mission, the [Orbiting Carbon Observatory 2](#) (OCO-2). OCO-2 launched into a [low Earth orbit](#) in 2014 and has been measuring CO₂ from space ever since, passing from pole to pole several times per day as the Earth turns beneath it.

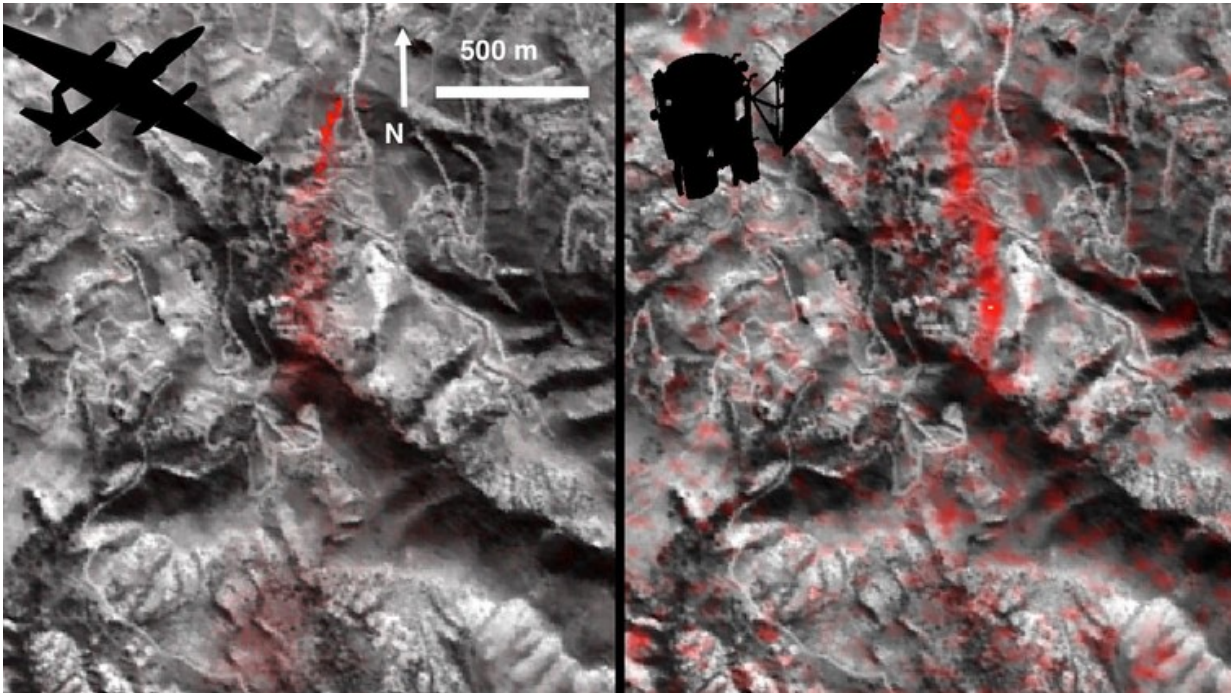
Though the instruments are similar, the difference in orbit is crucial. OCO-2 samples a narrow 10-km track over much of the globe on a 16-day repeat cycle, while GeoCarb will look at the terrestrial Western Hemisphere continuously from a fixed position, scanning most of this land mass at least once per day.

Where OCO-2 may miss observing the Amazon for a season due to regular cloud cover, GeoCarb will target the cloud-free regions every day with flexible scanning patterns. Daily revisits will show the biosphere changing in near-real time alongside weather satellites such as [GOES 16](#), which is located at 105 degrees west, helping to connect the dots between the components of Earth's system.

Nuances of the carbon cycle

Many [processes](#) affect levels of CO₂ in the atmosphere, including plant growth and decay, fossil fuel combustion and land use changes, such as clearing forests for farming or development. Attributing atmospheric CO₂ changes to different processes is difficult using CO₂ measurements alone, because the atmosphere mixes CO₂ from all of the different sources together.

As mentioned earlier, in addition to CO₂ and CH₄, GeoCarb will measure CO. Burning fossil fuel [releases](#) both CO and CO₂. This means that when we see high concentrations of both gases together, we have evidence that they are being released by human activities.



These images of the Aliso Canyon, California methane leak, taken 11 days apart in January 2016, are the first time the methane plume from a single facility has been observed from space. Photos were taken by instruments on (left) a NASA ER-2 aircraft at 4.1 miles (6.6 kilometers) altitude, and (right) NASA's Earth Observing-1 satellite in low-Earth orbit. Future instruments will provide more precise measurements. Credit: NASA

Making this distinction is key so we do not assume that human-induced CO₂ emissions come from a decrease in plant activity or a natural release of CO₂ from soil. If we can distinguish between man-made and natural emissions, we can draw more robust conclusions about the carbon cycle. Knowing what fraction of these changes is caused by human activities is important for understanding our impact on the planet, and observing and measuring it is essential to any conversation about strategies for reducing CO₂ emissions.

GeoCarb's measurement of methane will be a crucial element in understanding the global carbon-climate system. Methane is produced by natural systems, such as wetlands, and by human activities such as [natural gas production](#). We do not understand the methane portion of the carbon cycle as well as CO₂. But just as with CO₂, methane observations tell us a lot about the functioning of natural systems. Marshes release methane as part of the natural decay in the system. The rate of release is tied to how wet/dry and warm/cool the system is.

It is uncertain how much natural gas production contributes to methane emissions. One reason to quantify these emissions more accurately is that they represent [lost revenue](#) for energy producers. The Environmental Protection Agency estimates a U.S. leakage rate of around 2 percent, which could add up to [billions of dollars](#) annually.

We expect based on simulations that GeoCarb will produce maps that highlight the largest leaks with only a few days of observations. Finding leaks will reduce costs for energy producers and reduce the carbon footprint of natural gas. Currently, energy companies find leaks by sending personnel with detection equipment to suspected leak sites. Newer airborne sensors could make the process cheaper, but they are still deployed on a limited basis and in an ad hoc manner. GeoCarb's regular observations will provide leakage information to producers in a timely manner to help them limit their losses.

Watching the planet breathe

With daily scans of landmasses in the Western Hemisphere, GeoCarb will provide an unprecedented number of high-quality measurements of CO₂, CH₄ and CO in the atmosphere. These observations, along with direct measurements of photosynthetic activity from SIF observations, will raise our understanding of the carbon cycle to a new level.

For the first time we will be able to watch as the Western Hemisphere breathes in and out every day, and to see the seasons change through the eyes of the biosphere. Equipped with these observations, we will begin to disentangle natural and human contributions to the [carbon](#) balance. These insights will help scientists make robust predictions about Earth's future.

This article was originally published on [The Conversation](#). Read the [original article](#).

Provided by The Conversation

Citation: Watching the planet breathe—studying Earth's carbon cycle from space (2017, April 12) retrieved 20 April 2024 from <https://phys.org/news/2017-04-planet-breathestudying-earth-carbon-space.html>

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