GLOBAL CLIMATE CHANGE
Vital Signs of the Planet

NEWS | October 9, 2019

The Atmosphere: Getting a Handle on Carbon Dioxide

Sizing Up Humanity's Impacts on Earth's Changing Atmosphere: A Five-Part Series

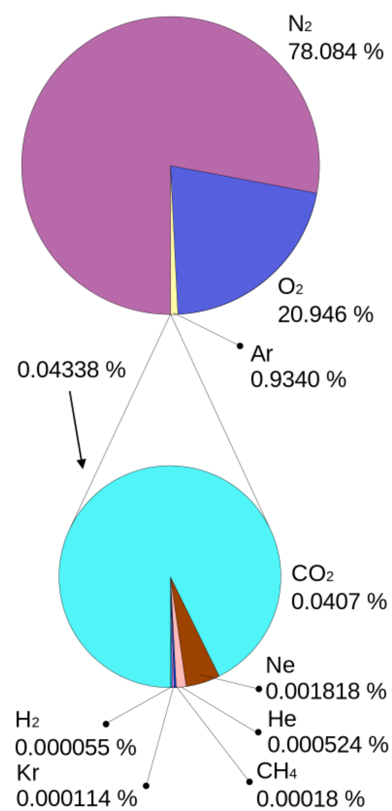
By Alan Buis,
NASA's Jet Propulsion Laboratory

Part Two

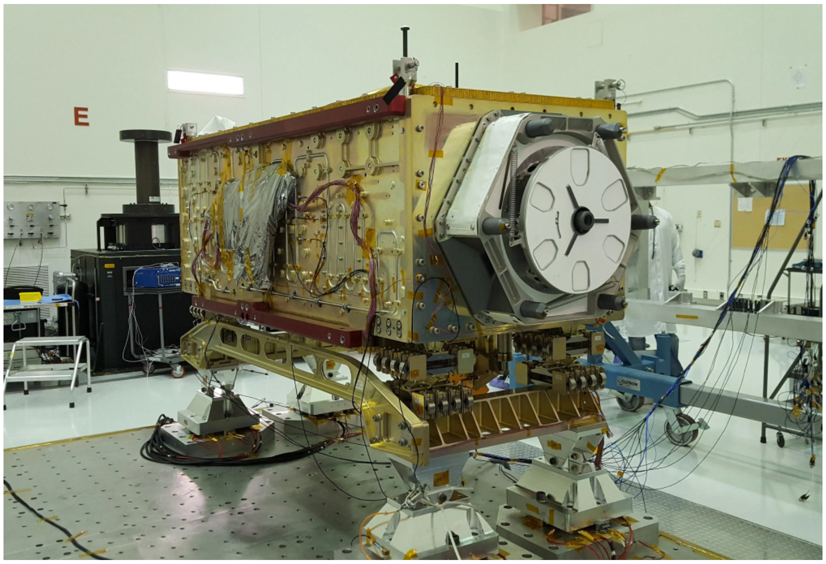
Earth's atmosphere is resilient to many of the changes humans have imposed on it. But, says atmospheric scientist David Crisp of NASA's Jet Propulsion Laboratory in Pasadena, California, that doesn't necessarily mean that our society is.

"The resilience of Earth's atmosphere has been proven throughout our planet's climate history," said Crisp, science team lead for NASA's Orbiting Carbon Observatory-2 (OCO-2) satellite and its successor instrument, OCO-3, which launched to the International Space Station on May 4. "Humans have increased the abundance of carbon dioxide by 45 percent since the beginning of the Industrial Age. That's making big changes in our environment, but at the same time, it's not going to lead to a runaway greenhouse effect or something like that. So, our atmosphere will survive, but, as suggested by UCLA professor and Pulitzer-Prize-winning author Jared Diamond, even the most advanced societies can be more fragile than the atmosphere is."

What's in the Air?



Composition of Earth's atmosphere by volume. Lower pie represents trace gases that together compose about 0.04% of the atmosphere (0.041197% at March 2019 concentration). Numbers are mainly from 1987, with carbon dioxide and methane from 2009, and do not represent any single source. Credit: Public domain



NASA's OCO-3 instrument sits on the large vibration table (known as the "shaker") in the Environmental Test Lab at NASA's Jet Propulsion Laboratory. Thermal blankets were later added to the instrument at NASA's Kennedy Space Center, where a Space-X Dragon capsule carrying OCO-3 launched on a Falcon 9 rocket to the space station on May 4, 2019. Credit: NASA/JPL-Caltech

Changes to our atmosphere associated with reactive gases (gases that undergo chemical reactions) like ozone and ozone-forming chemicals like nitrous oxides, are relatively short-lived. Carbon dioxide is a different animal, however. Once it's added to the atmosphere, it hangs around, for a *long* time: between 300 to 1,000 years. Thus, as humans change the atmosphere by emitting carbon dioxide, those changes will endure on the timescale of many human lives.

Earth's atmosphere is associated with many types of cycles, such as the carbon cycle and the water cycle. Crisp says that while our atmosphere is very stable, those cycles aren't.

"Humanity's ability to thrive depends on these other planetary cycles and processes working the way they now do," he said. "Thanks to detailed observations of our planet from space, we've seen some changes over the last 30 years that are quite alarming: changes in precipitation patterns, in where and how plants grow, in sea and land ice, in entire ecosystems like tropical rain forests. These changes should attract our attention.

By volume, the dry air in Earth's atmosphere is about 78.08 percent nitrogen, 20.95 percent oxygen, and 0.93 percent argon.

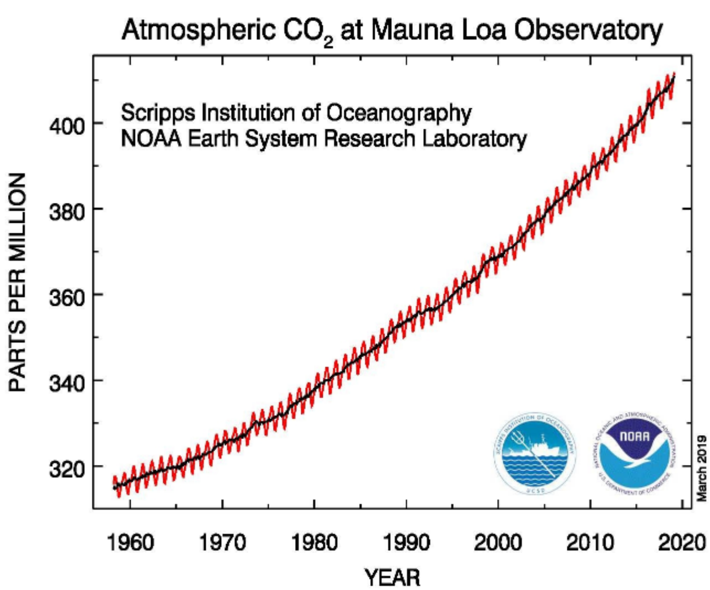
A brew of trace gases accounts for the other approximately 0.04 percent, including the greenhouse gases carbon dioxide, methane, nitrous oxide and ozone. Yet while these greenhouse gases make up just a tiny percentage of our atmosphere, they play major roles in trapping Earth's radiant heat and keeping it from escaping into space, thereby warming our planet and contributing to Earth's greenhouse effect.

The largest greenhouse gas by volume is actually the one most people tend to overlook: water vapor, whose concentration varies significantly depending on temperature. As the temperature of the atmosphere increases, the amount of humidity in the atmosphere also goes up, further heating our planet in a vicious cycle.

Tiny solid or liquid particles known as aerosols, which are produced both naturally and by human activities, are also present in variable amounts, along with human-produced industrial pollutants and natural and human-produced sulfur compounds.

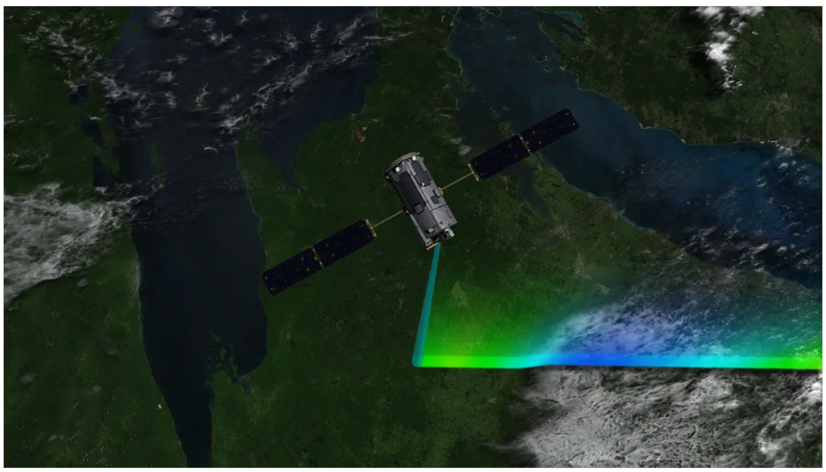
"One could say that because the atmosphere is so thin, the activity of 7.7 billion humans can actually make significant changes to the entire system," he added. "The composition of Earth's atmosphere has most certainly been altered. Half of the increase in atmospheric carbon dioxide concentrations in the last 300 years has occurred since 1980, and one quarter of it since 2000. Methane concentrations have increased 2.5 times since the start of the Industrial Age, with almost all of that occurring since 1980. So changes are coming faster, and they're becoming more significant."

The concentration of carbon dioxide in Earth's atmosphere is currently at nearly 412 parts per million (ppm) and rising. This represents a 47 percent increase since the beginning of the Industrial Age, when the concentration was near 280 ppm, and an 11 percent increase since 2000, when it was near 370 ppm. Crisp points out that scientists know the increases in carbon dioxide are caused primarily by human activities because carbon produced by burning fossil fuels has a different ratio of heavy-to-light carbon atoms, so it leaves a distinct "fingerprint" that instruments can measure. A relative decline in the amount of heavy carbon-13 isotopes in the atmosphere points to fossil fuel sources. Burning fossil fuels also depletes oxygen and lowers the ratio of oxygen to nitrogen in the atmosphere.



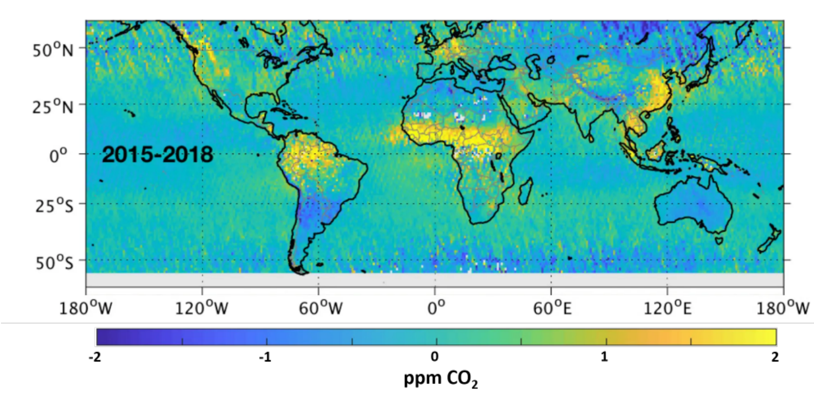
A chart showing the steadily increasing concentrations of carbon dioxide in the atmosphere (in parts per million) observed at NOAA's Mauna Loa Observatory in Hawaii over the course of 60 years. Measurements of the greenhouse gas began in 1959. Credit: NOAA

OCO-2, launched in July 2014, gathers global measurements of atmospheric carbon dioxide with the resolution, precision and coverage needed to understand how this important greenhouse gas — the principal human-produced driver of climate change — moves through the Earth system at regional scales, and how it changes over time. From its vantage point in space, OCO-2 makes roughly 100,000 measurements of atmospheric carbon dioxide every day.



Artist's rendering of NASA's Orbiting Carbon Observatory (OCO)-2 in orbit above the U.S. upper Great Plains. Credit: NASA-JPL/Caltech

Crisp says OCO-2 has already provided new insights into the processes emitting carbon dioxide to the atmosphere and those that are absorbing it.



Map of the most persistent carbon dioxide "anomalies" seen by OCO-2 (i.e. where the carbon dioxide is always systematically higher or lower than in the surrounding areas). Positive anomalies are most likely sources of carbon dioxide, while negative anomalies are most likely to be sinks, or reservoirs, of carbon dioxide. Credit: NASA/JPL-Caltech

"For as long as we can remember, we've talked about Earth's tropical rainforests as the 'lungs' of our planet," he said. "Most scientists considered them to be the principal absorber and storage place of carbon dioxide in the Earth system, with Earth's northern boreal forests playing a secondary role. But that's not what's being borne out by our data. We're seeing that Earth's tropical regions are a net *source* of carbon dioxide to the atmosphere, at least since 2009. This changes our understanding of things."

Measurements of atmospheric carbon dioxide in the tropics are consistently higher than anything around them, and scientists don't know why, Crisp said. OCO-2 and the Japan Aerospace Exploration Agency's Greenhouse gases Observing SATellite (GOSAT) are tracking plant growth in the tropics by observing solar-induced fluorescence (SIF) from chlorophyll in plants. SIF is an indicator of the rate at which plants convert light from the Sun and carbon dioxide from the atmosphere into chemical energy.

"We're finding that plant respiration is outstripping their ability to absorb carbon dioxide," he said. "This is happening throughout the tropics, and almost all of the time. When we first launched OCO-2, our first two years of on-orbit operations occurred during a strong El Niño event, which had a strong impact on global carbon dioxide emissions. Now we have more than five years of data, and we see that the tropics are always a source (of carbon dioxide), in every season. In fact, the only time we see significant absorption of carbon dioxide in the tropics is in Africa during June, July and August. So that's half the story.