Aircraft observations point to near neutral carbon dioxide exchange in northern tropical Africa

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African biomass burning plumes seen from the wing the NASA DC-8 as it descends to Ascension Island during the ATom-1 mission. Credit: Samuel Hall, NSF NCAR

The forests and grasslands of northern tropical Africa take in about as much carbon dioxide in the wet season as they release in the dry season, according to a new study based on observations from aircraft. The findings contradict earlier research that relied on satellite data and found that these ecosystems may be adding significantly more carbon to the atmosphere than they absorb over the course of a year.

The research, published in the journal *Global Biogeochemical Cycles*, highlights the difficulty of measuring carbon dioxide from space and the need for more frequent and robust observations from both the air and ground.

The research was led by the U.S. National Science Foundation National Center for Atmospheric Research (NSF NCAR).

"These findings help us better understand how carbon is moving through our complex Earth system, which is critical to accurately projecting the impacts of society's continued emissions of greenhouse gases," said NSF NCAR scientist Benjamin Gaubert, who led the study. "It's also great news that northern tropical Africa is not the large source of carbon that satellite observations suggested."

The NSF NCAR research team was interested in verifying whether the fluxes implied by satellite-based observations of carbon dioxide over northern tropical Africa in previous research were correct. The earlier work using satellite data over land suggested that the ecosystems of the region were a significant net source of carbon dioxide, potentially releasing more than a billion tons of carbon into the atmosphere annually. That amount is equivalent to about 10% of annual emissions from the burning of fossil fuels.

The possibility that these ecosystems were such a large carbon source was a surprise and challenged the scientific community's existing understanding of Earth's carbon cycle. The new study sought to determine whether the existing understanding of the carbon cycle was flawed or whether the estimates based on satellite observations were skewed.

An accurate understanding of the carbon cycle is critical for projecting how the climate will change and also for measuring the success of carbon-reduction efforts. While emissions of greenhouse gases are causing the concentration of carbon dioxide in the atmosphere to increase, the extent of that increase depends not just on the amount of carbon emitted, but also on the amount of carbon absorbed and released by the ocean and land surface. Forests, for example, absorb atmospheric carbon as they grow, but trees also emit carbon when they burn or decompose.

Similarly, the world's oceans act as a net carbon sink, but the ocean surface is always exchanging carbon with the atmosphere, absorbing and releasing the gas depending on photosynthesis by algae, temperature, and other factors.

But it has been scientifically challenging to determine where the carbon sources and sinks are, how much carbon is exchanged, and when. This is due, in part, to a scarcity of local atmospheric carbon dioxide observations, especially over many regions of the global South.

To supplement local observations, scientists have turned to satellite-based instruments, which allow for a global view. But measuring carbon dioxide with the necessary accuracy from space is difficult. For example, aerosols in the atmosphere, which can be produced by biomass burning and industrial processes, confound the ability of a satellite to accurately retrieve carbon dioxide concentrations. Because of this and other challenges, it's important to verify satellite data with aircraft and ground-based observations.

For the new study, the research team relied on airborne measurements of carbon dioxide collected during NASA's Atmospheric Tomography Mission (ATom). These measurements were taken during four, month-long global missions—one in each season—between 2016 and 2018.

The measurements included transects over the Atlantic ocean downwind of Africa. The researchers compared those observations to the concentrations of carbon dioxide that models would expect in the same locations if the earlier research was correct. They found that the aircraft observations were lower than the concentrations predicted by the models. In fact, the aircraft measurements pointed to nearly neutral net carbon emissions from northern tropical Africa, indicating that satellite measurements taken of atmospheric carbon dioxide in the region during the dry season are too high.

However, the authors noted that carbon dioxide data from satellites has improved carbon flux estimates for northern tropical Africa in other seasons, and that corrections to the satellite data continue to improve over time. Both the aircraft and satellite observations agreed that more carbon dioxide was absorbed during the wet season, and more was also released during the dry season, than researchers had previously inferred from surface observations alone.

There is growing urgency to develop comprehensive monitoring systems to support planning and validating greenhouse gas mitigation efforts, as demonstrated in the White House's National Strategy to Advance an Integrated U.S. Greenhouse Gas Measurement, Monitoring, and Information System, released in November. The success of these efforts will depend on our ability to more accurately account for carbon dioxide exchange with the natural components of the Earth system, as advanced by this study. This research highlights, in particular, the value of aircraft observations.

"Aircraft are invaluable for sampling the atmospheric interior," said NSF NCAR scientist Britton Stephens. "They help us to bridge between ground-based and satellite observations of carbon dioxide, and they help us overcome the limitations of both."

More information: Benjamin Gaubert et al, Neutral Tropical African CO2 Exchange Estimated From Aircraft and Satellite Observations, *Global Biogeochemical Cycles* (2023). DOI: 10.1029/2023GB007804

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