Scientists call for more eyes in the sky amidst alarming climate change

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In the midst of a record-breaking global heat wave, a recent international study presented a terrifying worst-case scenario: that "hothouse Earth" conditions are likely to prevail even if the world meets the carbon reduction levels of the Paris Agreement. Lead author Will Steffen from the Australian National University and Stockholm Resilience Centre said, "Human emissions of greenhouse gas are not the sole determinant of temperature on Earth. Our study suggests that human-induced global warming of 2°C may trigger other Earth system processes, often called 'feedbacks,' that can drive further warming – even if we stop emitting greenhouse gases."

Feedback processes include the release of methane from Arctic ices melted by high ocean temperatures, reduction of North American snow cover and Amazon rainforest dieback. These processes compound the inherent difficulty of studying the climate on a global scale, and substantial disagreements exist between models that attempt to predict the future of climate change.

Now, in an epic-scale Perspective column in the *Proceedings of the National Academy of Sciences*, researchers from Goddard Space Flight Center, the Jet Propulsion Laboratory and the University of Oklahoma describe the difficulties of teasing apart carbon cycle feedbacks, and how satellite observations are already making a significant contribution to resolving these uncertainties.

Regarding carbon cycle-climate feedbacks, the authors write, "If these feedbacks change with changing climate, which is likely, then the effect of the human enterprise on climate will change." In other words, climate feedback mechanisms alter the climate, which in turn affects the incidence and severity of feedbacks. "The current uncertainty of flux estimates of (the perturbation due to fossil fuel emission) is evidenced, in part, by disagreements between top-down derived flux estimates and bottom-up inventory methods," they write.

The paper is a catalog of the intimidating uncertainties climate scientists are confronting as they try to bring a holistic picture of climate trends into focus, including carbon and methane cycling. For instance, the authors observe that ocean models largely agree about global carbon inventories—25 percent of anthropogenic carbon is believed to be sequestered in the oceans—but the fact that there is no consensus about the specific regions responsible calls into question this seeming agreement.

The authors are emphatic about the utility of satellite observations for resolving such uncertainties. Satellites can observe column CO_2 emissions, even in areas of the world with poor reporting resources, which is key to understanding carbon cycling mechanisms in the tropics. A lack of current reporting from such regions greatly inhibits climate modeling, and existing models have greatly divergent conclusions as a result.

Satellites can also measure net fluxes in emissions by their correlation with solar-induced fluorescence (SIF) in the atmosphere. By sampling the oxygen-A band, satellites can determine the optical path length through the atmosphere. SIF is directly related to photosynthesis, so these observations provide measurements of net flux as well as gross fluxes.

Finally, the authors cite the long track records of satellites monitoring carbon monoxide produced by the burning of fossil fuels and biomass. Using a combination of these observation and measurement techniques, researchers could reduce uncertainties about climate feedbacks, tease apart the relationships between feedback mechanisms and anthropogenic carbon emissions, and raise the resolution and accuracy of their climate models. This is especially important as climate impacts of atmospheric carbon and methane are becoming alarmingly evident in weather patterns.

More information: Observing carbon cycle–climate feedbacks from space. *Proceedings of the National Academy of Sciences* DOI: 10.1073/pnas.1716613115

Abstract
The impact of human emissions of carbon dioxide and methane on climate is an accepted central concern for current society. It is increasingly evident that atmospheric concentrations of carbon dioxide and methane are not simply a function of emissions but that there are myriad feedbacks forced by changes in climate that affect atmospheric concentrations. If these feedbacks change with changing climate, which is likely, then the effect of the human enterprise on climate will change. Quantifying, understanding, and articulating the feedbacks within the carbon–climate system at the process level are crucial if we are to employ Earth system models to inform effective mitigation regimes that would lead to a stable climate. Recent advances using space-based, more highly resolved measurements of carbon exchange and its component processes—photosynthesis, respiration, and biomass burning—suggest that remote sensing can add key spatial and process resolution to the existing in situ systems needed to provide enhanced understanding and advancements in Earth system models. Information about emissions and feedbacks from a long-term carbon–climate observing system is essential to better stewardship of the planet.