Can photosynthesis be measured over large areas? Scientists find a way

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Cameras and sensors installed on a tower in a Massachusetts forest continuously collect environmental data, including on photosynthetically active radiation. Credit: Jim Tang

A research team led by geoscientists from Brown University and the Marine Biological Laboratory has provided some crucial ground-truth for a method of measuring plant photosynthesis on a global scale from low-Earth orbit.

The researchers have shown that chlorophyll fluorescence, a faint glow produced by plant leaves as a byproduct of photosynthesis, is a strong proxy for photosynthetic activity in the canopy of a deciduous forest. That glow can be detected by orbiting satellites and could be used to monitor global photosynthetic activity in real time.

"We show that fluorescence is tightly coupled to photosynthesis, capturing both daily and seasonal fluctuations," said Xi Yang, a postdoctoral researcher at Brown and the study's lead author. "This is the first time anyone has linked fluorescence to photosynthesis over a long time scale in a deciduous forest and validated orbital measurements of fluorescence with ground-based measurements."

The findings are published in the journal *Geophysical Research Letters*. Yang led the work as a graduate student in the Brown-Marine Biological Laboratory (MBL) graduate program, working with Brown geoscientist Jack Mustard and MBL associate scientist Jianwu (Jim) Tang.

Catching photons on the rebound

When plants photosynthesize, chlorophyll molecules in leaves absorb photons from sunlight. The plant then converts the energy from those

photons into sugar and other carbohydrates using carbon dioxide absorbed from the atmosphere as a carbon source. But not all the photons absorbed by chlorophyll are for photosynthesis. Around 1 percent of them are re-emitted as lower energy photons, which creates the faint glow known as fluorescence.

The glow isn't visible to the naked eye, but a few years ago scientists from NASA and the Japanese Aerospace Exploration Agency found that spectrometers aboard climate satellites could detect fluorescence coming from croplands and forest canopies. That raised the possibility of measuring photosynthesis on a global scale.

Currently, the gold standard for measuring photosynthesis involves directly measuring the exchange of carbon dioxide gas between plants and the air directly around them. The technique, called eddy covariance, relies on tower-mounted detectors that can only monitor an area of a few square kilometers. Even with hundreds of towers around the world, eddy covariance can still only provide a patchwork of data. That's part of the reason scientists have looked to orbital instruments to get a broader view of photosynthesis.

Scientists are just beginning to measure the extent to which orbital measurements of fluorescence correlate to ground-based measurements of photosynthesis. A few studies have shown fluorescence to be a good proxy over cropland, but there hadn't been any studies looking at the link to a forest canopy over an extended period. This latest study fills that gap.

For the study, the researchers made use of the Harvard Forest in Massachusetts. Over the course of a full summer, they compared photosynthesis measurements from the forest's eddy covariance tower with fluorescence data taken with a tower-mounted spectrometer above the forest. The readings from the ground-based spectrometer were then

compared to readings from an orbital instrument aboard the European Space Agency's GOME-2 satellite.

The study showed that fluorescence measurements from both the ground-based spectrometer and the satellite were tightly correlated to photosynthesis as measured by eddy covariance, capturing both day-to-day fluctuations and fluctuations that occurred over the course of the summer.

"The findings help to establish an empirical link between fluorescence and photosynthesis and help to validate the satellite product with ground-based observations," Yang said.

The fact that fluorescence appears to capture daily fluctuations of photosynthesis gives it an advantage over other remote sensing methods. One current method uses an index of greenness as a proxy for plant production. But greenness can sometimes lag well behind plant stress, Yang said, so fluorescence could be a much better way of getting real-time data.

"Measuring fluorescence is the hottest topic in remote sensing today. It is transforming how we measure photosynthesis on local to global scales," said Jack Mustard, professor of earth, environmental and planetary sciences and a fellow in the Institute at Brown for Environment and Society. "This work is fundamental in linking the signature of photosynthesis from leaf to orbit."

More information: Yang, X., J. Tang, J. F. Mustard, J.-E. Lee, M. Rossini, J. Joiner, J. W. Munger, A. Kornfeld and A. D. Richardson (2015). Solar-induced chlorophyll fluorescence that correlates with canopy photosynthesis on diurnal and seasonal scales in a temperate deciduous forest. *Geophys. Res. Lett.* 42, DOI: 10.1002/2015GL063201

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