Solar induced fluorescence (SIF) as an indicator of photosynthesis

David Bombard, Bowdoin Class of 2022

Photosynthesis is the chemical process green plants perform to convert carbon dioxide and water into sugar with oxygen as a byproduct. Sunlight is absorbed by colored pigments (chlorophyll, which give plants their green color, and carotenoids) to drive this reaction. Energy absorbed from sunlight is allocated to three different pathways: photosynthesis, heat dissipation, and solar induced fluorescence. Solar induced fluorescence (SIF) is the energy dissipated by plants in the form of infrared light due to exposure to natural sunlight. This energy is often dissipated (whether through heat or light) to avoid damage to the plant as excess energy not used for photosynthesis is very reactive and difficult to store. There is evidence that solar induced fluorescence is related to photosynthetic capacity and plant stress. Plants typically dissipate more energy when performing higher rates of photosynthesis, so, higher SIF values in plants usually correlates to higher photosynthetic levels. When plants are stressed (naturally or artificially), photosynthetic capacity often decreases along with SIF. However, SIF depends on several environmental variables and is not always proportional to photosynthesis in every circumstance. Previous research has shown the two correlate closely when measuring SIF of an entire forest from a tower above and averaging the values over one year (Magney et al., 2019).

Solar induced fluorescence can be measured by passive sensors that detect quantities of infrared radiation. This measurement can be observed on very different scales, from a tripod mounted sensor recording data of a forest face (as we used), to sensors mounted on airplanes or satellites measuring SIF of entire forests. No matter the scale, reliable relationships between photosynthesis, SIF, and many other environmental factors at different temporal and spatial scales must be determined before any conclusions can be drawn with confidence based on SIF data alone.

In mid-July 2019, Dr. Barry Logan, Jaret Reblin (a laboratory instructor in biology who works closely with Dr. Logan), Dalia Tabachnik (‘21), and myself packed our equipment and drove to the National Institute of Standards and Technology (NIST) main campus in Gaithersburg, MD. Together with several colleagues from Boston University, Hunter College, and a staff scientist at NIST, we worked to correlate photosynthesis and SIF at a forest edge on NIST property..

This required measuring SIF and photosynthetic rates, then altering rates of photosynthesis and remeasuring SIF to see if any measurable change had occurred. Photosynthetic rates were altered using two methods: a hormone spray and a branch pressure chamber. The hormone spray was a solution of abscisic acid (ABA), a hormone found naturally in many plants, that signals the redirection of resources. The pressure chamber method involved attaching a pressure chamber around a single branch and pressurizing the chamber to 1000 psi for 10 minutes using compressed CO_2. This forced gas into the plants’ vascular system, or xylem, preventing nutrients and water from reaching the affected branch. To ensure we had altered the rate of photosynthesis using these methods, we remeasured photosynthesis at the leaf level using a LiCor-6800 infrared gas analyzer while SIF was measured using a telescope 100 meters from the forest edge.

We successfully reduced photosynthesis by 70-80% using both methods (ABA hormone spray and pressure chamber). After preliminary analysis of our results, we found no significant correlation between SIF and photosynthesis in our experiment. This finding is valuable as it places limitations on the use of SIF as a proxy for photosynthesis under some temporal and spatial scales. It’s clear SIF can be used as a proxy when averaged over an entire growing season (Magney et al., 2019), but not at shorter timeframes and distances as our experiment showed.

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References: Magney, T. S., Bowling, D. R., Logan, B. A., Grossmann, K., Stutz, J., Blanken, P. D., … Frankenberg, C. (2019). Mechanistic evidence for tracking the seasonality of photosynthesis with solar-induced fluorescence. Proceedings of the National Academy of Sciences, 201900278. doi: 10.1073/pnas.1900278116