Solar-Induced Chlorophyll Fluorescence (SIF) emitted from vegetation can be used as a constraint for photosynthetic activity and is now observable on a global scale from space1,2. SIF observations have the potential to provide new and unique insights into Gross Primary Production (GPP) of vegetation and thus the global carbon budget3.

We report on the development of an automated remote sensing system for ground-based SIF measurements (http://www.kiss.caltech.edu/study/photosynthesis/technology.html) and show initial results of the last measurements of the SIF signal with the new instrument.

SIF as a constraint for photosynthesis

1. SIF as a constraint for photosynthesis

• Solar-Induced Chlorophyll Fluorescence (SIF) emitted from vegetation can be used as a constraint for photosynthetic activity and is now observable on a global scale from space1,2. SIF observations have the potential to provide new and unique insights into Gross Primary Production (GPP) of vegetation and thus the global carbon budget3.

• The dependence of the SIF signal on environmental conditions, such as water stress, radiation, etc. remains poorly understood on a leaf-to-canopy scale, thus limiting our ability to explore the full potential of SIF observations.

• We report on the development of an automated remote sensing system for ground-based SIF measurements (http://www.kiss.caltech.edu/study/photosynthesis/technology.html) and show initial results of the last measurements of the SIF signal with the new instrument.

2. Background of SIF

• SIF has been used in photosynthesis studies for several decades4

• SIF is an electrophysiological signal emitted between 660 – 800 nm by chlorophyll-a (CHL-a) leaf pigments during photosynthesis4:

\[ \Phi_F \]

Chi-a absorbs photons of blue and red light very efficiently. Absorption of a blue photon by CHL-a raises an electron from S_1 to an orbital of a highly excited state. Absorption of a red photon produces the state S_2, directly from there the e^- can relax to the ground state via emission of a chlorophyll fluorescence photon4.

• Probability of photons being emitted as chlorophyll fluorescence is directly proportional to the product of absorbed photosynthetic radiant and the fluorescence yield \( \Phi_F \):

\[ \Phi_F = \frac{\text{rate constants: } k_r \text{, } k_o \text{, } k_{\text{dec}} \text{, } k_{\text{heat} \text{ quenching}}} \]

3. Method

• The optical depth change within solar Fraunhofer lines and the O_2-A band due to SIF is used to detect SIF via remote sensing in the red region of the solar spectrum (Figure 3).

• The SIF measurement technique used here is based on decades of experience using Differential Optical Absorption Spectroscopy (DOAS)6,7, an established method to measure atmospheric trace gases.

• The SIF signal can be retrieved in the DOAS fitting procedure using an additive polynomial P. The optical density \( r \), which is the logarithmic ratio of the incident and attenuated intensity \( I_0 \) and \( I \) can be written as:

\[ r = \ln \left( \frac{I_0}{I} \right) = \sum_i a_i \cdot P(i) + \text{constant not an instrument parameter} \]

4. Instrumental set-up

• The telescope set-up also includes a commercial photosynthetic active radiation (PAR) sensor (LI-COR Li-190S) to provide PAR quantity as an independent measurement, as incoming PAR is the driver of photosynthesis.

5. First SIF measurements with test instrument on the rooftop of the UCLA Mathematics Sciences building

• The SIF signal of a single leaf of a cast iron plant (Aspidistra elatior) (after 11 a.m.) can be clearly distinguished from a diffuser signal (before 11 a.m.).

6. Summary

• We developed an automated remote sensing system for ground-based SIF measurements of plants.

• Theoretical studies show that the relative uncertainty of the SIF retrieval is approximately 9%. Initial test measurements on the rooftop of the UCLA Mathematical Sciences building show that we can clearly detect the SIF signal and distinguish vegetation (trees, leaves) from non-vegetation (walls or the sky). A clear SIF signal can be detected in the SIF retrieval (blue line) (Figure 8).

• We are currently working on understanding the influence of clouds, the measurement geometry, and the movement of the leaves on the SIF signal.

• Such instruments will be built and deployed at various locations to study the variations in photosynthetic activity of different plants in field experiment and long-term observation mode settings.

Acknowledgements:


2. Background of SIF


5. Porcar-Castell et al., 2014: Linking chlorophyll a fluorescence to photosynthesis for remote sensing applications: mechanisms and challenges.
