MEDWIN PUBLISHERS
Committed to Create Value for Researchers

Open Access Journal of Agricultural Research
ISSN: 2474-8846

Research Progress and Prospect of Solar-Induced Chlorophyll Fluorescence (SIF) in Remote Sensing

Zhai L[1,2]*

[1]College of Biosystems Engineering and Food Science, Zhejiang University, China
[2]Key Laboratory of Spectroscopy Sensing, Ministry of Agriculture and Rural Affairs, China

***Corresponding author:** Li Zhai, College of Biosystems Engineering and Food Science, Zhejiang University, Hangzhou 310058, Key Laboratory of Spectroscopy Sensing, Ministry of Agriculture and Rural Affairs, Hangzhou 310058, China, Tel: +86-157-54304001; Email: lizhai@zju.edu.cn

Commentary
Volume 7 Issue 2
Received Date: August 09, 2022
Published Date: August 18, 2022
DOI: 10.23880/oajar-16000291

Understanding of Solar-induced Chlorophyll Fluorescence (SIF) Remote Sensing

To date, assorted optical-based remote sensing instruments and techniques have been developed vigorously to monitor ecosystem physiological functions and matter-energy exchange status [1-4]. Although numerous studies have investigated remotely sensed reflectance-based vegetation indices (VIs) which characterize the greenness of terrestrial vegetation, ave been utilized to estimate vegetation physiological parameters at larger scales, there is still intrinsic limitation that VIs cannot reflect the live photosynthetic rate. As the most crucial physiological activity of plant, photosynthesis comprises a series of complex and intricate electrochemical reactions in chloroplasts [5]. Firstly, light energy was consumed by leaf chloroplasts in three pathways: photochemical reaction, heat dissipation and fluorescence emission which occur simultaneously and compete with each other [6-8]. And then, chlorophyll a molecules enter an excited state after absorbing photons and release excess energy through vibrational relaxation, after that fluorescence emerged during this process within 650-800 nm and characterized by two peaks (the first peak at 690 nm and the second peak at 760 nm) [7,9,10]. As a by-product of photosynthesis, fluorescence is inextricably linked to photosynthesis which is a sensitive, non-invasive and relatively simple method to observe vegetation photosynthetic status. Therefore, SIF has become a promising tool to detect variable photosynthetic physiological patterns, which may be due to changes of vegetation structure and functional activities, or upscale from canopy to ecosystem and then to global scale [11-14].

Various SIF Observation Platforms and Research Advances

SIF observation platforms are divided into three categories: ground-based, UAV-based and satellite-based observation platforms [15-17]. The satellite-based SIF observations mainly focus on the monitoring of global carbon dioxide cycle, marine ecosystem and climate change, which were usually conducted in rainforests, needleleaf forests, savannas, and croplands according to seasonal variations [18-20]. In addition to the ongoing satellites for SIF and carbon measurement, such as GOSAT (Global Greenhouse Gas Observation by Satellite), GOME-2 (Global Ozone Monitoring Experiment-2) and OCO-2 (Orbiting Carbon Observatory-2), another fluorescence detector (FLEX) dedicated to measure SIF signal exclusively will be in operation since 2023, which will greatly promote global SIF probe [21]. However, UAV-based and ground-based SIF measurements generally benchmark on small scale forest and farmland ecosystems with higher spectral and spatial resolution, which have become popularized among scientists, compared with satellite-based observation platforms [15,22]. Similar to satellite-based observation platform, UAV-based SIF measurements can be imaging data or non-imaging data, which also need rigorous and accurate atmospheric and geometric correction processes due to sensitive atmospheric interference [23]. Owing to limited distance from crop canopy (from centimeter to meter) to sensor which is hardly affected by various atmospheric disturbances (such as dust particles, aerosols, water vapor, etc.), there is no need to carry out strict atmospheric correction for ground-based SIF observation [24]. And also, ground-based SIF signal is an ideal marker for calibration and verification of UAV-based and space-based platforms. Some studies have demonstrated that SIF are sensitive to various stresses (such as drought, heatwave, nitrogen and others), which will be helpful for early warning of natural disasters in agricultural production [25-28]. In addition, there are some new findings in the phenological observation of evergreen broad-leaved forest, deciduous broad-leaved forest and snow covered vegetation on plateau, which also confirmed that SIF can represent the seasonality effect on leaf pigment content in advance than commonly used VIs [29,30].

Challenges and Prospects of SIF in Future Studies

Although various SIF observation platforms can provide promising methodologies for vegetation physiological dynamics monitoring, there are still some challenges in investigating plant growth status in a physical mechanism interpretable way, such as fast and noninvasive acquisition of canopy photosynthesis related traits. And also, associations and combination of SIF signal from different observation platforms remain fully exploration [31,32]. Finally, efforts are urgently required to develop affordable and effective SIF observation sensors for high throughput crop phenotyping in the future.

References

1. White HJ, Gaul W, Sadykova D, León-Sánchez L, Caplat P, et al. (2020) Quantifying large-scale ecosystem stability with remote sensing data. Remote Sens Ecol Conserv 6(3): 354-365.

2. Murray NJ, Keith DA, Bland LM, Ferrari R, Lyons MB, et al. (2018) The role of satellite remote sensing in structured ecosystem risk assessments. Sci Total Environ 619-620: 249-257.

3. Eddy IMS, Gergel SE, Coops NC, Henebry GM, Levine J, et al. (2017) Integrating remote sensing and local ecological knowledge to monitor rangeland dynamics. Ecol Indic 82: 106-116.

4. Zhumanova M, Mönnig C, Hergarten C, Darr D, Wrage Mönnig N (2018) Assessment of vegetation degradation in mountainous pastures of the Western Tien-Shan, Kyrgyzstan, using eMODIS NDVI. Ecol Indic 95: 527-543.

5. https://doi.org/10.1016/j.jadohealth.2015.04.026.

6. Zaman NK, Abdullah MY, Othman S, Zaman NK (2018) Growth and Physiological Performance of Aerobic and Lowland Rice as Affected by Water Stress at Selected Growth Stages. Rice Sci 25(2): 82-93.

7. Baker NR (2008) Chlorophyll fluorescence: A probe of photosynthesis in vivo. Annu Rev Plant Biol 59: 89-113.

8. Kiss AZ, Ruban AV, Horton P (2008) The PsbS protein controls the organization of the photosystem II antenna in higher plant thylakoid membranes. J Biol Chem 283(7): 3972-3978.

9. Johnson MP, Ruban AV (2009) Photoprotective energy dissipation in higher plants involves alteration of the excited state energy of the emitting chlorophyll(s) in the light harvesting antenna II (LHCII). J Biol Chem 284(35): 23592-23601.

10. Deng C, Zhang D, Pan X, Chang F, Wang S (2013) Toxic effects of mercury on PSI and PSII activities, membrane potential and transthylakoid proton gradient in Microsorium pteropus. J Photochem Photobiol B Biol 127: 1-7.

11. Guanter L, Alonso L, Gómez Chova L, Amorós López J, Vila J, et al. (2007) Estimation of solar-induced vegetation fluorescence from space measurements. Geophys Res Lett 34(8): 1-5.

12. MacBean N, Maignan F, Bacour C, Lewis P, Peylin P, et al. (2018) Disney, Correction: Strong constraint on modelled global carbon uptake using solar-induced chlorophyll fluorescence data. Sci Rep 8: 41598.

13. Yao L, Yang D, Liu Y, Wang J, Liu L, et al. (2021) A New Global Solar-induced Chlorophyll Fluorescence (SIF) Data Product from TanSat Measurements. Adv Atmos Sci 38: 341-345.

14. Zhao F, Guo Y, Verhoef W, Gu X, Liu L, et al. (2014) A method to reconstruct the solar-induced canopy fluorescence spectrum from hyperspectral measurements. Remote Sens 6 (10): 10171-10192.

15. Wang N, Suomalainen J, Bartholomeus H, Kooistra L, Masiliūnas D, et al. (2021) Diurnal variation of sun-induced chlorophyll fluorescence of agricultural crops observed from a point-based spectrometer on a UAV. Int J Appl Earth Obs Geoinf 96: 102276.

16. Yang P, van der Tol C, Verhoef W, Damm A, Schickling A, et al. (2019) Using reflectance to explain vegetation biochemical and structural effects on sun-induced chlorophyll fluorescence. Remote Sens Environ 231: 110996.

17. Li J, Zhang Y, Gu L, Li Z, Li J, et al. (2020) Seasonal variations in the relationship between sun-induced chlorophyll fluorescence and photosynthetic capacity from the leaf to canopy level in a rice crop. J Exp Bot

Copyright© Zhai L.

71(22): 7179-7197.

18. Gentine P, Alemohammad SH (2018) Reconstructed Solar-Induced Fluorescence: A Machine Learning Vegetation Product Based on MODIS Surface Reflectance to Reproduce GOME-2 Solar-Induced Fluorescence. Geophys Res Lett 45: 3136-3146.

19. Berkelhammer M (2019) Synchronous modes of terrestrial and marine productivity in the North Pacific. Front Earth Sci 7: 1-13.

20. Wu X, Xiao X, Zhang Y, He W, Wolf S, et al. (2018) Spatiotemporal Consistency of Four Gross Primary Production Products and Solar-Induced Chlorophyll Fluorescence in Response to Climate Extremes Across CONUS in 2012. J Geophys Res Biogeosciences 123(10): 3140-3161.

21. Bandopadhyay S, Rastogi A, Juszczak R (2020) Review of top-of-canopy sun-induced fluorescence (Sif) studies from ground, uav, airborne to spaceborne observations. Sensors (Switzerland) 20(4).

22. Du S, Liu L, Liu X, Guo J, Hu J, et al. (2019) SIFSpec: Measuring solar-induced chlorophyll fluorescence observations for remote sensing of photosynthesis. Sensors (Switzerland) 19(13).

23. Norton AJ, Rayner PJ, Koffi EN, Scholze M (2018) Assimilating solar-induced chlorophyll fluorescence into the terrestrial biosphere model BETHY-SCOPE v1.0: Model description and information content. Geosci Model Dev 11: 1517-1536.

24. Yang X, Shi H, Stovall A, Guan K, Miao G, et al. (2018) FluoSpec 2-an automated field spectroscopy system to monitor canopy solar-induced fluorescence. Sensors (Switzerland) 18 (7).

25. Zhang YJ, Hou MY, Xue HY, Liu LT, Sun HC, et al. (2018) Photochemical reflectance index and solar-induced fluorescence for assessing cotton photosynthesis under water-deficit stress. Biol Plant 62: 817-825.

26. Ben Cheng Y, Middleton EM, Zhang Q, Huemmrich KF, Campbell PKE, et al. (2013) Integrating solar induced fluorescence and the photochemical reflectance index for estimating gross primary production in a cornfield. Remote Sens 5(12): 6857-6879.

27. Springer KR, Wang R, Gamon JA (2017) Parallel seasonal patterns of photosynthesis, fluorescence, and reflectance indices in boreal trees. Remote Sens 9(7): 1-18.

28. Acebron K, Matsubara S, Jedmowski C, Emin D, Muller O, et al. (2021) Diurnal dynamics of nonphotochemical quenching in Arabidopsis npq mutants assessed by solar-induced fluorescence and reflectance measurements in the field. New Phytol 229(4): 2104-2119.

29. Magney TS, Bowling DR, Logan ZA, Grossmann K, Stutz J, et al. (2019) Mechanistic evidence for tracking the seasonality of photosynthesis with solar-induced fluorescence. Proc Natl Acad Sci USA 116: 11640-11645.

30. Meng L, Zhou Y, Gu L, Richardson AD, Peñuelas J, et al. (2021) Photoperiod decelerates the advance of spring phenology of six deciduous tree species under climate warming. Glob Chang Biol 27(12): 1-14.

31. Dalezios K, Dalezios Nr, Adamowski K, Savedrecs 1: 553-568.

32. Gomez Chova L, Tuia D, Moser G, Camps Valls G (2015) Multimodal Classification of Remote Sensing Images: A Review and Future Directions. Proc IEEE 103: 1560-1584.

Copyright© Zhai L.