High-Precision Estimate of Ecosystem-Level Photosynthesis with Solar-Induced Fluorescence Detected by Satellite GOSAT-2

Principal Investigator: Tomomichi KATO
Institution: Hokkaido University, Sapporo City, Hokkaido, JAPAN
Tel: +81-11-706-4942
E-mail: tkato@cen.agr.hokudai.ac.jp
Cooperated by: Graduate School of Life Sciences, Tohoku University
Japan Agency for Marine-Earth Science and Technology
Graduate School of Agriculture, Kyoto University
Faculty of Agriculture, Ryukyus University

[Abstract]

Key Words: Satellite remote-sensing, Ground remote-sensing, High resolution spectral measurement, Single leaf photosynthesis model, 3D radiative transfer model, Carbon cycle

The solar-induced fluorescence (SIF) has been recognized as a desirable proxy of ecosystem-level photosynthesis in large scale and for more accurate detection of carbon uptake by land ecosystem. The Greenhouse gases Observing Satellite (GOSAT) -2 has been recording the SIF at global scale for many years, however, the lack of ground-based validation data reduces its value for accurate detection of terrestrial carbon sequestration with simultaneous use of the computer simulation model of SIF and photosynthesis.

Multiple ground sites for SIF observation have been established over Japan and Alaska, as main sites: Temperate Deciduous Broad leaf forest (Takayama, Gifu), Rice paddy (Tsukuba, Ibaraki), Boreal Evergreen Needle leaf forest (Fairbanks, Alaska), Temperate Evergreen Needle leaf forest (Kiryu, Shiga), Subtropical Evergreen Broad leaf forest (Yona, Okinawa), and as co-operative sites: Wheat field (Histujigaoka, Hokkaido), Bog (Bibai, Hokkaido), Deciduous Needle leaf forest (Fujinomiya, Yamanashi) and Young Decidous Needle leaf forest (Teshio, Hokkaido). The high resolution spectrum were automatically uploaded onto the data server in Hokkaido University, and processed to retrieve the SIF by spectral fitting method. The monthly averaged GOSAT-2 SIF showed the similar seasonality to the ground observation at Takayama, Tsukuba, Alaska, where the available SIF data were the most, indicating the high accuracy in SIF detection by GOSAT-2.

The combined model of both single-leaf scale SIF/photosynthesis and 3 dimensional radiative transfer processes, named as Forest Light Environmental Simulator (FLiES)-SIF, which represents the 3 dimensional structures of SIF and photosynthesis in forest stand, has been developed from the our previous project (2RF-1601). The single-leaf scale behavior on the relationship between SIF and photosynthesis has been examined by laboratory and field experiments, and the site scale validation conducted in broad leaf deciduous forest in Takayama city and rice paddy in Tsukuba city, Japan, represented well the seasonal and seasonal trends in both SIF and Gross Primary Production (GPP) as similar as observed at an eddy flux tower. Finally, the FLiES-SIF constrained by satellite TROPOMI SIF (NASA, as a delegation of next generation satellite GOSAT-GW) produced the spatial SIF map over Japan at very high resolution of 0.05^{o} x 0.05^{o} grid system, while the one by GOSAT-2 produced at low resolution of 1.0^{o} x1.0^{o}, which makes us expect the potential use of SIF product from GOSAT-GW for better estimating the terrestrial ecosystem uptake of atmospheric carbon dioxide via photosynthesis, which could lead to accurate estimation on future climate change.

[References]

1) Nakashima N., Kato T., Morozumi T., Tsujimoto K., Akitsu T.K., Nasahara K.N., Murayama S., Muraoka H. and Noda H.M., 2021: Area-ratio Fraunhofer line depth (aFLD) method approach to estimate solar-induced chlorophyll fluorescence in low spectral resolution spectra in a cool-temperate deciduous broadleaf forest. *Journal of Plant Research*, 134, 713–728. https://doi.org/10.1007/s10265-021-01322-3 (IF=2.629)
2) Sakai Y, Kobayashi H, Kato T, 2020: FLiES-SIF version 1.0: three-dimensional radiative transfer model for estimating solar induced fluorescence, *Geoscientific Model Development* 13 (9), 4041-4066 (IF=6.135)
3) Hikosaka K (2021) Photosynthesis, chlorophyll fluorescence and photochemical reflectance index in photoinhibited leaves. *Functional Plant Biology*, 48:815–826. 10.1071/FP20365 (IF=3.10)
4) Tsujimoto K, Hikosaka K (2021) Estimating leaf photosynthesis of C_3 plants grown under different environments from pigment index, photochemical reflectance index, and chlorophyll fluorescence. *Photosynthesis Research*, 148: 33–46. 10.1007/s11120-021-00833-3 (IF=3.573)
5) Hikosaka K, Tsujimoto K (2021) Linking remote sensing parameters to CO_2 assimilation rates at a leaf scale. *Journal of Plant Research*, 134:695–711. 10.1007/s10265-021-01313-4 (IF=2.629)
6) Kohzuma K, Tamaki M, Hikosaka K (2021) Corrected photochemical reflectance index (PRI) is an effective tool for detecting environmental stresses in agricultural crops under light conditions. *Journal of Plant Research*, 134:683–694. 10.1007/s10265-021-01316-1 (IF=2.629)
7) Kohzuma K, Sonoike K, Hikosaka K (2021) Imaging, screening and remote sensing of photosynthetic activity and stress responses. *Journal of Plant Research*, 134:649–651. https://doi.org/10.1007/s10265-021-01324-1 (IF=2.629)