Detection of ecosystem-level photosynthesis by Sun-Induced Chlorophyll Fluorescence in rice paddy field

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Chlorophyll fluorescence emission from ecosystem induced by sunlight (Sun-Induced Fluorescence: SIF) is now a key factor to accurately estimate the ecosystem-level photosynthesis activity as suggested by satellite studies, and has been recently detected by satellites [Frankenberg et al., 2011; Guanter et al., 2012; Joiner et al., 2013] and measured at field stations [Daumard et al., 2010; Porcar-Castell, 2011]. However, the few example of field-based assessment on the representation ability reduces its value for the availability to better understand the dynamics in CO₂ uptake by land ecosystem.

To elucidate the potential of SIF to estimate ecosystem GPP in typical Asian crop type, the canopy-top SIF was calculated from the spectrum data in Japanese rice paddy field in Mase in central Japan (36°03′N, 140°01′E, 11 m a.s.l.), and compared with eddy-tower measured GPP on half-hourly and daily bases during seven years from 2006 to 2012. The rice (Oriza sativa L.; cultivar Koshihikari) was transplanted in May and harvested in September normally. The SIF was estimated from the spectrums of downward Sun irradiance and upward canopy-reflected radiance measured at the height of 3m above ground by HemiSpherical Spectro-Radiometer (HSSR), consisting of the spectroradiometer (MS-700, Eko inc., Tokyo, Japan) with the full-width at half maximum (FWHM) of 10 nm and wavelength interval of 3.3 nm. The SIF around 760nm (O₂-A band: SIF₇₆₀) was calculated by the modified version of Fraunhofer Line Depth principle [Maier et al., 2003].

The GPP increased almost linearly as both SIF₇₆₀ and APAR (Absorbed Photosynthetically Active Radiation) increased based on monthly-averaged diurnal courses during the growing season in 2006. The slopes of their regression lines differed much among the months in APAR, but in SIF₇₆₀. These nearly constant relationships among the months between GPP and SIF₇₆₀ were kept for all the observation years. The daily SIF₇₆₀ indicated the best performance to represent GPP with the highest determinant coefficient of 0.88 and lowest RMSE of 2.00 μmolCO₂ m⁻² s⁻¹ than other environmental indices did. Thus, those strong relationships of SIF to GPP confirmed that the SIF is a quite useful proxy of ecosystem-level photosynthesis in the rice paddy field.