Multi-layer measurement of upward and downward solar-induced chlorophyll fluorescence in a cool-temperate deciduous broadleaf forest

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Strong representation of Sun-Induced Fluorescence (SIF) for the ecosystem-level photosynthesis activity has been confirmed by satellite studies [*Frankenberg et al*., 2011; *Joiner et al.,* 2013] and by field studies [*Porcar-Castell*, 2011, *Yang et al*., 2015]. However, the lack of taking care of SIF emission below the tree canopy top may underestimate the contribution of sub-canopy and the understory species to total ecosystem CO_2dynamics.
To examine the potential contribution of SIF emission from lower part of tree ecosystem to total ecosystem SIF emission, the downward SIF from tree canopy and upward SIF from understory were calculated from the spectrum data in a cool temperate forest in in central Japan (36˚08′N, 137˚25′E, 1420 m a.s.l.) as well as the upward SIF from canopy top, and the fractional ratios among them are compared on half-hourly and daily bases from 2006 to 2007. The top canopy is dominated by Oak and Birches, and the sub-canopy layer and shrub layers are dominated by *Acer*, *Hydrangea* and *Viburnum species*. The understory is dominated by an evergreen dwarf bamboo *Sasa senanensis*, and covered partially by the seedlings of oak and maple, and herbaceous species [*Muraoka and Koizumi*, 2005]. The SIF was estimated from the spectrums of downward and upward irradiances measured at two heights of 18m and 2m above ground by HemiSpherical Spectro-Radiometer, consisting of the spectroradiometer (MS700, Eko inc., Tokyo, Japan) with the FWHM of 10 nm and wavelength interval of 3.3 nm. The SIF around 760nm (O_2-A band: SIF_{760}) was calculated according to the Fraunhofer Line Depth principle with the additional arrangements.
The SIF emission intensity was kept in the order as canopy upward > canopy downward > understory upward for most of growing season, except for the spring time when the snow was just melted and the Sasa bamboo kept green leaves at the forest floor. On the other hand, the relative intensities among three SIF emissions seem to change temporally. The lower upward/downward SIF ratio and lower understory/overstory SIF ratio in spring and autumn may have showed the phonological trend in foliage volume and chemistry in deciduous forest. On annual average, 43% higher upward SIF from overstory to that from understory showed high contribution of sunlit tissue and leaves in top canopy. The fractional ratio of overstory upward SIF to total of overstory and understory upward SIF of 70% is lower than the overstory ratio to total in NPP of 83% (Ohtsuka et al., 2007) and that in APAR of 82%. Large contribution of understory in upward SIF may indicate that current satellite and field observations may miss the contribution of sub-top crown foliage to ecosystem photosynthesis (GPP).

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