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Seasonal change in photosynthetic function of cedar and cypress forest estimated by tower-based chlorophyll fluorescence

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Estimating the carbon cycle in terrestrial ecosystem is very important for predicting the climate change in future. Remote sensing observation with vegetation indices (VIs, for ex., Normalized Differential Vegetation Index: NDVI) has contributed greatly to estimate terrestrial carbon budget. Because conventional VIs represent generally the greenness of ecosystem, however, there has been the less accuracy especially for winter time in evergreen forest where the VIs tend to overestimate the photosynthesical activity due to its nearly constant greenness.

Chlorophyll fluorescence is emitted from the chlorophyll a and b to release the excess sun-light energy, and has been used for detecting the photosynthesis stress in numerous ecophysiological studies so far. Recently, the chlorophyll fluorescence has been utilized to represent the gross primary production (GPP), ecosystem photosynthesical activity, by the satellite remote sensing studies (e.g. Frankenberg *et al*., 2011, GRL). However, small number of chlorophyll fluorescence observation on the ecosystem scale at the ground reduces its availability despite its highly expected usefulness.

The aim of this study is to clarify the relationships between chlorophyll fluorescence, and photosynthesis and light use efficiency (LUE) by the ground based measurement in coniferous evergreen forest. The observations were carried out in the plantation forest consisting of mature Japanese cedar and Japanese cypress in Takayama, Japan, from 2007 to 2008. Downward and upward spectral radiances were measured with hemispherical spectroradiometer (MS-700, Eko Instruments, Japan) mounted at 30m-high above the ground surface. We calculated the Sun-Induced fluorescence (F_S) around the O_2-A band from the spectral data with the Fraunhofer Line Depth method. The GPP was calculated from the carbon fluxes measured with eddy covariance at the top of the tower (Nagai *et al*., 2012). Both F_S and GPP were averaged for 30 minutes.

F_S showed the strong correlation to GPP linearly in the diurnal course (sunny day (2007/08/10): r^2 = 0.81, cloudy day (2007/07/24): r^2 = 0.87) and logarithmically in the seasonal change (2008 (half-hour): r^2 = 0.68, 2008 (daily): r^2 = 0.87). The GPP was fitted against the F_S for each month by the following rectangular hyperbolic curve:

$$\mathrm{GPP} = \alpha \mathrm{GPP}_{SAT} F_S \,/\, (\mathrm{GPP}_{SAT} + \alpha F_S),$$

where α is the initial slope of the F_S-GPP curve and GPP_{SAT} is the saturated GPP at high F_S emission. These two parameters showed the clear seasonal change. The root-mean-square error (RMSE) calculated for 2008 was 4.56 μmolCO_2 m^{-2} s^{-1}. We also investigated the relationship between F_S and LUE in daily averages. The F_S-LUE relationship could be regressed by logarithm curve for each month (r^2 = 0.46 ~0.95). The seasonal changes in the regression coefficients for F_S-GPP and F_S-LUE curves were thought to be induced by the seasonal variation in the temperature-dependency of photosynthesis and the phenology.

We conclude that F_S can be utilized to estimate GPP and LUE in evergreen forest, and that relationship between F_S and GPP is influenced by environmental factors such as air temperature.

Keywords: Remote sensing, Light use efficiency, Eddy covariance, Carbon cycle