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Detection of chlorophyll fluorescence using the oxygen A-band

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A part of solar radiation energy absorbed by plants is used for photosynthesis. The remaining energy is dissipated into heat, or emitted as fluorescence. The solar-induced chlorophyll fluorescence is directly linked to the instantaneous photosynthesis activity of plants. Therefore, global measurements of chlorophyll fluorescence from space will provide detailed information on carbon fixation. Moreover, if concentration of atmospheric carbon dioxide can be measured simultaneously with chlorophyll fluorescence, we would obtain a unique data set for better understanding of global carbon cycle.

Chlorophyll fluorescence is emitted in the wavelength range of 0.65-0.8 micron, which overlaps oxygen A-band around 0.76 micron. The radiative intensity is estimated to be 2 mW/m^2/str/nm=10^{-8} W/cm^2/str/cm^{-1} at wavelength of 0.76 micron. The TANSO-FTS on board the Japanese Greenhouse Gases Observing SATellite (GOSAT), launched successfully in January 2009, records oxygen A-band spectra with resolution of 0.2 cm^{-1}. Although the primary purpose of recording oxygen A-band spectra is to correct the effects of aerosol and cirrus on the amount of greenhouse gases such as carbon dioxide and methane measured at 1.6 and 2 micron wavelengths, they can also be used to detect chlorophyll fluorescence. In fact, the noise level of TANSO-FTS is about 2x10^{-9} W/cm^2/str/cm^{-1} in the oxygen A-band, which is lower than the intensity of chlorophyll fluorescence.

We have developed an algorithm to derive from oxygen A-band spectra radiative intensity of chlorophyll fluorescence, which is modeled as isotropic emission from the ground surface. The parameters simultaneously derived with chlorophyll fluorescence are ground albedo, surface pressure, temperature shift (deviation from meteorological data, assuming uniform in vertical direction), aerosol optical thickness, and a zero-level offset seen in GOSAT TANSO-FTS L1B spectra. The zero level offset is caused by detector signal non-linearity, and cannot be corrected by a simple filling-in method using Fraunhofer lines.

The Figure shows intensity of chlorophyll fluorescence derived from cloud-screened data during July 26-28 in 2009. The results are preliminary, and have not validated yet. Although the data are sparse, several points may be pointed out to discuss validity of out result. First of all, chlorophyll fluorescence is not detected in desert regions such as Sahara. In addition, strong emission is detected in North America, Eastern Europe, Central Africa, and Southeast Asia. The global distribution of strong fluorescence emission is consistent with the result of Joiner et al. (2011) and Frankenberg et al. (2011), who derived fluorescence emission from GOSAT spectra with a filling-in method of Fraunhofer lines. Further data analyses are now underway to obtain monthly mean and seasonal variation of chlorophyll fluorescence in global scale, as well as simultaneous retrieval of atmospheric carbon dioxide concentration.

Keywords: carbon cycle