Predicting photosynthetic light use efficiency from multi-angular spectral reflectance measurements

Gross primary production (GPP), is a critical component of carbon modeling and can be expressed as,

$$GPP = \varepsilon \times f_{PAR} \times PAR$$

where PAR is the photosynthetically active radiation (400-700nm) and f_{par} is the fraction of PAR that gets absorbed by the plant canopy. ε describes the efficiency, with which this absorbed energy can be used for the production of biomass and is determined by numerous environmental stress factors which reduce the plant's capacity to photosynthesize through a mechanism called photo-protection. On a leaf basis, this mechanism has been closely related to changes in certain leaf pigments, which drive the reflectance at a wavelength of 531 nm (ρ531) and can be measured using the photochemical reflectance index (PRI) comparing ρ531 to an insensitive reference band. Upscaling of this relationship to canopy, stand, landscape and global levels, however, still remains challenging. Short term dynamics existing in plant photosynthesis result in a need to observe canopy reflectance at different times of the day and throughout the growing season. The ongoing measurement of spectra over these diurnal and annual cycles, however, introduces additional complexity due to changes in the viewing geometry caused by differences in sun and observer positions as well as canopy structure. The resulting directional effects cause changes in reflectance brightness that can be ascribed to volume, specular and hotspot effects.

In this study, we utilize permanently established, high spectral resolution measurements of canopy reflectance obtained from an automated tower based platform to establish a PRI-ε relationship for a coniferous forest canopy during a full growing season. A Bidirectional Reflectance Distribution Function (BRDF) is used to account for the directional effects inherent to variations in the sun and viewing geometry. A strong correlation is found between PRI and estimates of ε obtained from gas exchange measurements. Further study is underway to investigate the influence of the radiation regime and canopy structure on ε over the observed viewing directions and time period.