Satellite Retrievals of GPP using the Photochemical Reflectance Index (PRI): Off-nadir MODIS Twice per day; Nadir Hyperion paired with fAPARchl

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MODIS

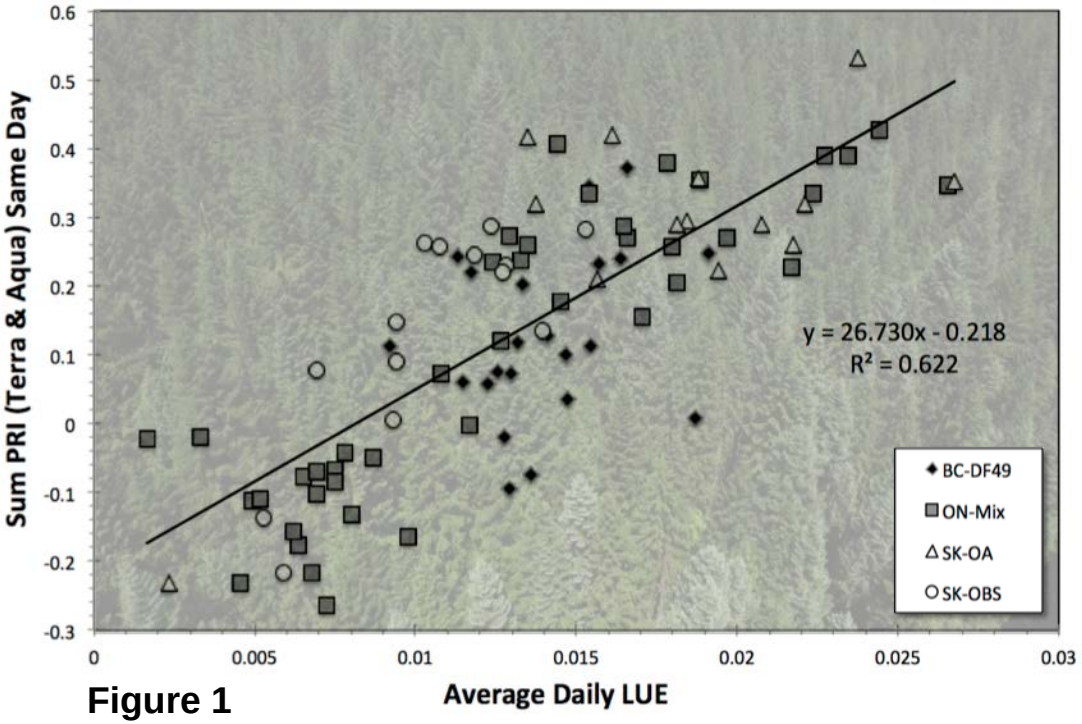

Figure 1

EO-1 Hyperion

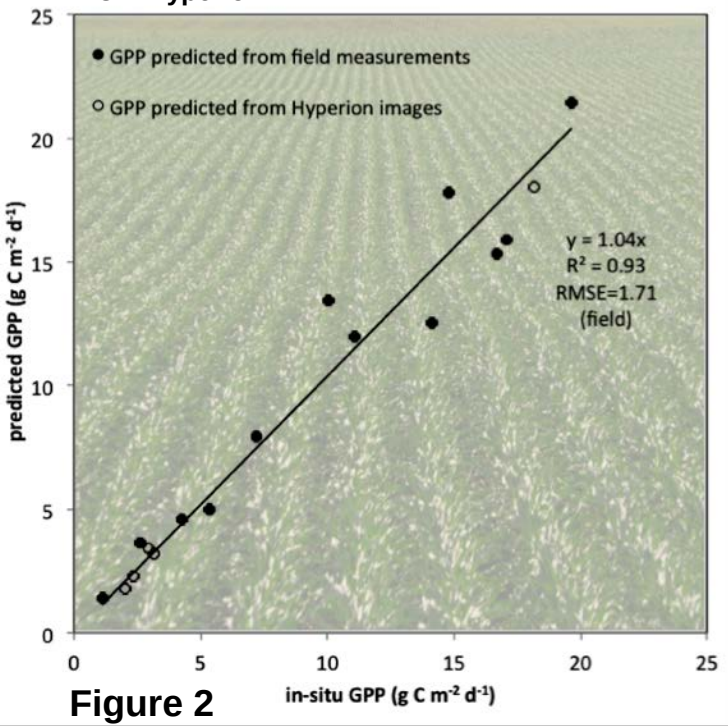

Figure 2

Fig. 1: Our study highlights the value of off-nadir directional PRI reflectance-derived observations from MODIS (at >1 km), and the value of pairing morning (Terra) and afternoon (Aqua) satellite observations to monitor stress responses that inhibit carbon uptake and influence GPP in Canadian forest ecosystems.

Fig. 2: We can also monitor GPP at high spatial resolution (30 m) with nadir observations of PRI paired with fAPARchl, the RT-derived fraction of PAR absorbed by canopy chlorophyll. Carbon dynamics can be tracked with space-based hyperspectral visible through shortwave infrared (VSWIR) imaging spectrometers such as NASA's soon to be decommissioned EO-1/Hyperion and the future Hyperspectral Infrared Imager (HyspIRI) mission.

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References:

Middleton, E.M., K.F. Huemmrich, D.R. Landis, T.A. Black, A.G. Barr, and J.H. McCaughey (2016). Photosynthetic efficiency of northern forest ecosystems using a MODIS-derived Photochemical Reflectance Index (PRI). Rem. Sens. Environment, in review.

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Technical Description of Images:

Figure 1. The daily sum for MODIS PRI computed from Terra + Aqua across the four study sites (n = 92). The daily average LUE was computed as the average of the two flux tower LUE values determined at the AM and PM overpass times (r^2 =0.62; RMSE= 0.013; p < 0.000). **PRIsum** uses "Same-Day" AM and PM MODIS observations from any view (forward, nadir, back, VZA≤45^o). **PRIsum** = 26.73*LUE - 0.2176. Identifying the sites reduced the overall unexplained variation by 6% (r^2 = 0.68). MODIS pixels are >1km. (Middleton et al.)

Figure 2. Comparison between tower flux GPP and the GPP estimated from field measurements and the EO-1/Hyperion 30m images for the USDA-ARS OPE3 experimental watershed (Zhang et al.).

Model #1 (shown): GPP = (0.87 × **fAPARchl** − 0.01) × **fAPARchl** × PAR, R2=0.97 (fAPARchl, fraction of absorbed PAR by chlorophyll).

Model #2 (not shown): GPP = (6.31 × $\mathbf{PRI_{nadir}}$ + 0.91) × **fAPARchl** × PAR, R2=0.93 (PRI, photochemical reflectance index).

Scientific Significance:

- The first study highlights the value of satellite high spectral resolution data, off-nadir directional reflectance observations, and the value of pairing morning and afternoon satellite observations to monitor stress responses that inhibit carbon uptake in Canadian forest ecosystems. In addition, we show that MODIS-PRI values, when derived from either: (i) forward views only, or (ii) Terra/Aqua same day (any view) combined observations, provided more accurate estimates of tower-measured daily LUE than those derived from either nadir or backscatter views or those calculated by the widely used semi-operational MODIS GPP model (MOD17) which is based on a theoretical maximum LUE and environmental data. Consequently, we demonstrate the importance of diurnal as well as off-nadir satellite observations for detecting vegetation physiological processes.
- The second study shows a spectrally based daily $fAPAR_{chl}$-PRI_{nadir} integration GPP model that could be routinely implemented from space. This GPP model integrates these two spectral vegetation parameters related to photosynthetic function: PRI_{nadir} and $fAPAR_{chl}$. Field measurements show that both seasonal PRI_{nadir} and chlorophyll light use efficiency (e_{chl}) are highly correlated with $fAPAR_{chl}$. We also show that foliage $fAPAR_{non\text{-}chl}$ and the ratios $fAPAR_{non\text{-}chl}/fAPAR_{foliage}$ and $fAPAR_{non\text{-}chl}/fAPAR_{chl}$ are useful for vegetation phenology studies. They quantitatively provide the allocation of APAR within the photosynthetic versus non-photosynthetic sections in foliage, which vary with plant functional types and over seasons.