Clarifying Linkages between Canopy SIF and Physiological Function for High Latitude Vegetation

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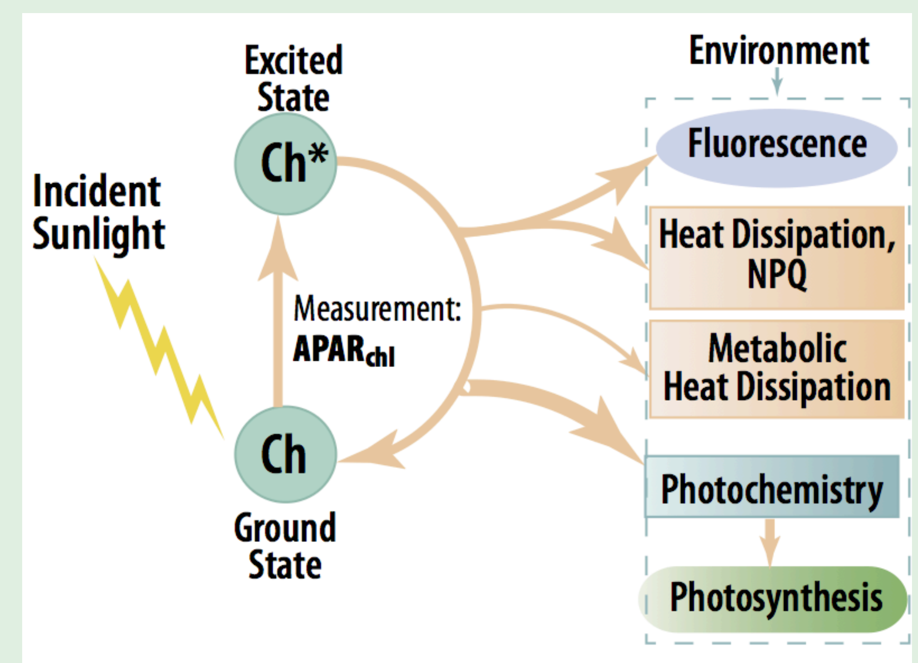
Objectives

Determine *in situ* relationships between solar induced fluorescence (SIF) and vegetation photosynthetic capacity under different environmental conditions at tundra and boreal forest sites, and to scale these observations from leaf-level to the plot/canopy level and finally to apply these relationships to the landscape level across the ABoVE domain using satellite data. The satellite imagery will be used to describe SIF spatial variability along with diurnal, seasonal and multi-year changes; and we will apply appropriate radiative transfer and physiologically-based models to derive gross primary productivity (GPP) and describe its variability across the ABoVE domain, validating the satellite-derived GPP estimates against flux tower data.

Background

Photons absorbed by a chlorophyll molecule may follow three pathways: photochemistry, heat loss (nonphotochemical quenching, NPQ), or Chl fluorescence (ChlF) (Fig.1 left). SIF is closely linked to the photosynthesis and has the potential to estimate GPP at different temporal and spatial scales. SIF may be particularly useful in high latitude evergreen forests where SIF tracks seasonal photosynthetic activity better than the usually used spectral reflectance signal (NDVI) (Fig. 1 right).



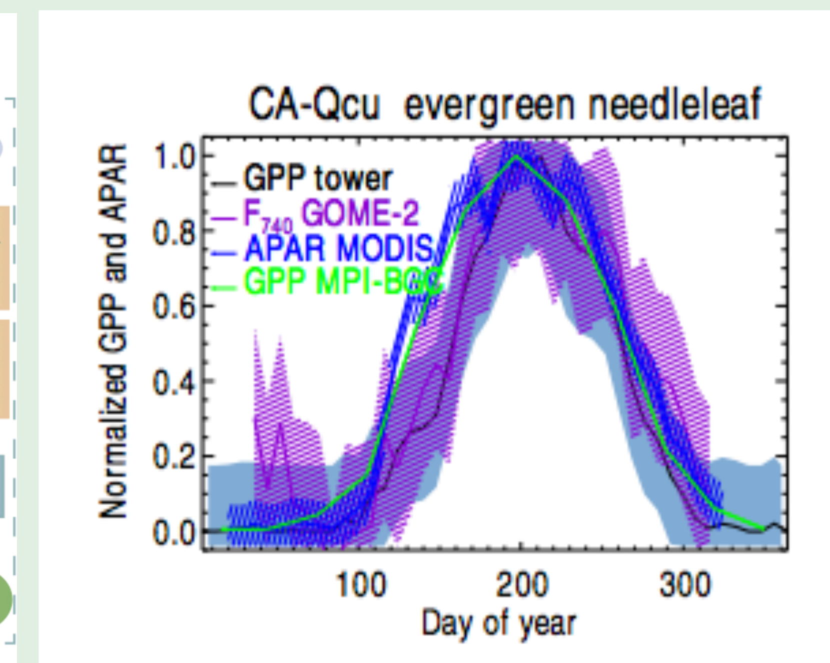


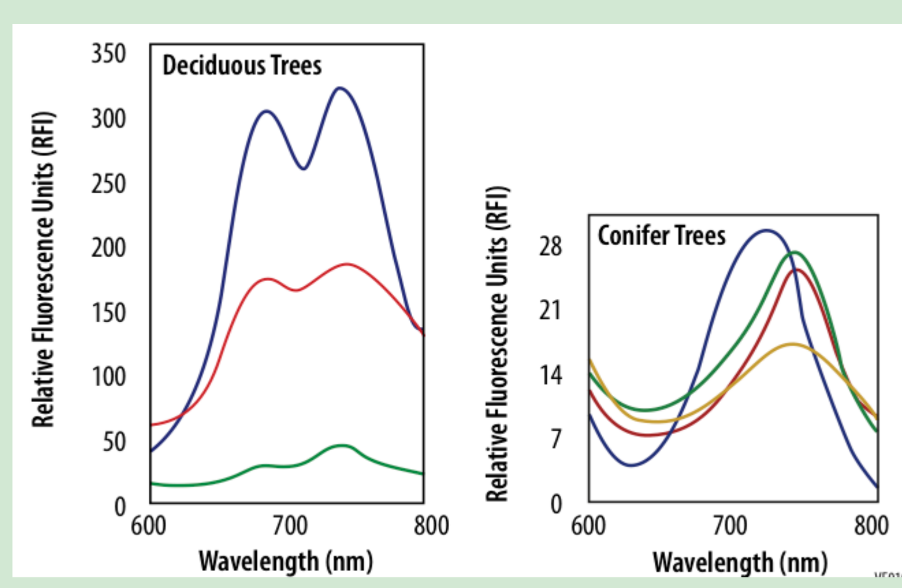
Figure 1. Left: Potential pathways of energy from photons absorbed by chlorophyll in plants. Right: Seasonal patterns for a boreal spruce site of GPP measured at a flux tower, far-red SIF from the GOME-2 satellite, Absorbed Photosynthetically Active Radiation (APAR) derived from MODIS reflectances, and GPP from the MPI-BGC model (Joiner et al. 2014).

Methodology

We will use a multi-scale measurement approach to study the scaling of photosynthesis and ChlF from leaf level to canopy level and up to satellite. Measurements will be collected at two sites: near the NEON Barrow and Caribou-Poker Creeks flux towers, tundra and boreal forest, respectively.

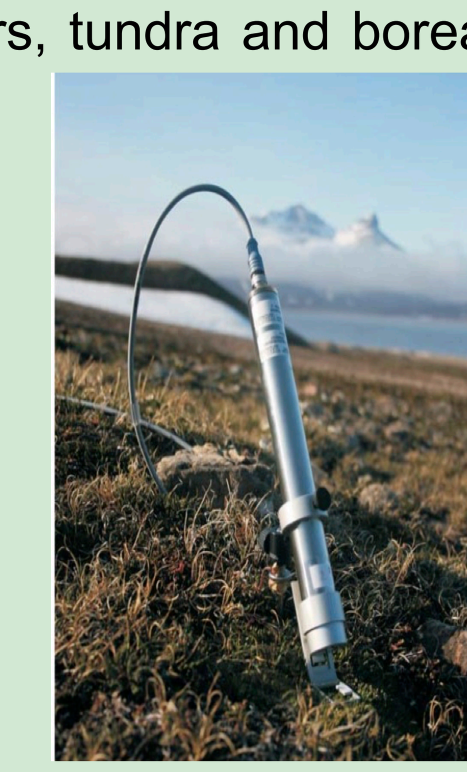
Leaf Level

The FloWat leaf clip measures *in situ* ChlF emission spectra along with spectral reflectance and transmittance.



Measurements of laser-induced F emission spectra indicate significant differences for different boreal forest types (Chappelle and Williams 1987).

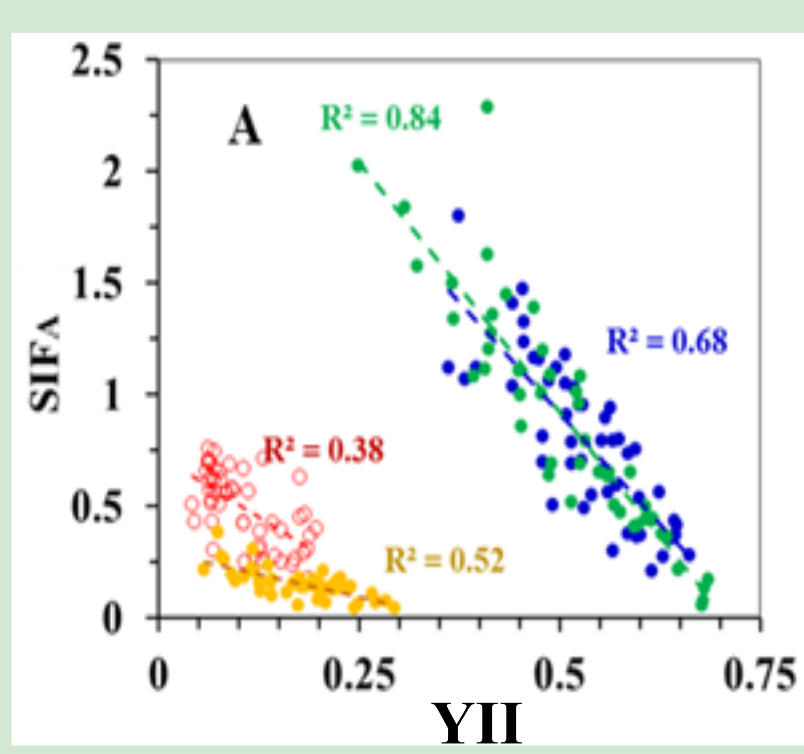
Li-Cor 6400 uses gas exchange to measure photosynthesis.



The MONITORING-PAM (MoniPAM) makes unattended, long-term measurements of ChlF, providing relative electron transport rates and photochemical yields of photosystem II.

Canopy Level

FLoX (Dual FLuorescence boX) measures canopy SIF and spectral reflectance at ~1 minute intervals.

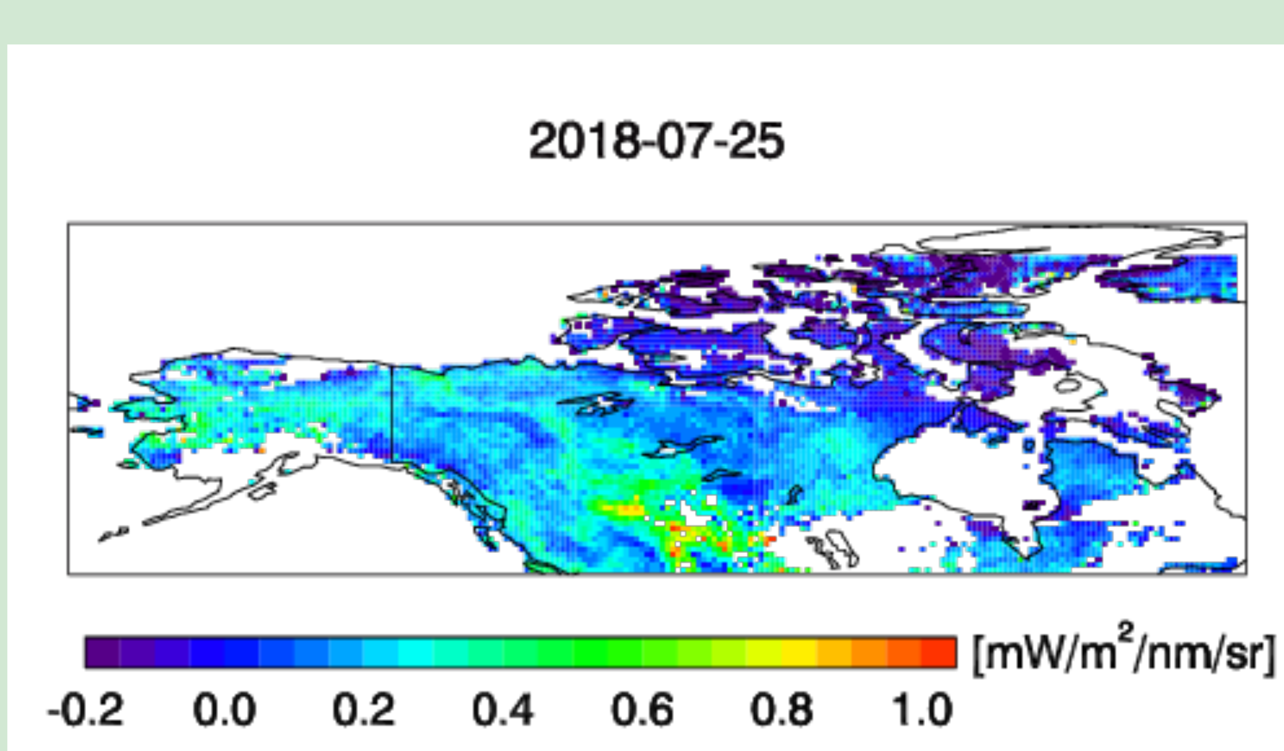


Example of relationships between diurnal observations of canopy SIF from FLoX and leaf level yield to PSII from MoniPAM (YII) for corn on selected days in different parts of the growing season: young (blue), mature green), senescing: initial (red), and advanced (yellow) (Campbell et al. 2019).

Ecosystem CO_2 fluxes from NEON flux towers using eddy covariance techniques.

Spatial variability in spectral reflectance and SIF measured with QEPro high spectral resolution spectrometers along transects sampled through the growing season.

Region



Daily SIF retrievals from TROPOMI over the ABoVE domain. Data are 0.5˚ by 0.5˚ grid with cloud fraction <0.3, a coarser spatial resolution than the 7 km data that will be used in this study.

Impacts on ABoVE Science

Ground measurements will develop the links between photosynthetic processes with chlorophyll fluorescence and spectral reflectance indices. Guided by the ground results, SIF retrieved from satellite can improve assessments of growing season length and ecosystem productivity, providing new insights into the relationships between season length, productivity, carbon balance, and other critical feedback processes for ecosystems across the ABoVE domain.

Acknowledgements

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