CLARIFYING THE LINKAGES BETWEEN CANOPY REFLECTANCE, SIF AND PHYSIOLOGICAL FUNCTION FOR HIGH LATITUDE VEGETATION

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ABSTRACT

Information from remotely sensed solar induced fluorescence (SIF) and spectral reflectance has the potential to provide important information on the physiological status and productivity of terrestrial ecosystems. Information from these optical signals may be particularly useful in the high latitude boreal forest and tundra ecosystems, which represent large areas of the Earth that are difficult to access and are experiencing significant climate change. However, these ecosystems have characteristics such as dominance of evergreen conifers and significant coverage of lichens and mosses that may result in SIF and spectral reflectance signals that differ from other parts of the world. As part of NASA's Arctic-Boreal Vulnerability Experiment (ABoVE) we are studying the relationships between in situ measurements of solar induced fluorescence (SIF), spectral reflectance, and vegetation photosynthetic capacity under different environmental conditions at tundra and boreal forest sites to scale the observed relationships and parameters from the leaf to the plot and canopy levels.

Leaf and canopy measurements collected from the dominant vegetation cover types by numerous campaigns have been assembled and are currently used to parameterize the Soil Canopy Observation, Photochemistry and Energy fluxes model (SCOPE) to simulate SIF emissions by species, and to link the field, airborne and satellite observations to canopy photosynthesis. During the summer of 2019, leaf-level and near-canopy spectral reflectance and SIF were measured on sample canopies from the following boreal vegetation species: sphagnum moss (*Sphagnum spp*., two species), lichen (*Cladonia rangiferina*), black spruce (*Picea mariana*), and cotton grass (*Eriophorum spp*.). Leaf-level reflectance and SIF spectra measurements were collected using the FluoWat leaf clip in conjunction with near-canopy diurnal observations of reflectance and SIF from FLoX (Fluorescence Box) systems. During the summer of 2020, light curves were collected using a Moni-PAM fluorimeter on samples of moss, lichen, and black spruce to describe the dependence of leaf-level photosynthesis on the incoming photosynthetically active radiation (PAR).

Using the measured leaf-level reflectance with the Fluspect leaf model, parameterizations were developed that successfully simulated lichen spectral reflectance, however moss simulations had significant deviations in blue spectral bands. The difference in spectral response among lichen samples was mostly associated with moisture content. The near-canopy reflectance spectra of lichen and moss was significantly different as compared to black spruce. The red reflectance was higher for lichen and moss due to lower chlorophyll content. Spruce had flat NIR reflectance, while NIR reflectance for lichen and moss increased with increasing wavelength. There were likely more non-vegetation components in lichen and moss, which may be influencing the NIR spectral shape more than structure. While the reflectance of moss and lichen varied considerably during the diurnal measurements the reflectance of spruce did not vary much during the diurnal observations, which could be due to spruce having a more stable leaf pigment pool.

Satellite imagery of SIF from TROPOMI were used to describe spatial variability and seasonal and multi-year patterns across the ABoVE domain. Currently, TROPOMI provides the most complete SIF measurement from space with multiple daily observations at higher latitudes, obtained at different view and sun angle geometries (i.e., different various solar and view zenith angles, SZA and VZA). Using SCOPE simulations, with increasing SZA we observed an increase in SIF, at all VZAs. This is due to the increase in path length through the canopy with SZA, thus increasing the amount of intercepted PAR. In general, at lower SZA higher SIF was observed at higher LAI, with exceptions in the hot spots where VZA=SZA and at SZA>70 degrees. The ground measurements and model results will be used with TROPOMI data to interpret the satellite SIF and derive estimates of ecosystem gross primary productivity. Additional ground measurements have been postponed due to COVID-19 pandemic and will be collected in the summers of 2021 and/or 2022. This study develops the important link between plant physiological responses and canopy SIF required to confidently utilize satellite SIF data, and facilitates the use of satellite remote sensing hyperspectral observations, available currently from PRISMA (Italy) and DESIS (DLR, ISS) and in near future from FLEX (ESA, EU), EnMAP (DLR, GDR) and SBG (NASA, USA), to scale ecosystem models to larger spatial scales.

Index Terms— vegetation, reflectance, chlorophyll fluorescence, photosynthesis, SIF, leaf- and canopy-level