Radiative transfer and viewing geometry considerations for remote sensing as a proxy for carbon uptake in boreal ecosystems

Zoe Pierrat[1], Alexander Norton[2], Lea Baskin Monk[1], Nicholas Parazoo[3], Andrew Maguire[4], Katja Grossmann[5], Troy Magney[6], Alan Barr[7], Bruce Johnson[7], and Jochen Stutz[1]

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[2]Jet Propulsion Laboratory, California Institute of Technology
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[4]NASA Jet Propulsion Laboratory
[5]Heidelberg University
[6]University of California Davis
[7]University of Saskatchewan

November 22, 2022

Abstract

The boreal forest plays an important role in the global carbon cycle but has remained a significant source of uncertainty. Remote sensing can help us better understand the boreal forest's role in the global carbon cycle. A faint light signal emitted by plant's photosynthetic machinery, known as solar-induced chlorophyll fluorescence (SIF), is a promising remotely sensed proxy for carbon uptake, also known as gross primary productivity (GPP), due to its connection to photosynthesis and its strong relationship with GPP when observed by satellite. However, SIF and GPP are fundamentally different quantities that describe distinct, but related, physiological processes. The relationship between SIF and GPP is therefore complicated by both physical and ecophysiological controls. In particular, the dynamics of the SIF/GPP relationship are poorly understood under varying viewing directions and light conditions. This is further complicated in evergreen systems where canopy clumping and the presence of needles create a unique radiative environment. We use a combination of tower-based SIF and GPP measurements from a boreal forest field site compared with a coupled biochemical-radiative transfer model to understand illumination effects on the SIF/GPP relationship. We find that GPP is amplified under cloudy sky conditions in both measurements and model results. SIF on the other hand, shows no significant difference between sunny or cloudy sky conditions in modeled results, but does show a difference in measurements. We suggest that these differences may be due to viewing geometry effects that are important for SIF under sunny sky conditions or the presence of clumping. Accounting for the differences in the SIF/GPP relationship therefore is critical for the utility of SIF as a proxy for GPP. In summation, our results provide insight into how we can use remote sensing as a tool to understand photosynthesis in the boreal forest.

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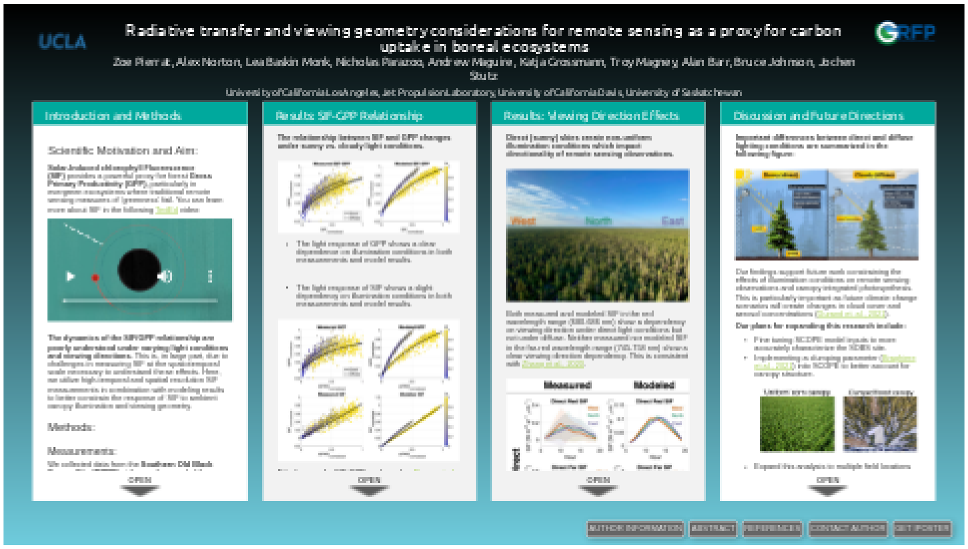

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University of California Los Angeles, Jet Propulsion Laboratory, University of California Davis, University of Saskatchewan

PRESENTED AT:

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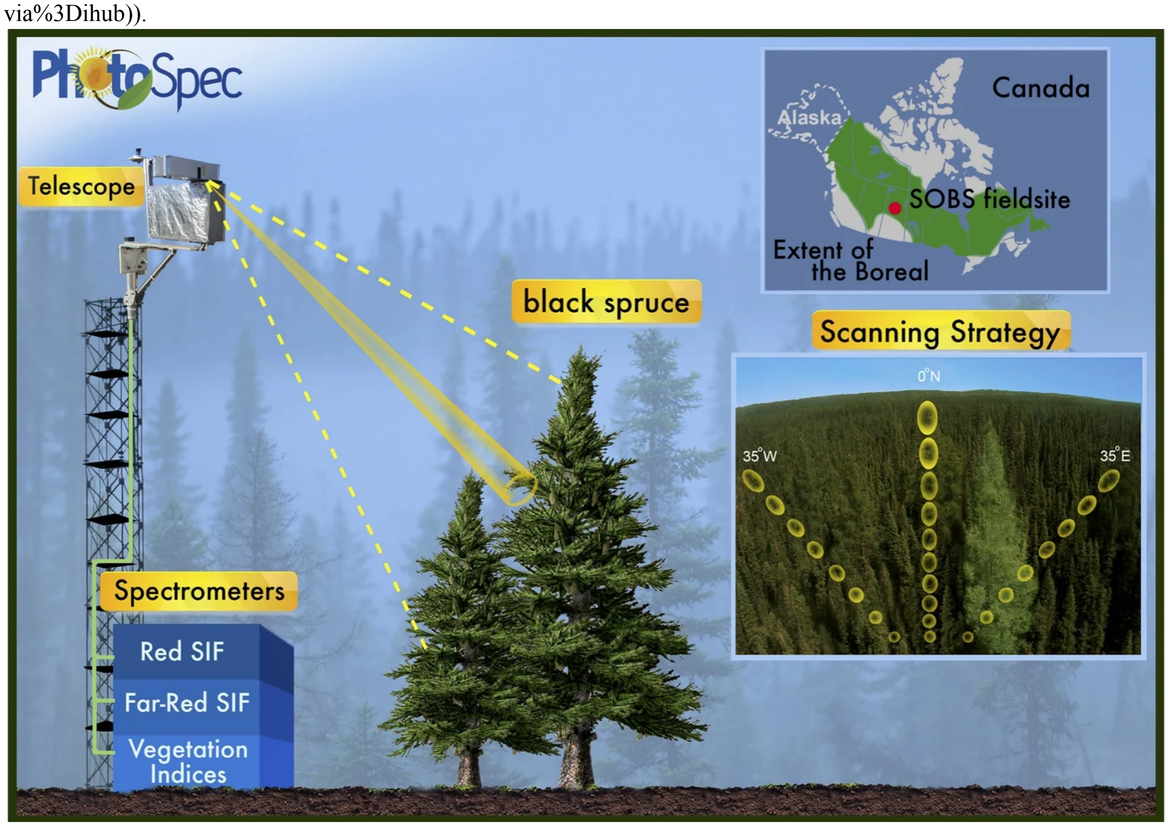

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- We drove the model using input parameters measured from the SOBS field site
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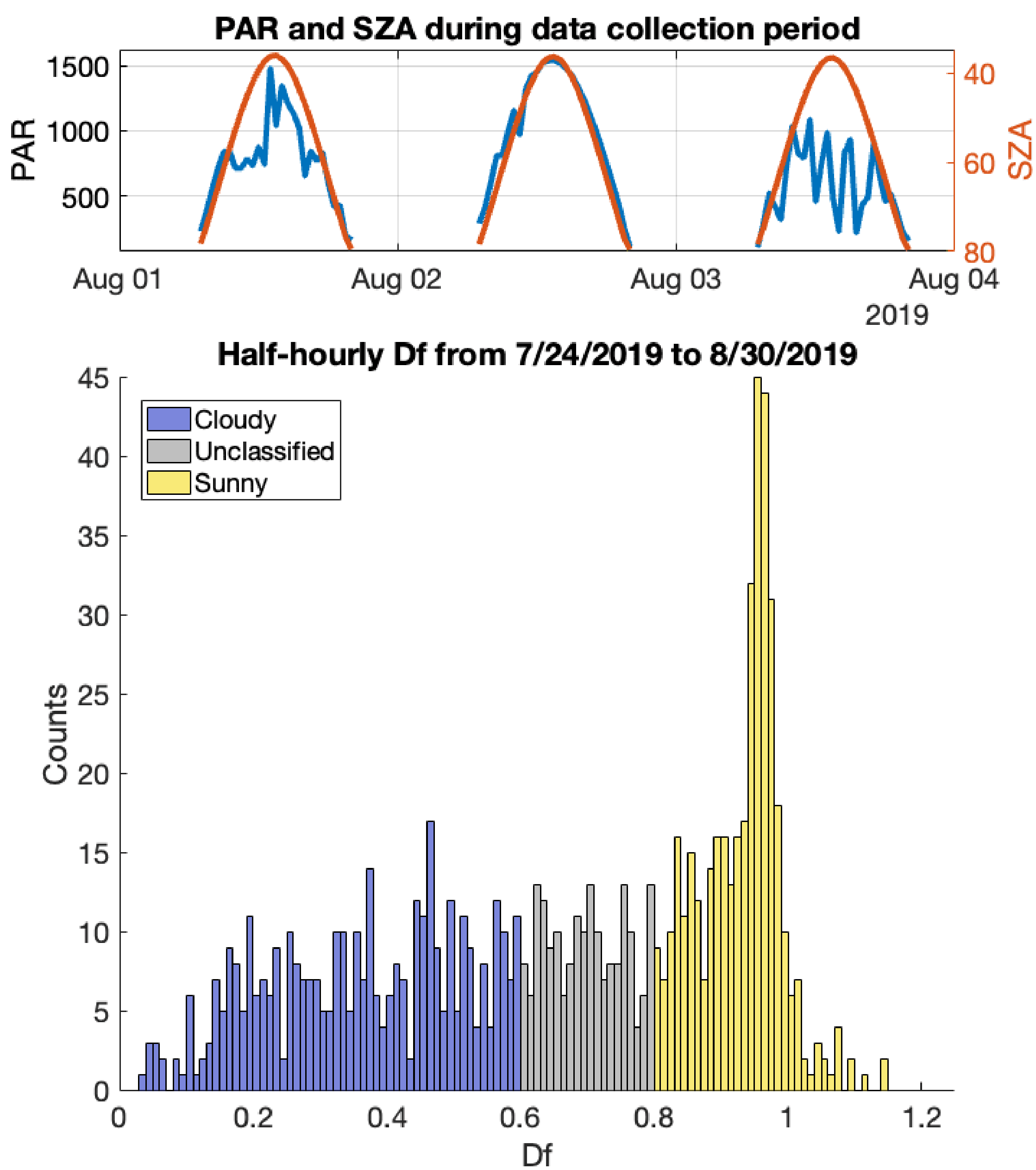

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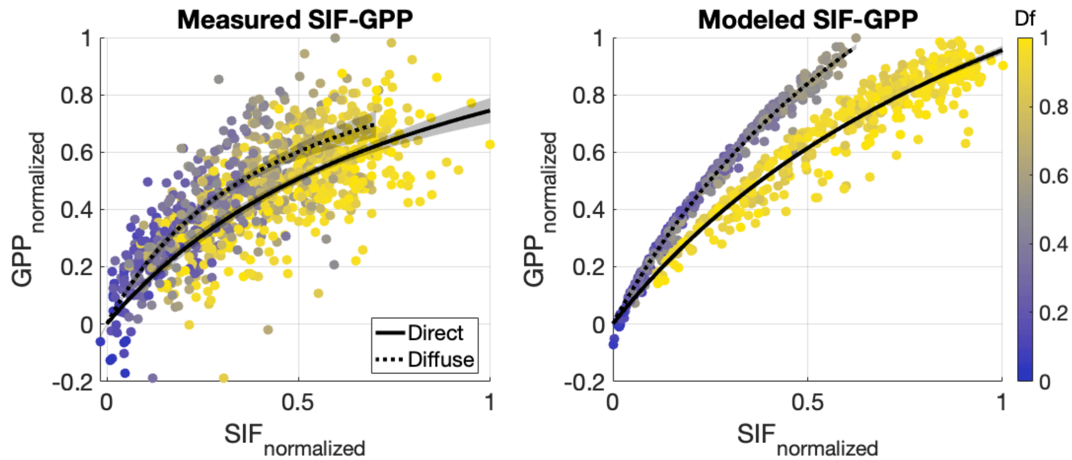

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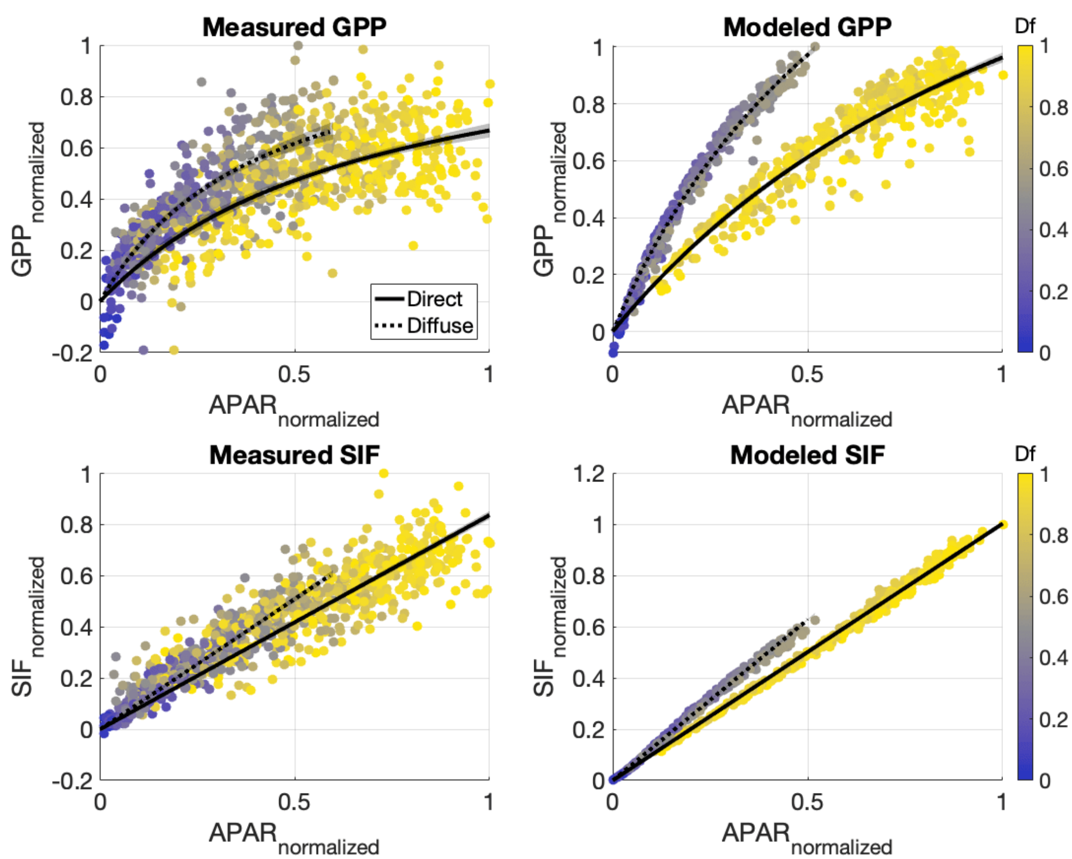

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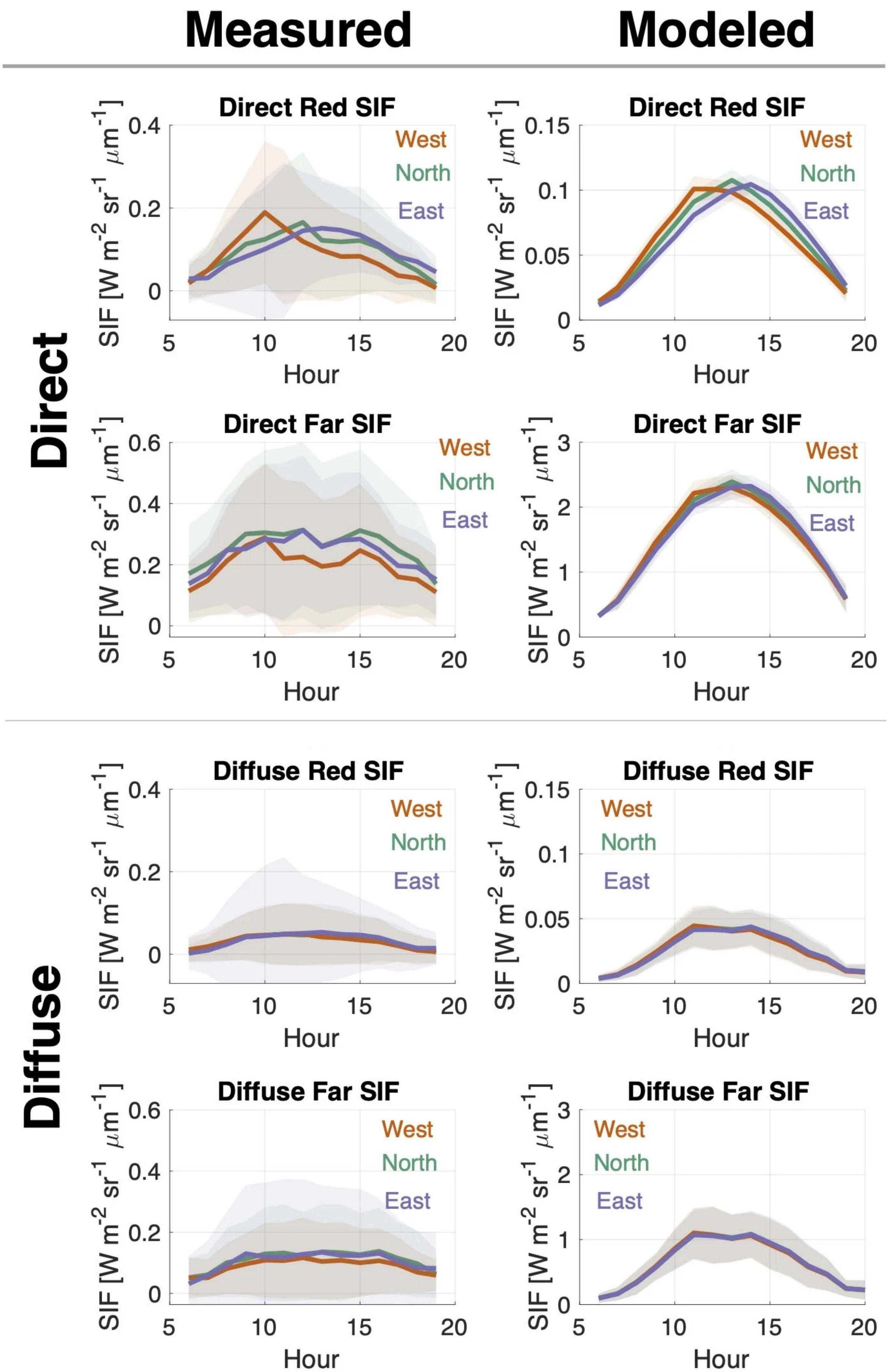
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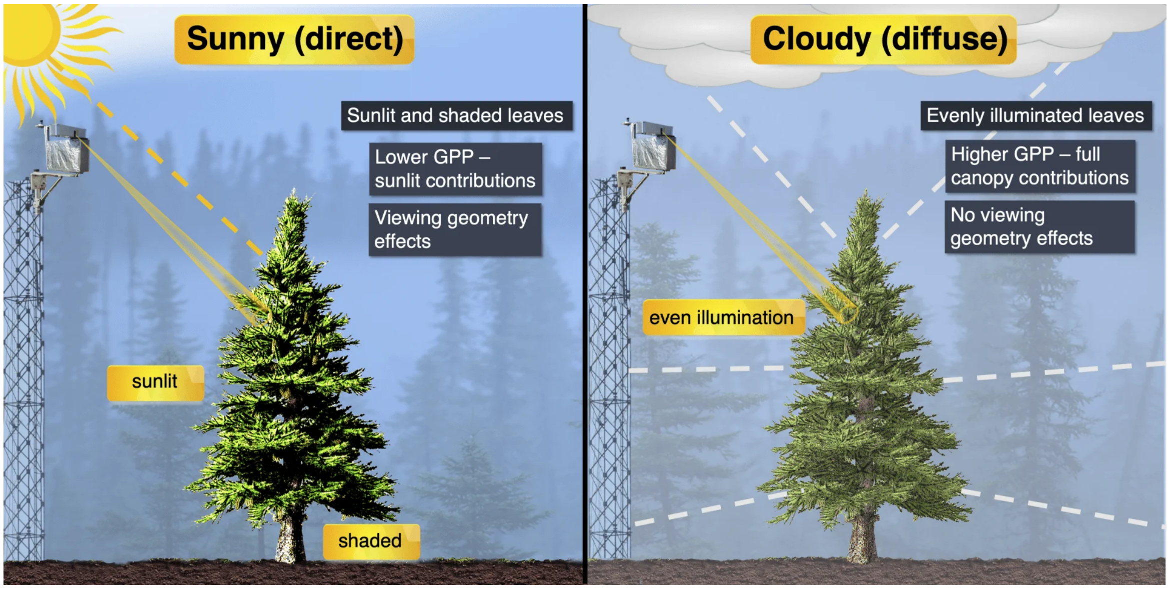
DISCUSSION AND FUTURE DIRECTIONS

Important differences between direct and diffuse lighting conditions are summarized in the following figure:



Our findings support future work constraining the effects of illumination conditions on remote sensing observations and canopy integrated photosynthesis. This is particularly important as future climate change scenarios will create changes in cloud cover and aerosol concentrations (Durand et. al., 2021 (https://www.sciencedirect.com/science/article/pii/S0168192321003701?via%3Dihub#fig0007)).

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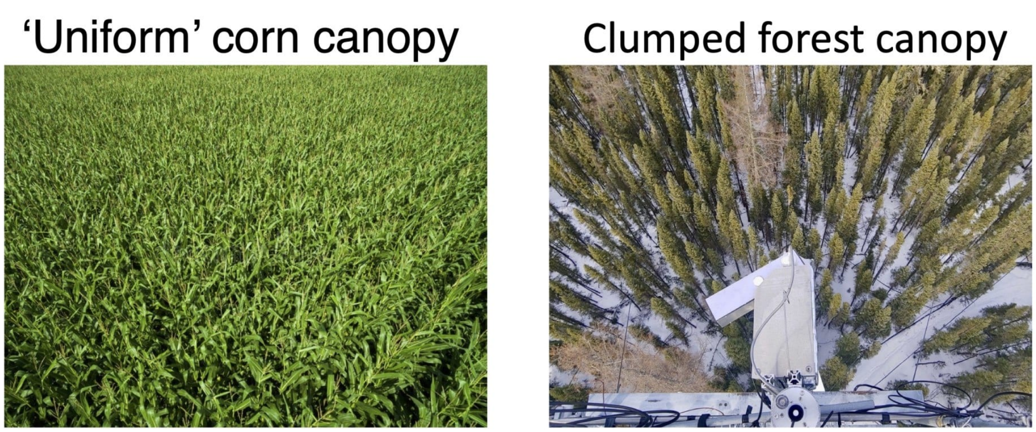

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Andrew Maguire - Jet Propulsion Laboratory

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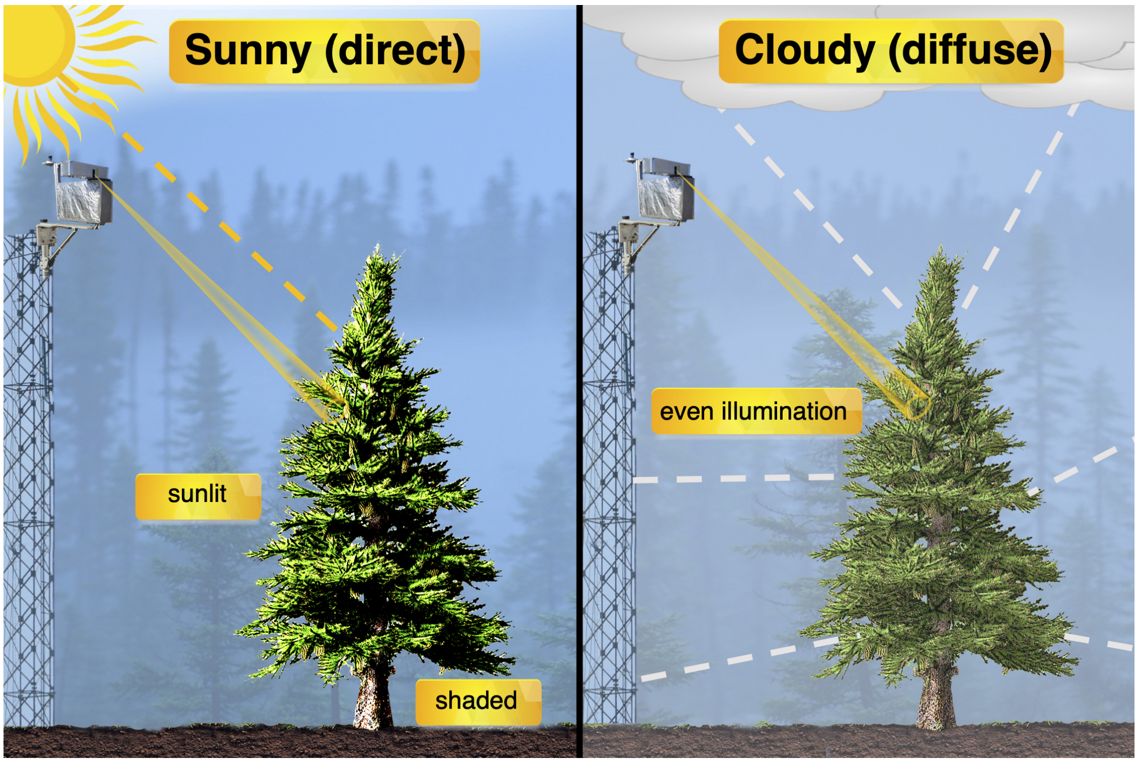

(https://agu.confex.com/data/abstract/agu/fm21/4/6/Paper_835064_abstract_783618_0.jpg)

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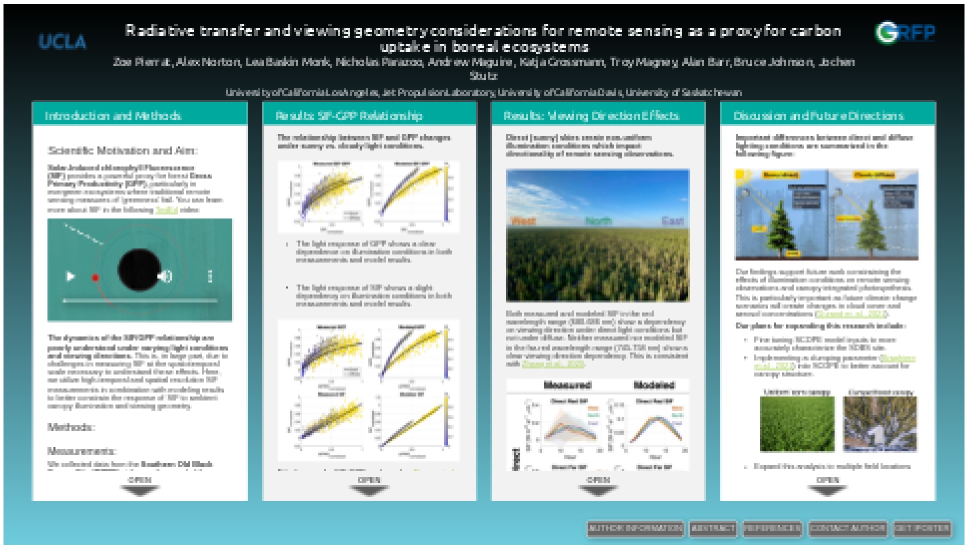

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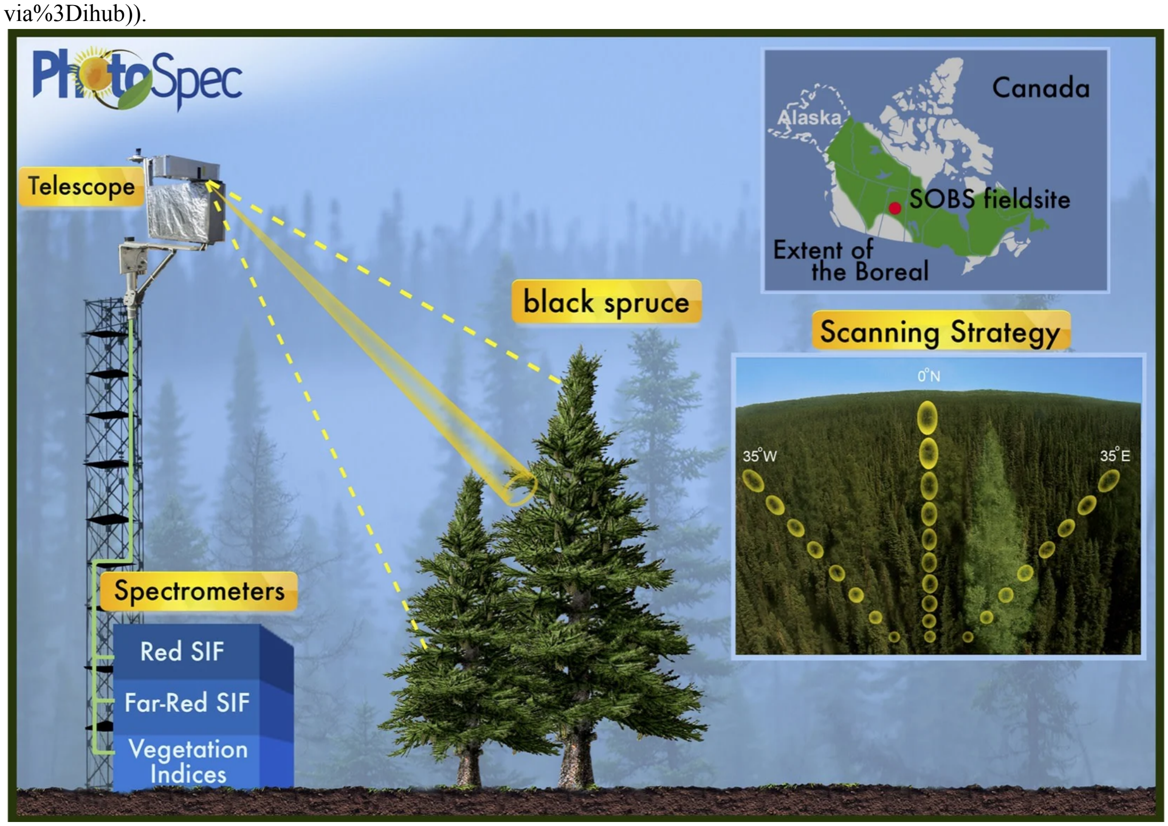

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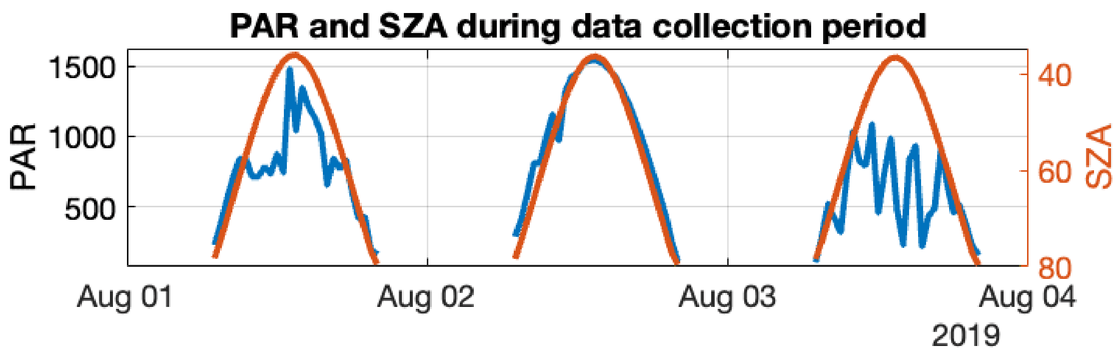

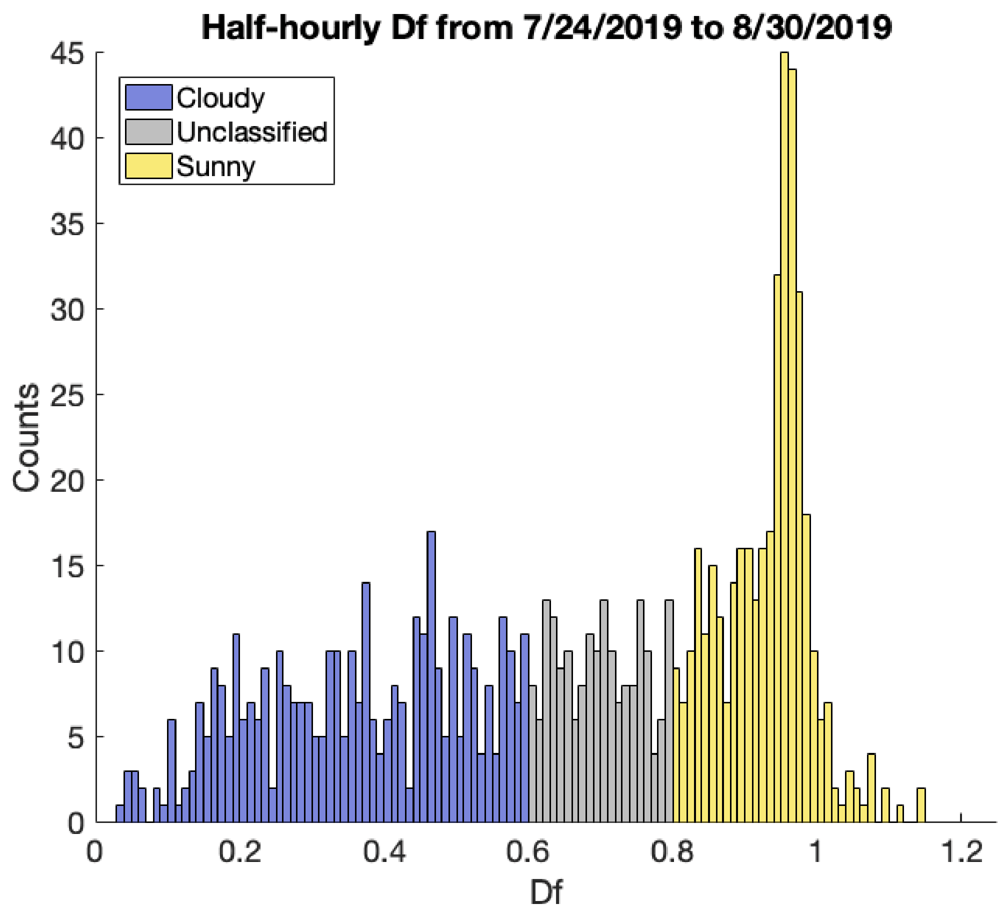

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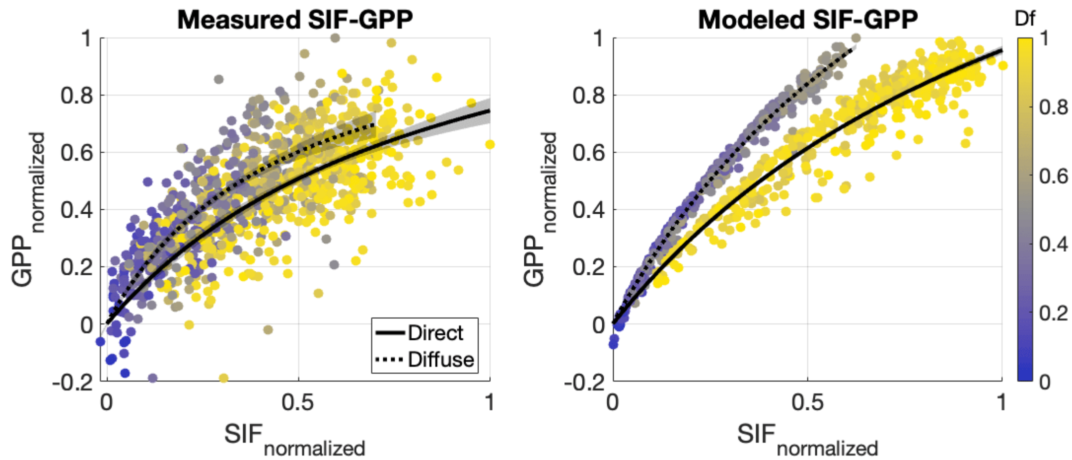

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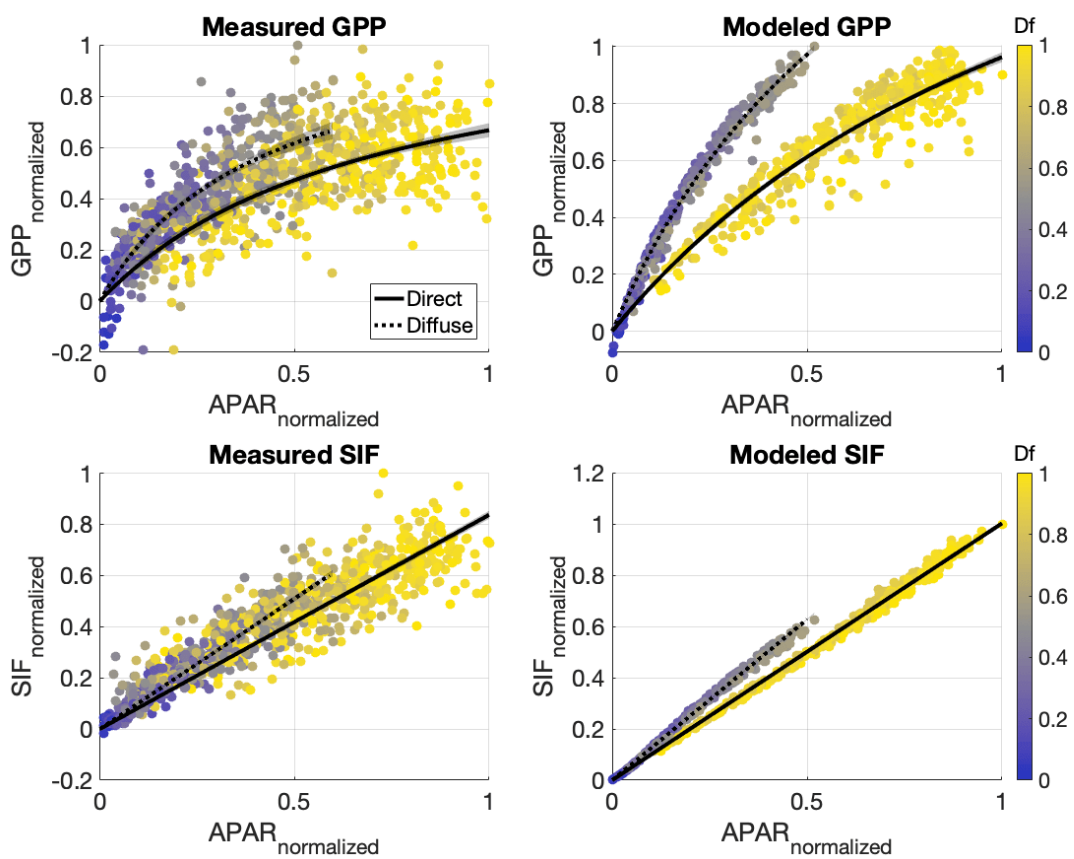

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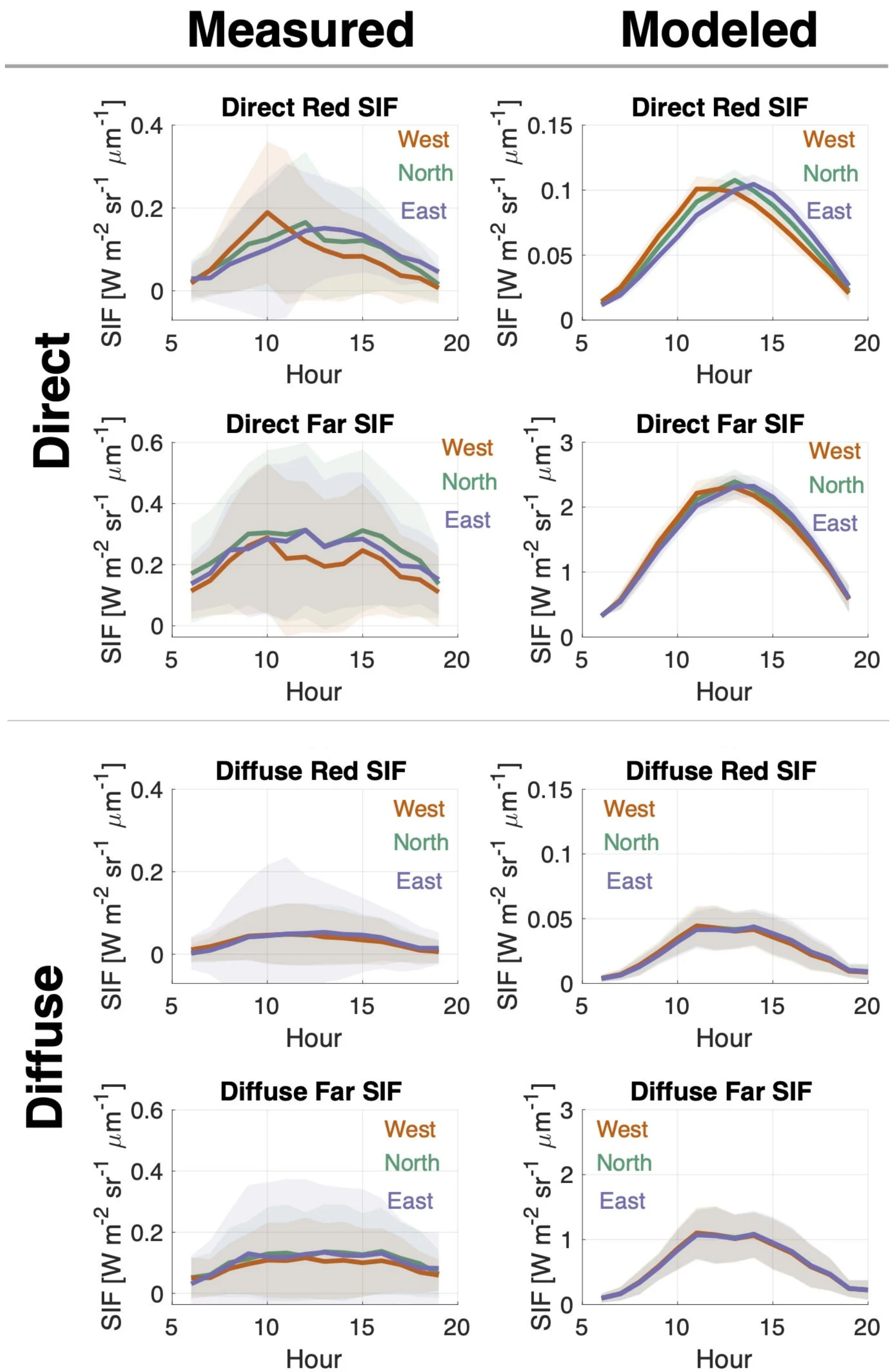
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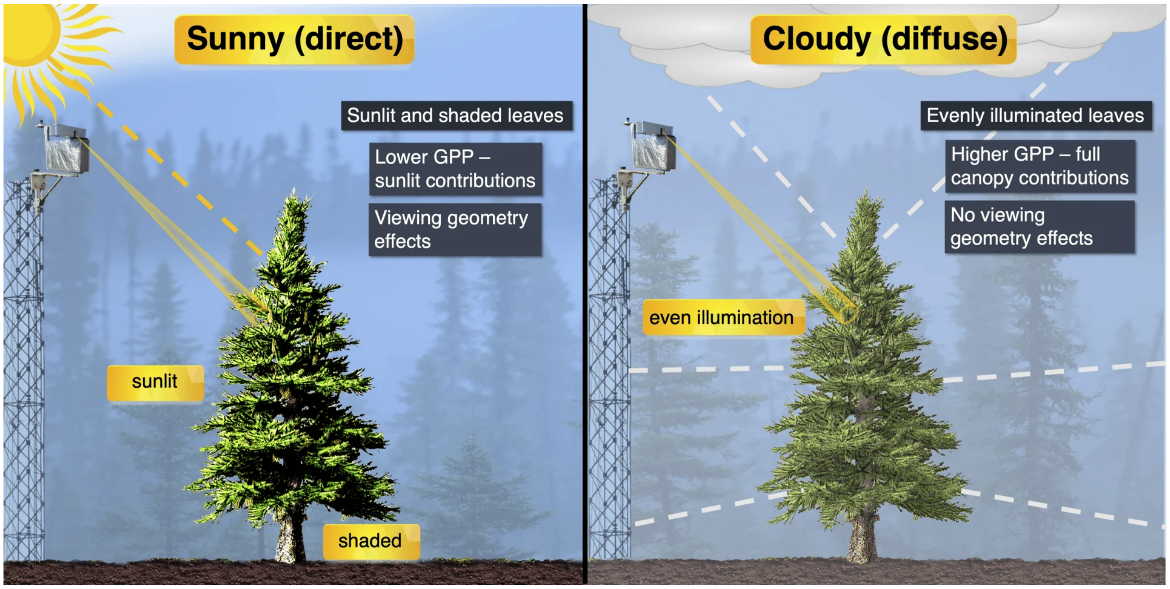

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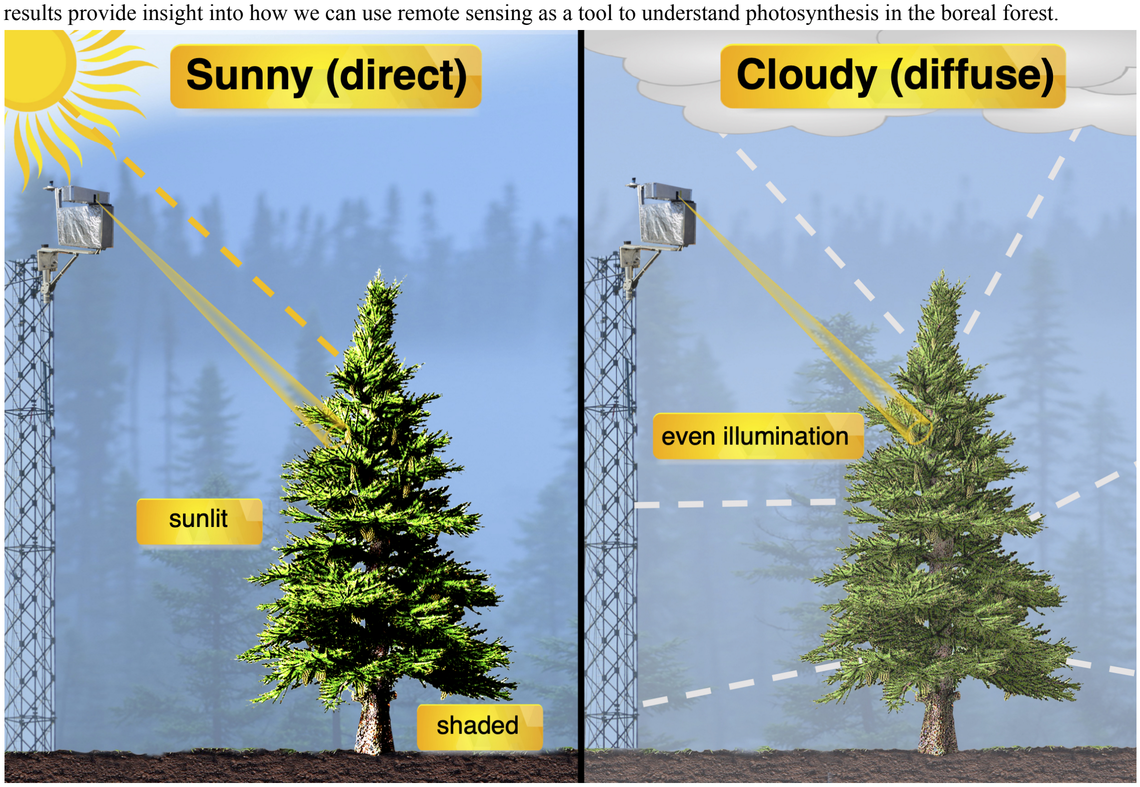
ABSTRACT

The boreal forest plays an important role in the global carbon cycle but has remained a significant source of uncertainty. Remote sensing can help us better understand the boreal forest's role in the global carbon cycle. A faint light signal emitted by plant's photosynthetic machinery, known as solar-induced chlorophyll fluorescence (SIF), is a promising remotely sensed proxy for carbon uptake, also known as gross primary productivity (GPP), due to its connection to photosynthesis and its strong relationship with GPP when observed by satellite. However, SIF and GPP are fundamentally different quantities that describe distinct, but related, physiological processes. The relationship between SIF and GPP is therefore complicated by both physical and ecophysiological controls. In particular, the dynamics of the SIF/GPP relationship are poorly understood under varying viewing directions and light conditions. This is further complicated in evergreen systems where canopy clumping and the presence of needles create a unique radiative environment. We use a combination of tower-based SIF and GPP measurements from a boreal forest field site compared with a coupled biochemical-radiative transfer model to understand illumination effects on the SIF/GPP relationship. We find that GPP is amplified under cloudy sky conditions in both measurements and model results. SIF on the other hand, shows no significant difference between sunny or cloudy sky conditions in modeled results, but does show a difference in measurements. We suggest that these differences may be due to viewing geometry effects that are important for SIF under sunny sky conditions or the presence of clumping. Accounting for the differences in the SIF/GPP relationship therefore is critical for the utility of SIF as a proxy for GPP. In summation, our results provide insight into how we can use remote sensing as a tool to understand photosynthesis in the boreal forest.



(https://agu.confex.com/data/abstract/agu/fm21/4/6/Paper_835064_abstract_783618_0.jpg)

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