MSA: Dynamics of Chlorophyll Fluorescence and Its Relationship with Photosynthesis from Leaf to Continent: Theory Meets Data

Project Summary

Overview:

Although measurements of solar-induced chlorophyll fluorescence (SIF) from remote sensing platforms have been growing rapidly, it remains a challenge to gain mechanistic insights into terrestrial gross primary productivity (GPP) with these datasets. So far studies that have analyzed SIF-GPP relationships are largely correlative and based on the empirical light use efficiency (LUE) concept. Such studies serve as a good starting point for the promising field of SIF research and its applications in ecosystem science. To move forward, however, we must now delve into the vast number of complexities and processes that have been hidden in simple correlative analyses to understand the dynamics of SIF and its relationship with GPP. Significant progresses can be made by developing a SIF analytical framework that is based on sound knowledge of plant science and that can be applied across species, time, and climate conditions. This framework can be applied to large geographical scales to guide both the interpretation of satellite SIF measurements in a physiologically meaningful way, as well as the implementation of SIF data assimilation for constraining GPP estimates.

The overall goal of this proposal is to develop a cross-scale analytical framework, built upon the mechanistic models of light reactions of photosynthesis. To achieve this goal, we propose to 1) develop and verify a leaf-level theoretical modeling framework for SIF and photosynthesis by building a database with key parameters (e.g., non-photochemical quenching, NPQ; fraction of open photosystem II reaction centers, q_L) of light reactions across species and environmental conditions at Cornell Botanic Garden and Musgrave Research Farm; 2) integrate the theoretical model with canopy radiative transfer to understand the driving factors for SIF-GPP dynamics across the NEON eddy covariance (EC) tower sites at wide ecoregions; 3) constrain GPP estimates and variability across conterminous US (CONUS) using the analytical framework implemented into the NCAR Community Land Model (CLM).

Intellectual Merit:

To our knowledge, this proposed research is the first of its kind in its aim to establish the theoretical foundation for integrated SIF and photosynthesis research with coordinated studies of light and dark reactions. It will enable significant theoretical and practical advances for studying the dynamics of SIF and its relationship with GPP for a wide range of ecosystems and bio-climatic conditions at different time scales. The proposed approach will bring together the fundamental plant physiology theories with satellite remote sensing retrievals. The proposed analytical framework will unlock the power of the satellite SIF in constraining the estimates and variability of GPP at large scales, which will eventually lead to improved carbon sources/sinks attribution.

Broader Impacts

The database developed in this study will be permanently stored beyond the lifespan of this project and to be accessible and expandable by the science community at large. This project will have important broader impacts on graduate and undergraduate education at Cornell University. The research activities built into the course the PI teaches will directly impact up to 100 students over the three-year award period. The partnership with Cornell Botanic Garden and Musgrave Research Farm will greatly enhance the public engagement with plant and ecosystem science and technology. This project will directly address societal needs by offering innovative strategies for constraining carbon source/sinks to inform climate change mitigation and adaptation.