Mechanisms linking solar-induced fluorescence and vegetation reflectance to boreal forest productivity: Phase 2 project

Christian Frankenberg (PI)[a,b] | **Troy S. Magney (Science PI)[a,b]** | Jochen Stutz (co-I)[c] | Nicholas Parazoo (co-I)[b] | Barry Logan (co-I)[d] | David Bowling (co-I)[e] | Philipp Köhler[a] | Zoe Pierrat[c] | Elena Sparrow[d]

a. Environmental Science and Engineering, California Institute of Technology, Pasadena, CA, USA | b. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
c. Dept. of Atmospheric Sciences, UCLA, Los Angeles, CA, USA | d. Bowdoin College, Brunswick, ME, USA | e. University of Utah, Salt Lake City, UT, USA

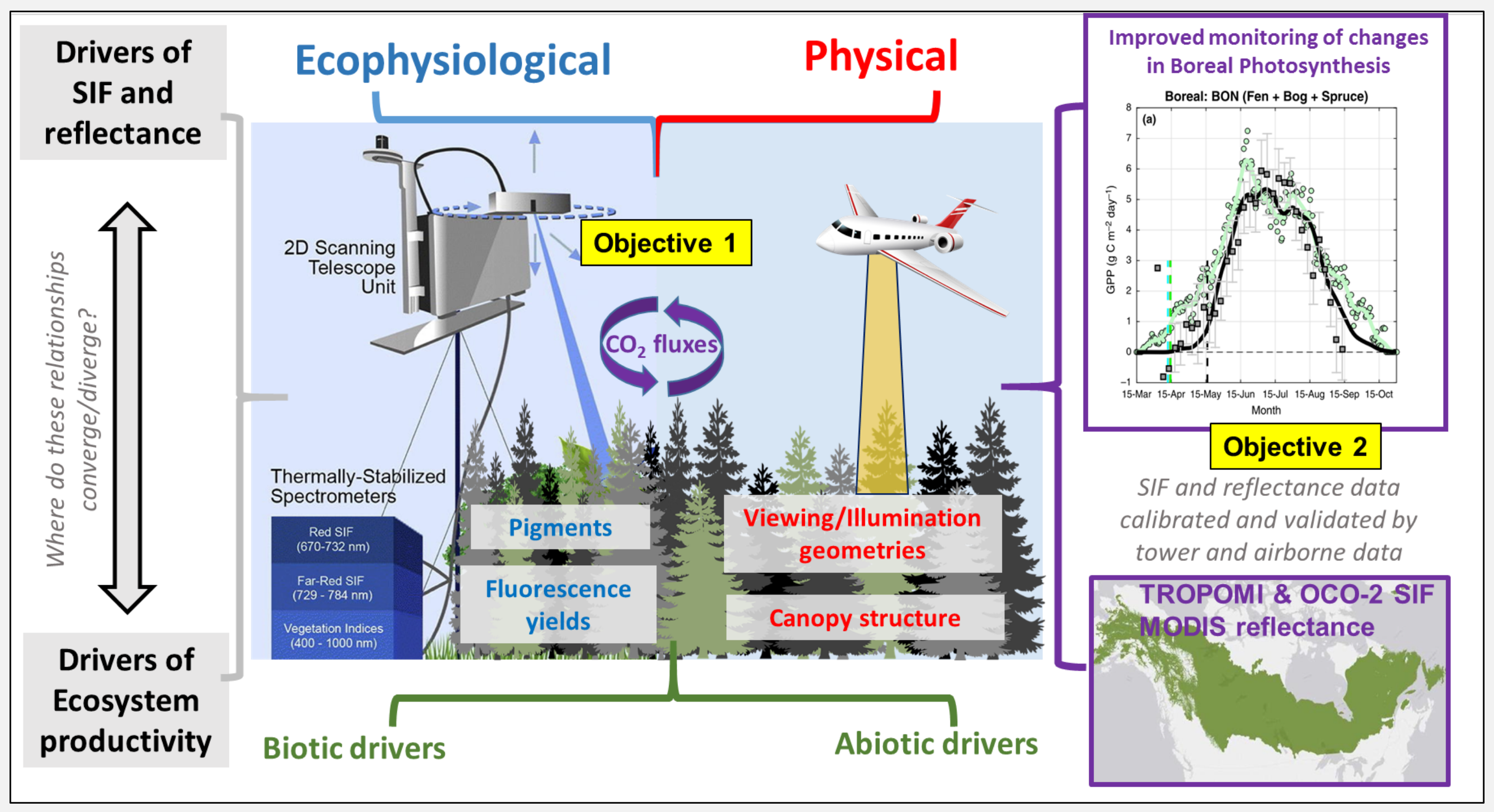
National Aeronautics and Space Administration

Introduction

The Boreal forest has experienced a widespread transformation in ecosystem structure and function that will only amplify under global climate change.

- **Challenge:** Accurately determining the timing of seasonal Gross Primary Production (GPP) onset and decline, and its long-term change, remains a major challenge in satellite remote sensing in evergreen forests.
- **Question:** How can we disentangle the physical (structural, viewing/illumination geometries) from ecophysiological (fluorescence and photosynthetic yields) factors driving top-of-canopy reflected and emitted radiation (SIF) to inform GPP estimates?
- **Question:** How can insights gained at high temporal (ground-based spectroscopy) and spatial (aircraft measurements) resolutions be used to advance the use of satellite measurements of SIF and vegetation reflectance to estimate GPP across the Boreal region?

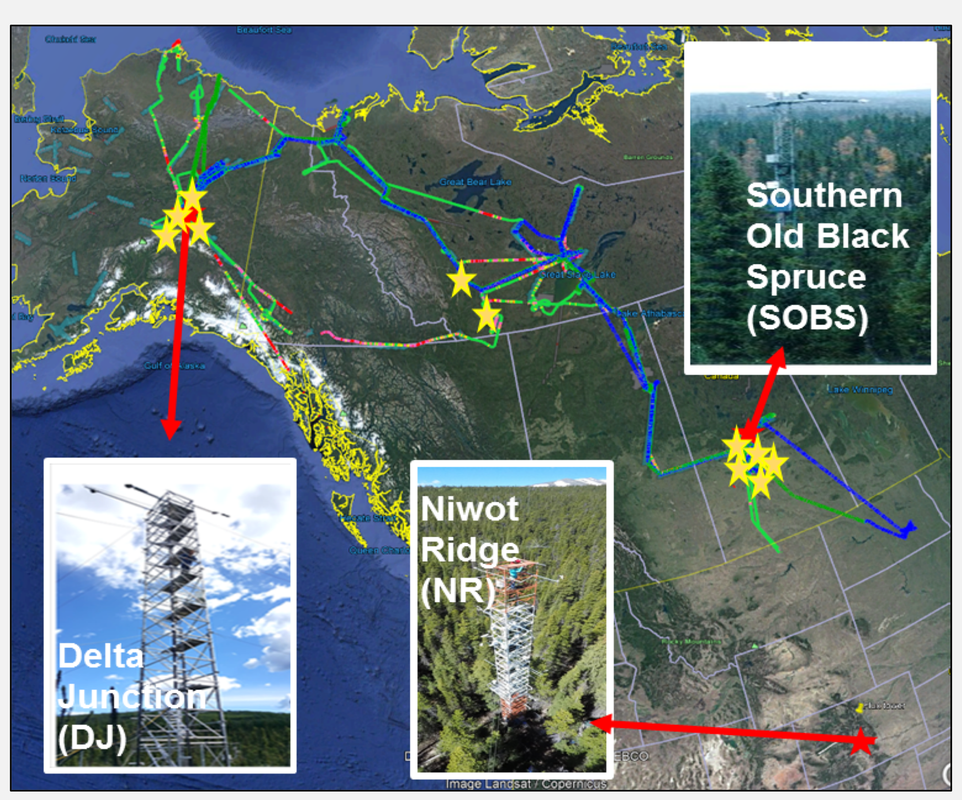
Objectives



Objective 1 will focus on the canopy scale using tower and airborne observations to understand the ecophysiological and physical drivers of SIF spectra. Objective 2 will use new insights gained from small-scale investigations to scale to the greater Boreal region.

Objective 1: Establish a quantitative framework to describe the ecophysiological and physical mechanisms linking surface measurements of SIF and vegetation reflectance to GPP at established tower sites and coincident airborne campaigns. This framework will be implementable in global photosynthesis models.

Objective 2: Reduce uncertainties in satellite-based estimates of GPP across the Boreal region by applying a process-based understanding of both the temporal and spatial dynamics of SIF and vegetation reflectance at fine scales.



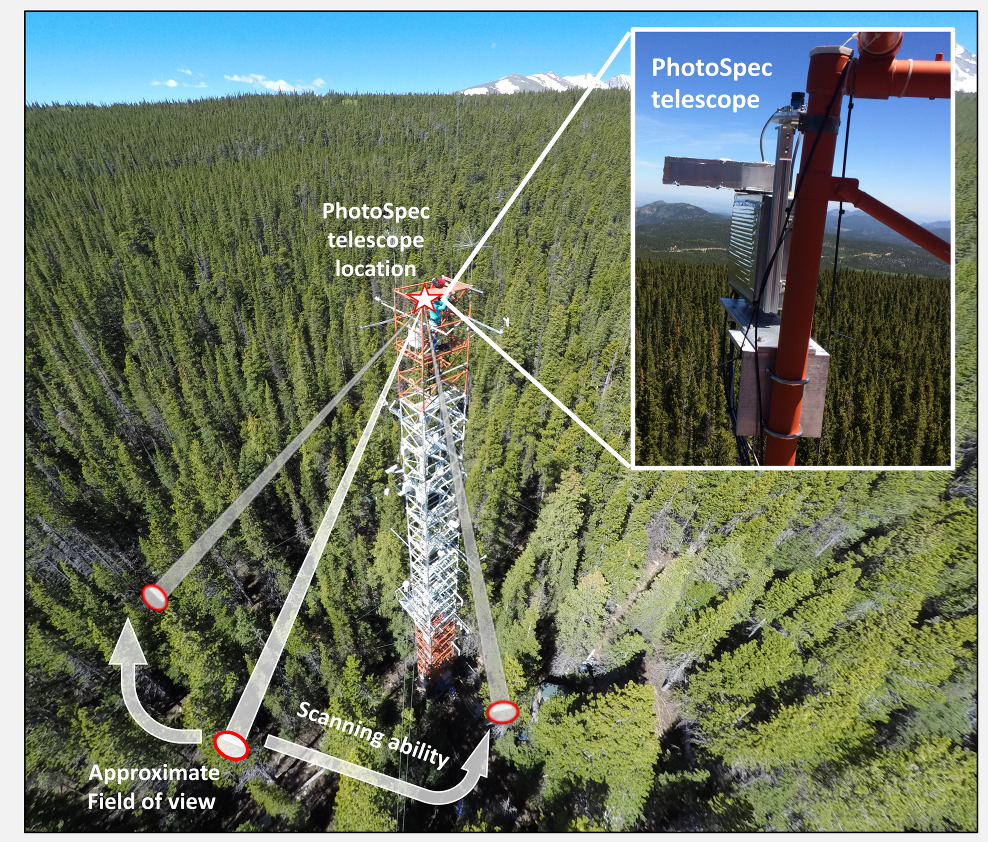
Three tower field locations indicated by red stars. ABoVE flight lines (Green = AVIRIS, blue = CFIS). Yellow stars represent AmeriFlux and NEON flux tower sites

Methods

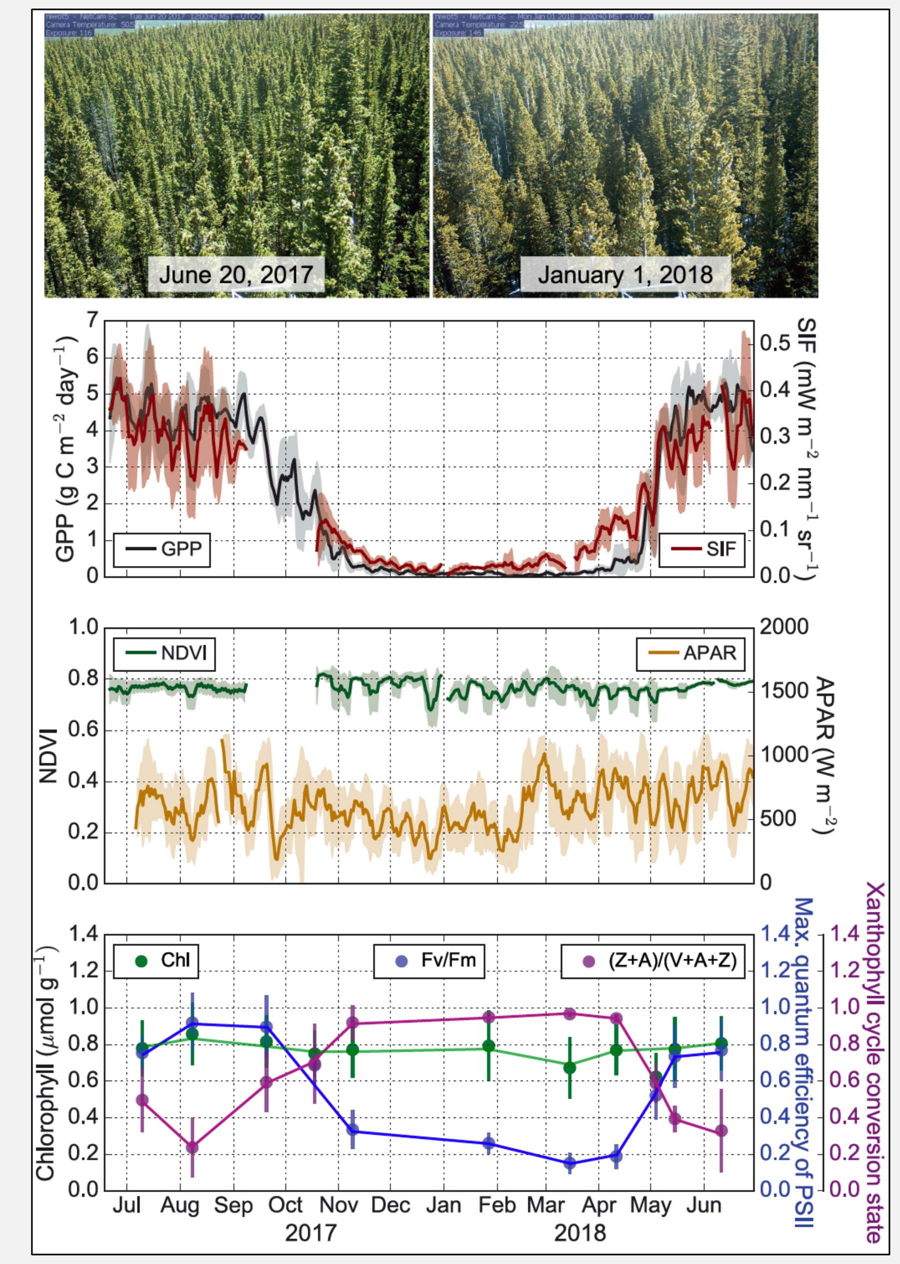
A multi-scale approach to understand the ecophysiological and physical mechanisms linking SIF, vegetation reflectance, and pigment composition to Boreal forest productivity.

Needle-scale: Seasonal sampling of photosynthetic and photoprotective pigments in conjunction with needle fluorescence.

Canopy-scale: Collect and analyze SIF in the red (680 nm) and far-red (740nm) spectral regions and vegetation reflectance from 400-900 nm from our PhotoSpec spectrometer system with 2D scanning capabilities



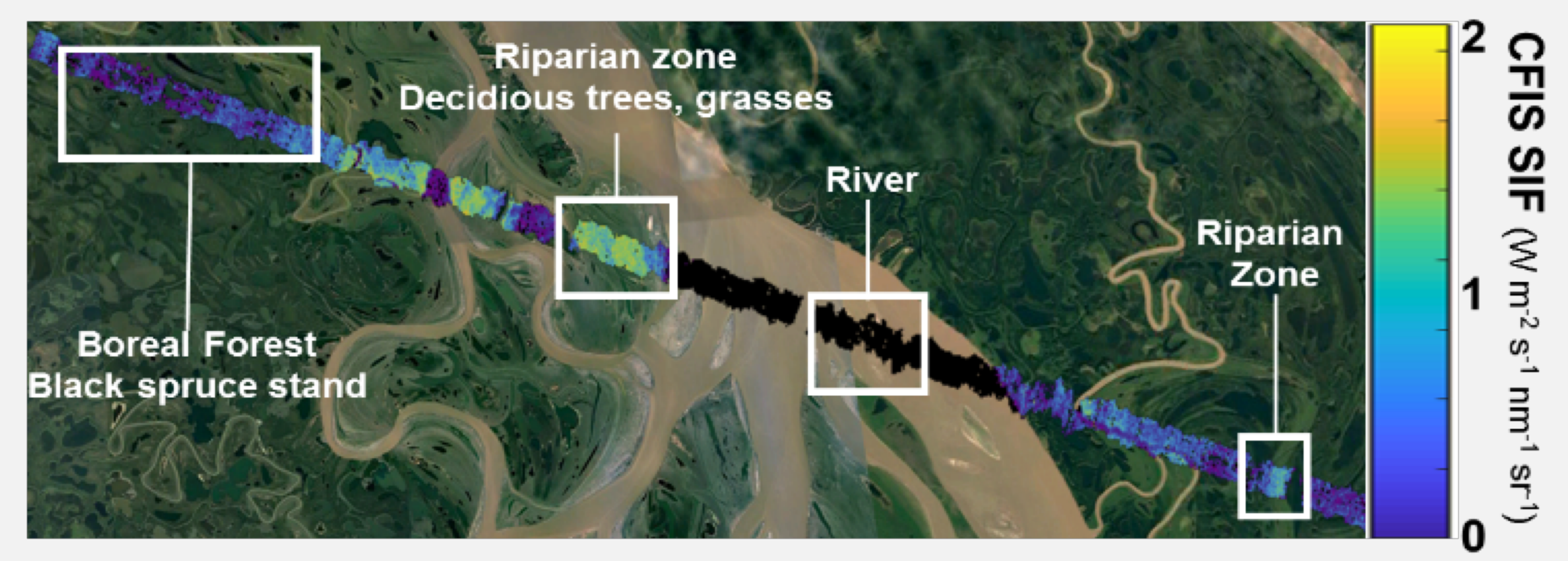
PhotoSpec at Niwot Ridge, Colorado



Magney et al., 2019, *PNAS* doi: 10.1073/pnas.1900278116

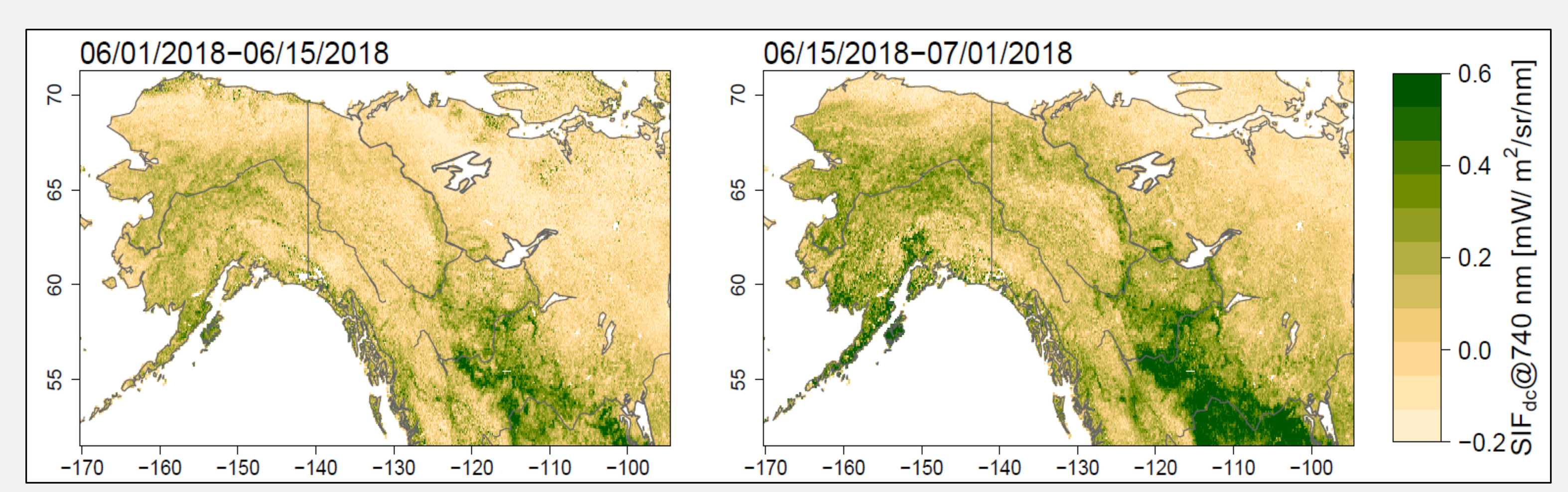
Above: SIF, GPP, needle-fluorescence, and photoprotective pigments show dramatic and rapid seasonal changes associated with winter acclimation, while NDVI, APAR, and Chlorophyll are relatively invariant.
Will we observe the same in the ABoVE domain? Sampling across a wide range of environmental conditions will help.

Airborne scale:
Link far-red SIF from the Chlorophyll Fluorescence Imaging Spectrometer (CFIS) with hyperspectral reflectance (400-2500 nm) from the Next Generation Airborne Visible/ Infrared Imaging Spectrometer (AVIRIS-NG)



Data from a CFIS overflight in 2017 over the Mackenzie River delta shows the spatial patterns of SIF, with explanatory boxes describing the range of SIF observed.

Satellite scale:
Information from both the temporal (canopy tower observations) and spatial (airborne observations) domains will inform SIF data from TROPOMI and OCO-2 SIF, as well as MODIS reflectance data.



TROPOMI SIF data showing the green-up of the ABoVE domain during the spring onset of photosynthesis in 2018. Weekly data at a 3 x 7 km resolution will dramatically increase our ability to interpret SIF and GPP seasonality.

ABoVE ARCTIC - BOREAL VULNERABILITY EXPERIMENT

20-23 May 2019. | ABoVE Science Team Meeting, La Jolla, CA