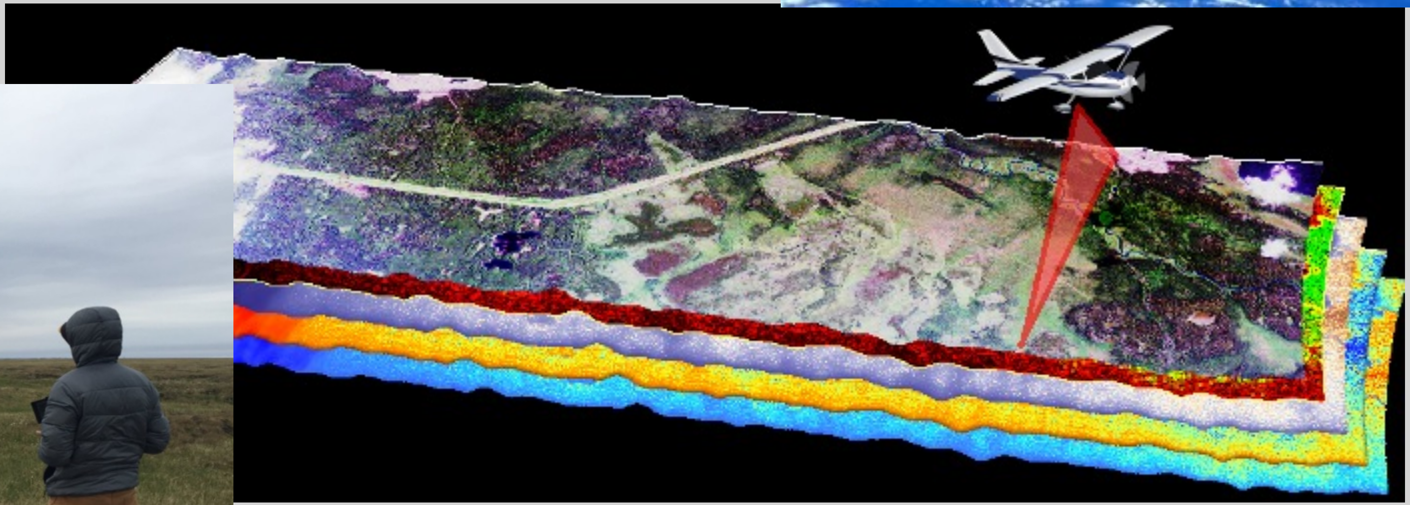
Spectral Imaging Working Group

Co-Chairs: Peter Nelson, Fred Huemmrich

~ 82 members



We have identified some areas of interest

- Scaling - addressing scaling from ground to drones to aircraft to satellite, involving processing and analysis techniques and data synthesis.

- Relating spectral reflectance characteristics to vegetation traits and processes

- Solar Induced Fluorescence (SIF) studies - addressing the measurement and use of solar induced fluorescence and its relationship to biophysical processes.

Recently published study:

JGR Biogeosciences

RESEARCH ARTICLE

10.1029/2021JG006697

Remote Sensing of Tundra Ecosystems Using High Spectral Resolution Reflectance: Opportunities and Challenges

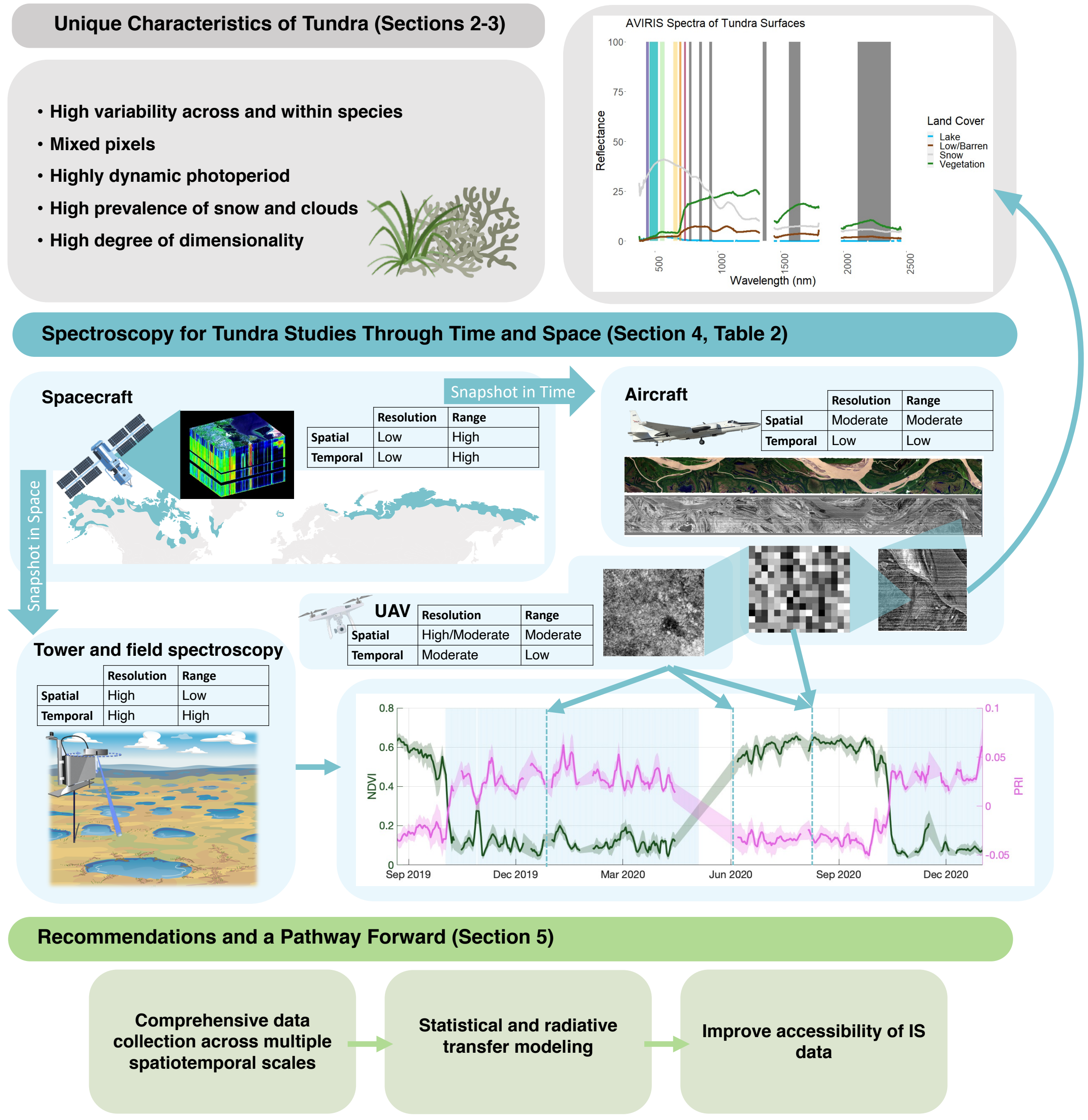
Peter R. Nelson[1], Andrew J. Maguire[2], Zoe Pierrat[3], Erica L. Orcutt[4], Dedi Yang[5], Shawn Serbin[5], Gerald V. Frost[6], Matthew J. Macander[6], Troy S. Magney[4], David R. Thompson[2], Jonathan A. Wang[7], Steven F. Oberbauer[8], Sergio Vargas Zesati[9], Scott J. Davidson[10,11], Howard E. Epstein[12], Steven Unger[8], Petya K. E. Campbell[13], Nimrod Carmon[2], Miguel Velez-Reyes[9], and K. Fred Huemmrich[13]

Special Section:
The Earth in living color: spectroscopic and thermal imaging of the Earth: NASA's Decadal Survey Surface Biology and Geology Designated Observable

Key points:

Imaging spectroscopy (IS) can help to measure critical Arctic tundra properties, physiological function, and temporal dynamics

To properly interpret IS data users must consider spectral complexity of tundra driven by composition, sensitivity to climate, and phenology



Next SIWG Synthesis Effort

We are discussing synthesis studies on scaling in optical remote sensing for high latitudes leading to another group paper

1) Spatial scaling

    Do different types of landscapes have different spatial breakpoints in reflectance?

2) Temporal scaling

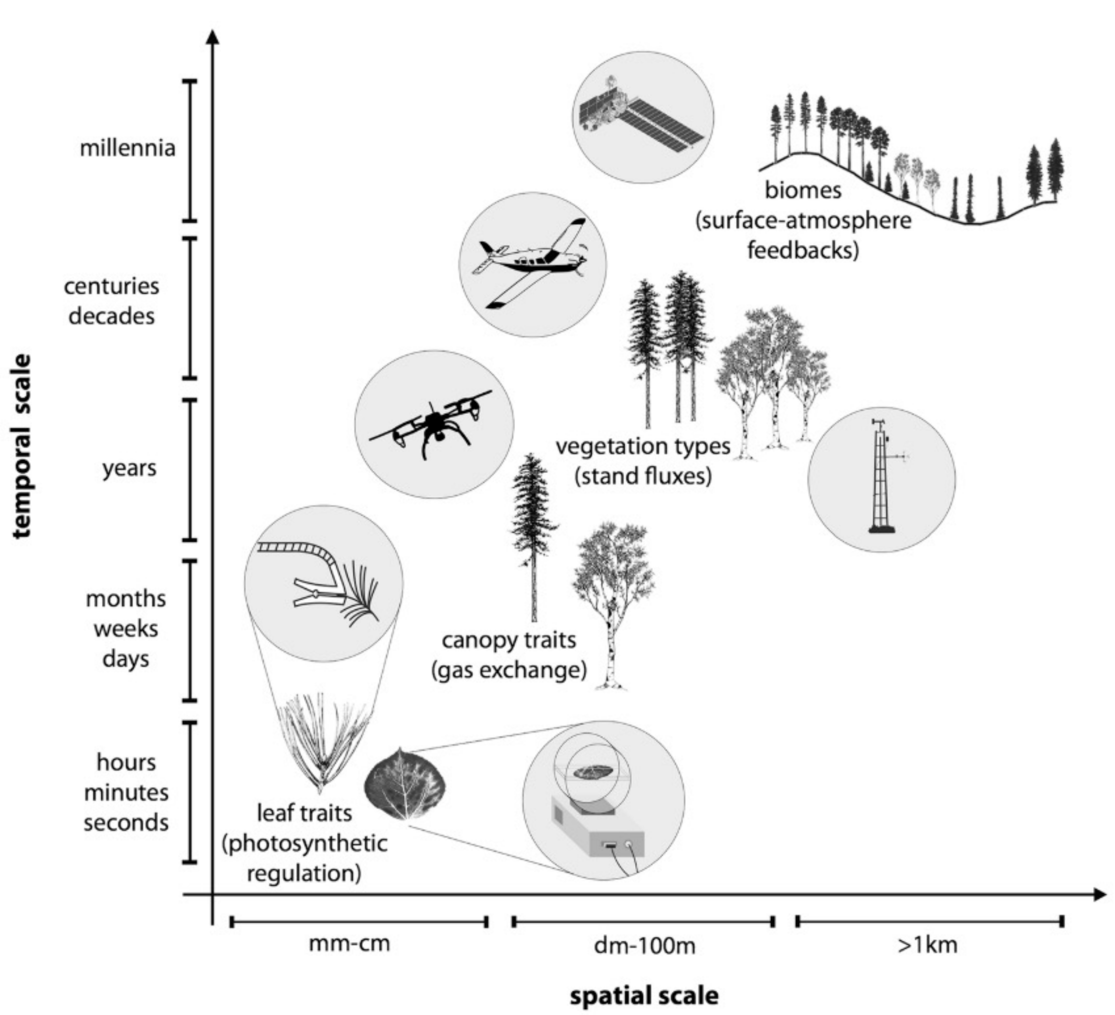
    How to resolve short term responses, seasonal responses, disturbances, and multiyear green/browning trends?

3) Spectral scaling

    What spectral resolution is required for different types of retrievals?

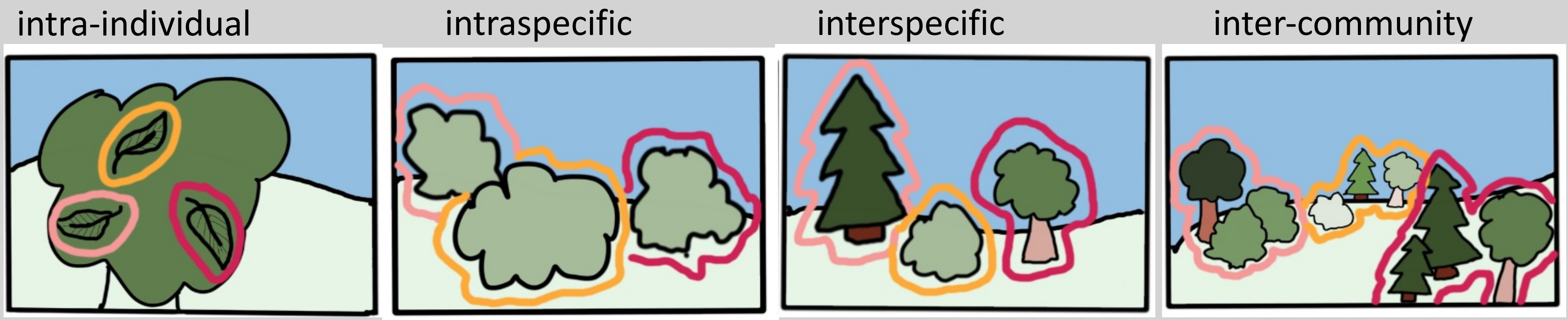
4) What are the cross-component scale dependencies?

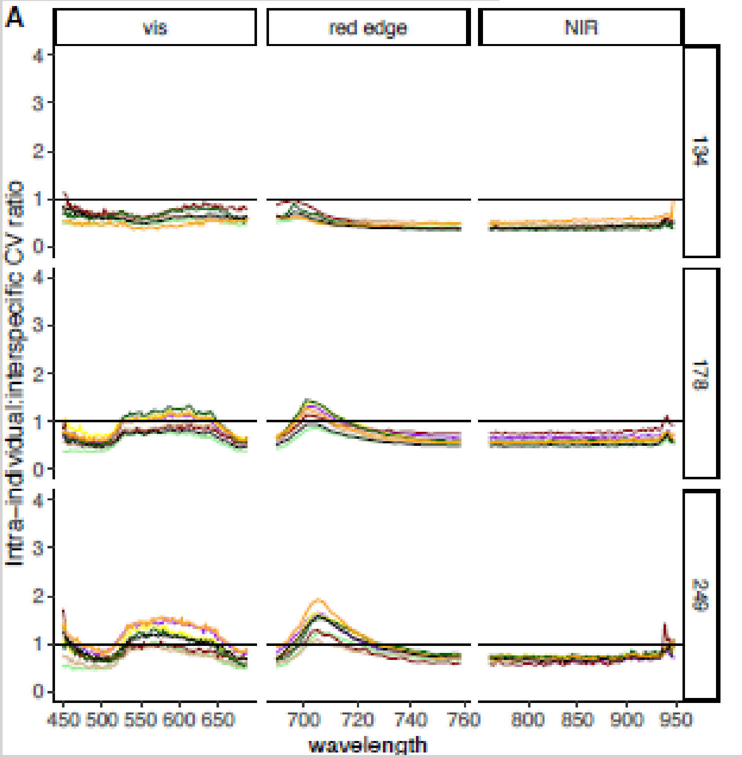
We have been having monthly meetings, all are welcome



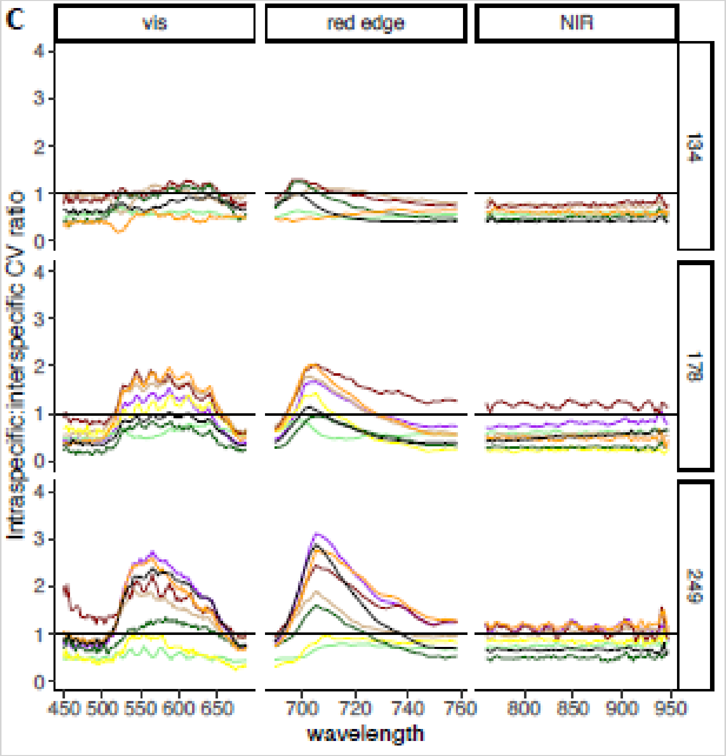
Gamon et al., 2019

Consider four levels of organization (leaf, individual, species, community)
- What is the variation between levels across wavelengths and time during the growing season?





Leaf-to-leaf variability (CV) relative to inter-specific variability by wavelength (left to right) and Julian date (top to bottom)



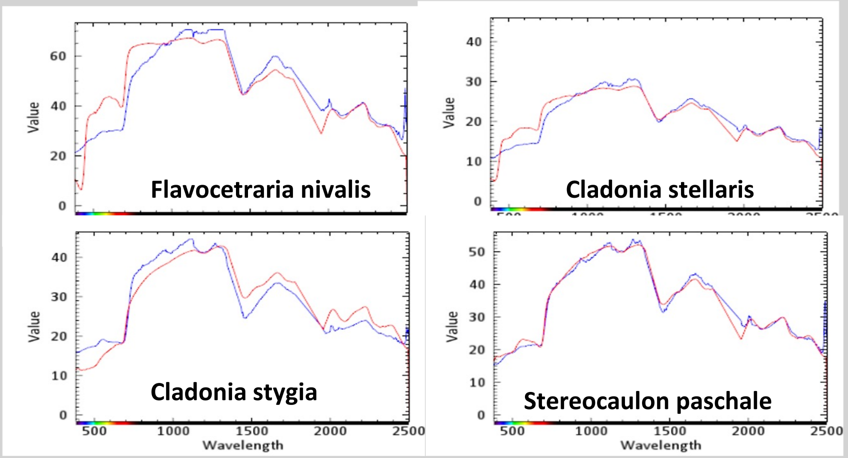
Individual-to-individual variability relative to inter-specific variability by wavelength (left to right) and Julian date (top to bottom)

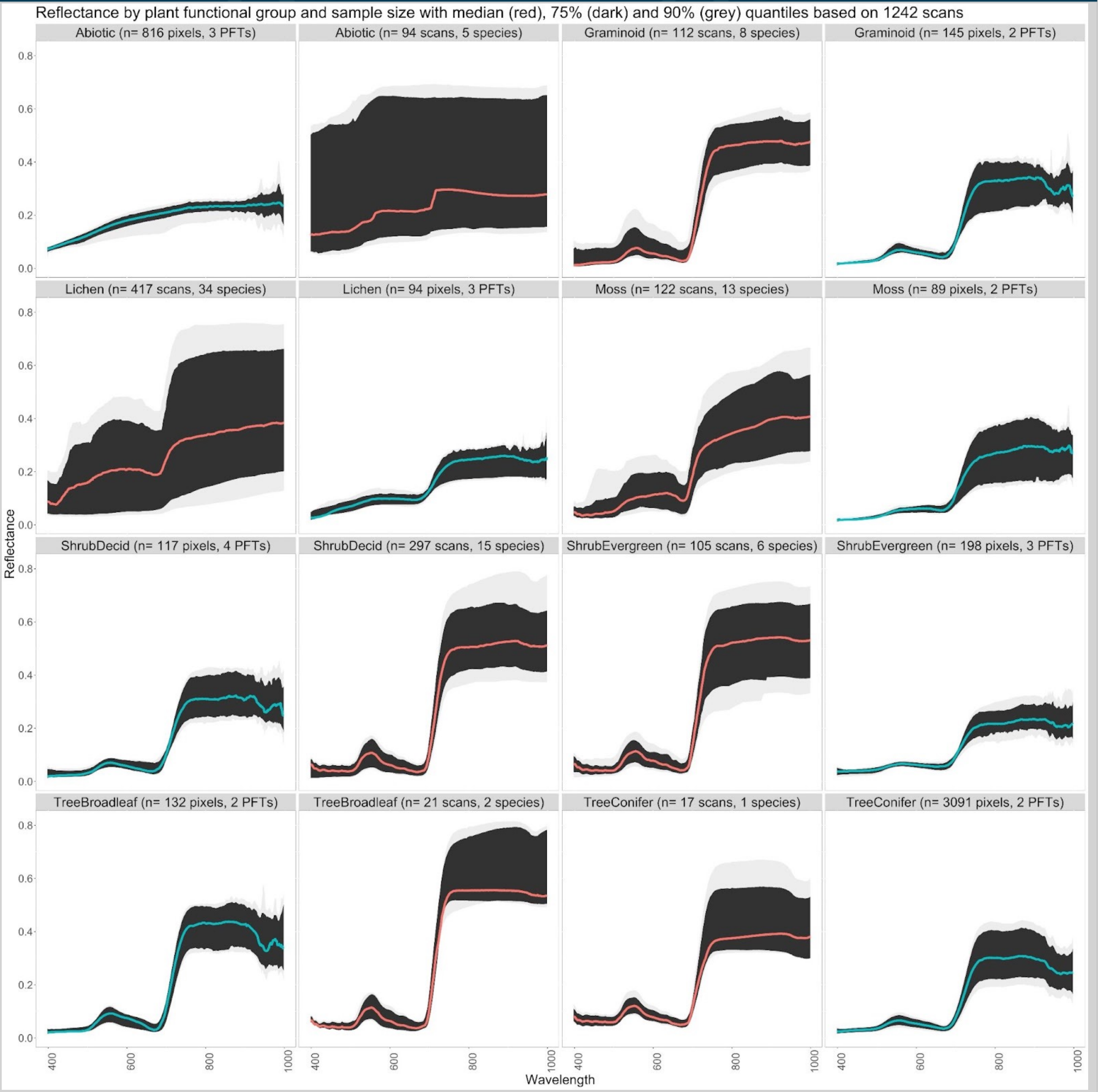
Howard Epstein

Spectral scaling between ground and airborne spectrometers

Peter R. Nelson, Kenneth Bundy, Matt Macander - Biome Shift - PI Goetz Phase 3

- Ground reflectance measurements (red line below) at the leaf-level for PFTs shows agreement in pure AVIRIS pixels (blue line - below for select lichen end member)
- Pure patches of each PFT were digitized in the UAV VNIR images, which also show agreement to ground spectra
- Ground (red)/image(blue) reflectance comparison by PFT shows similar shape but differing magnitudes and variability
- How best to deal with cross-instrument data use?





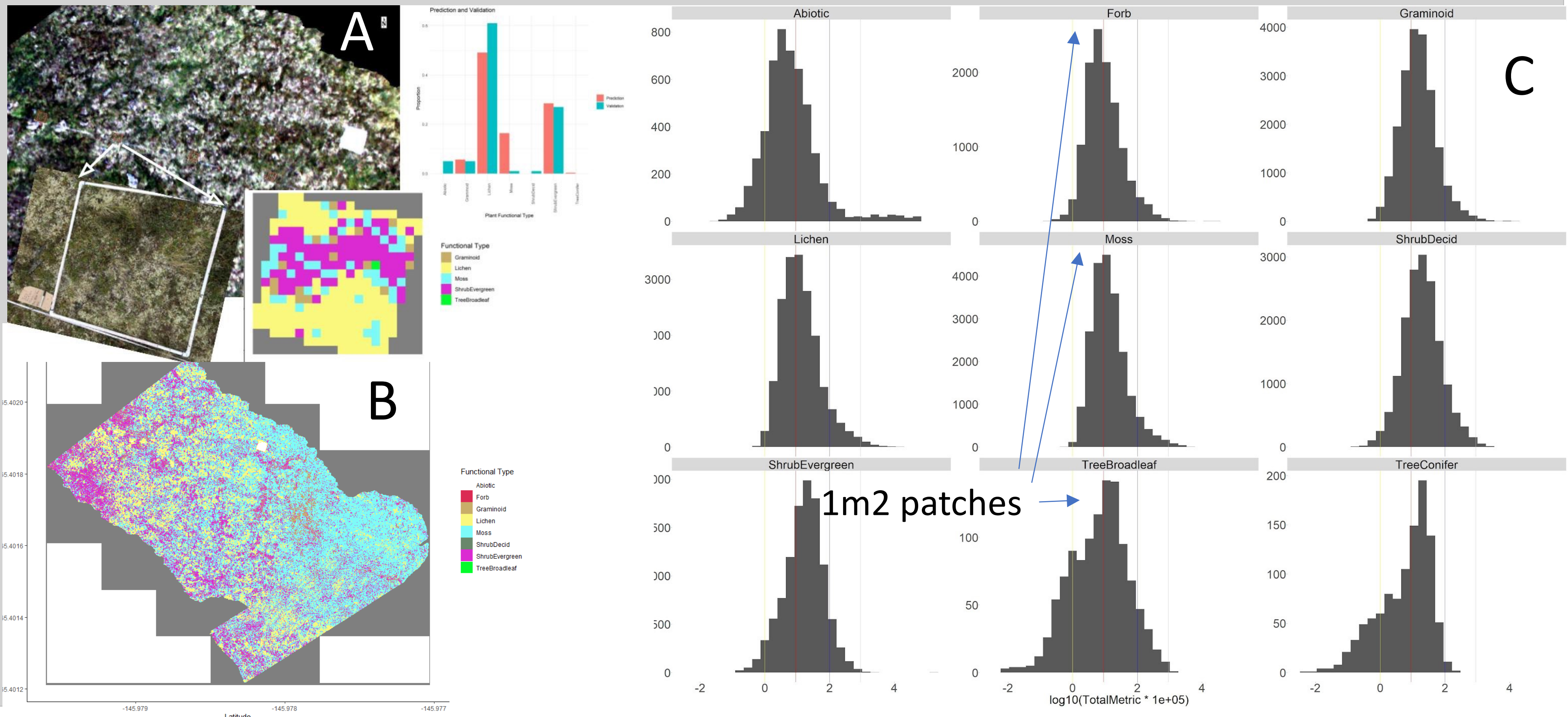
Patch sizes of plant functional types from UAV-based VNIR spectrometer data indicate much of the area occurs in patches too small to be resolved in airborne and space-based imagery

Peter R. Nelson, Kenneth Bundy, Matt Macander
- Biome Shift - PI Goetz Phase 3

1) Ground based spectra modeled PFT occurrence in UAV VNIR images (Panel A) compared to human estimates of PFT cover

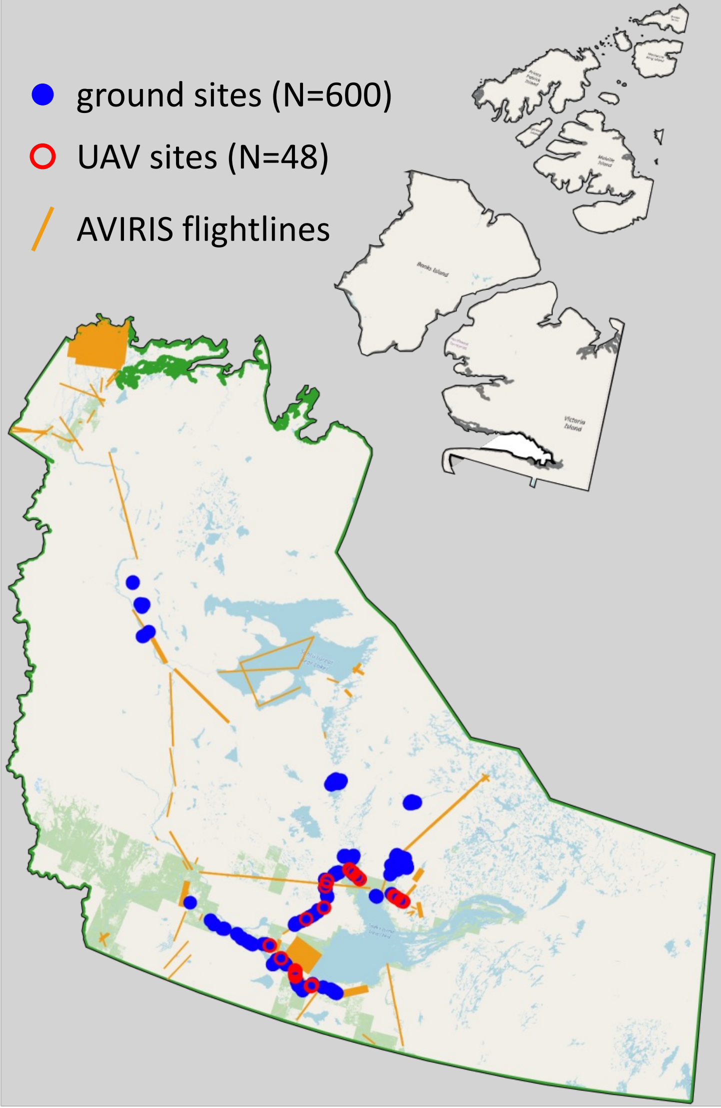
2) PFT maps made for 77 VNIR images in ABoVE domain mostly under AVIRIS (Panel B).

3) Patch size total area distributions (Panel C) of many PFTs from those 77 images mostly fall well below spatial resolution of airborne and space based products (0 on X axis = 1m2 patch = yellow line)



Stacked ground-UAV-AVIRIS data set for lichen mapping in NWT, Canada

Maria Belke-Brea, J. van der Sluijs, R. Fraser, G. Degré-Timmons, S. Cumming, J. Baltzer



Upscaling to AVIRIS for lichen mapping

↑

Classification of UAV data (random forest algorithm)

↑

UAV training data set for 13 veg. and ground classes

↑

UAV data collection at sites overflown by AVIRIS

↓

Ground truthing: All UAV sites have in situ veg. data

Done

To do

? Upscaling questions:

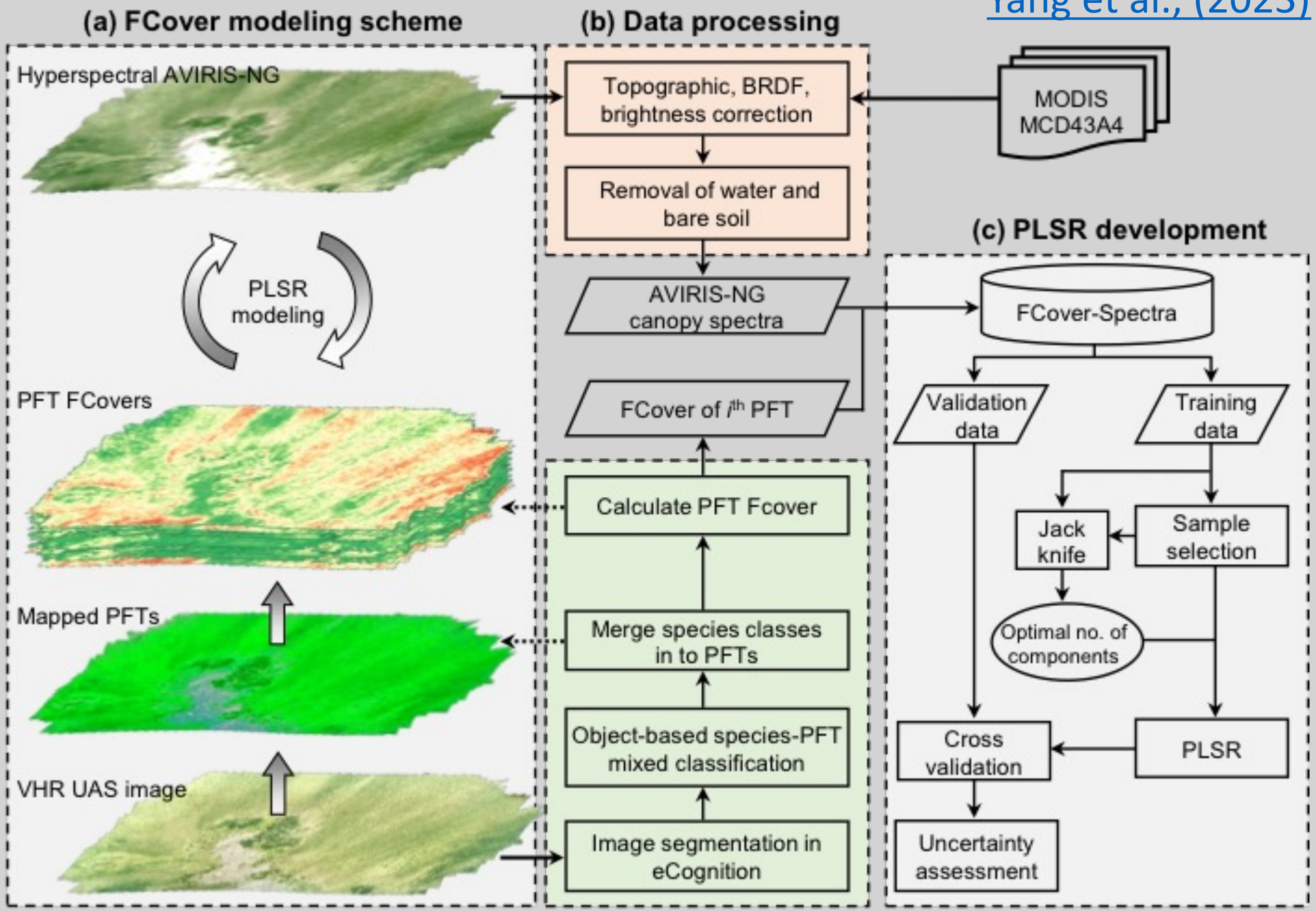
1. What is the threshold of lichen detectability in AVIRIS data?
2. How well does high spectral resolution compensate for lower spatial resolution?

RGB-UAV data specs:

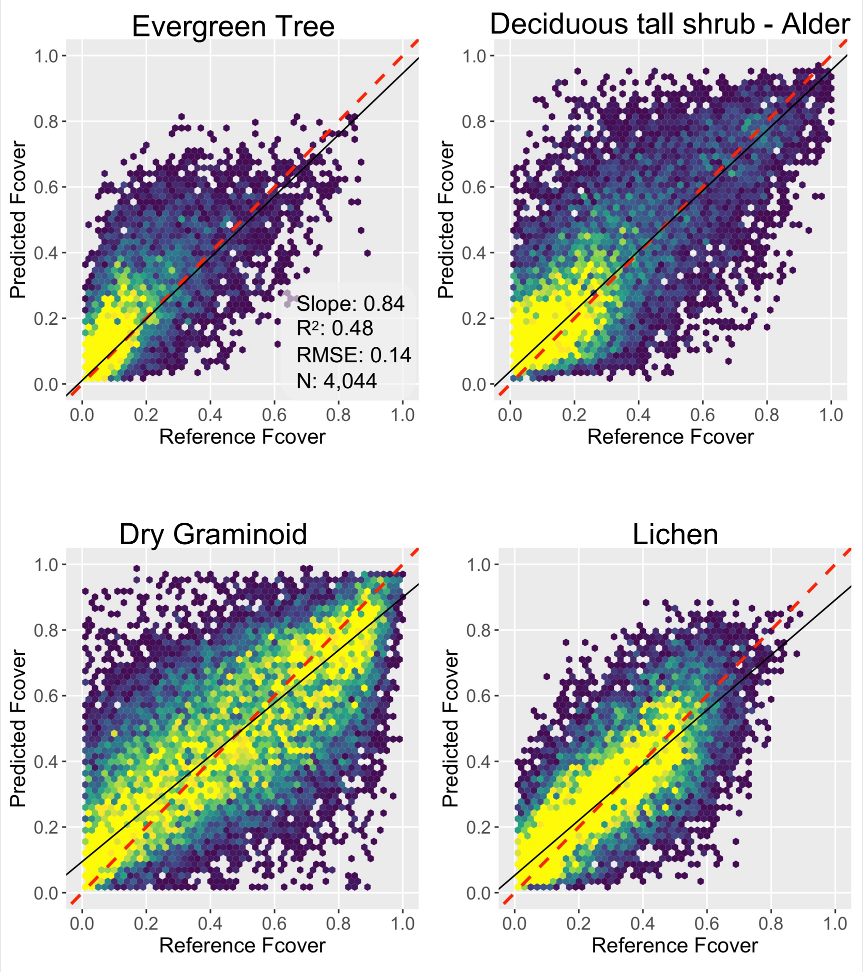
- 19600 m^2 mapped area per mission
- Spatial resolution: ~ 1 cm
- ~30 000 overlapping pixels with AVIRIS

High-resolution UASs allow researchers to map and upscale plant functional type composition at unprecedent details.

Yang et al., (2023)

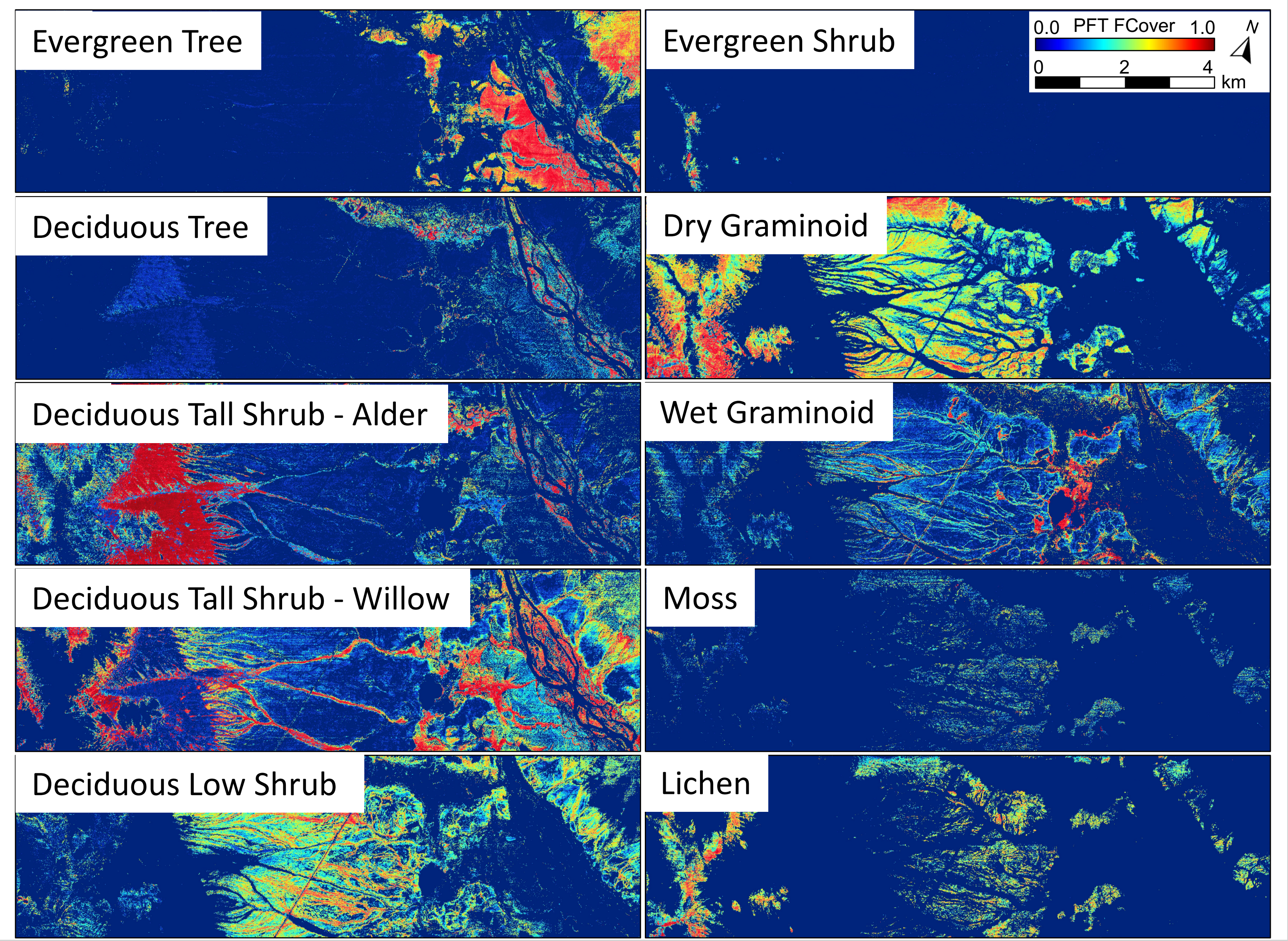


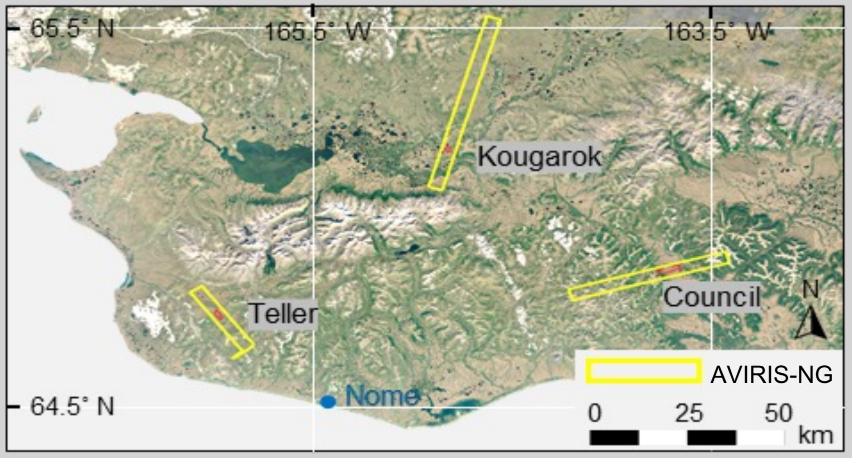
Examples of PFT fractional cover validation results against maps derived from high-resolution UAS data



Shawn Serbin & Daryl Yang

Example results from Council, Seward Peninsula





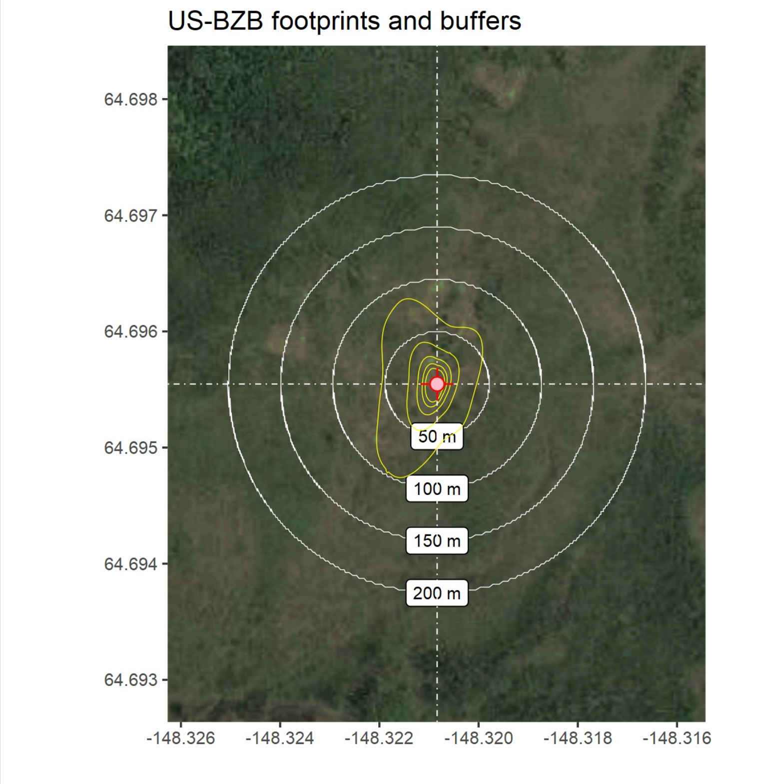
Findings:

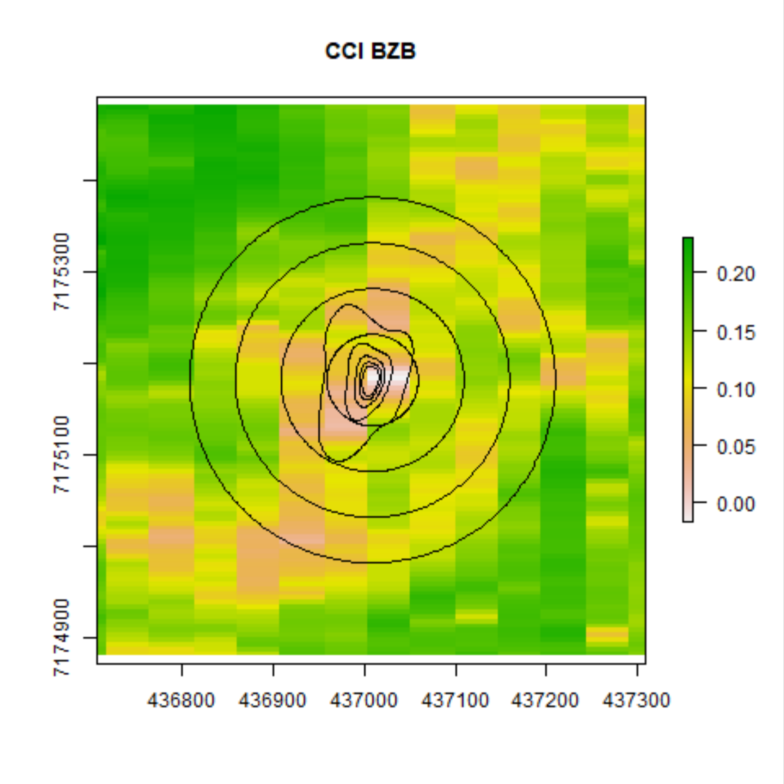
- The fractional cover of 12 Arctic PFTs are accurately captured with the UAS-based upscaling.
- The developed scaling method is highly capable of differentiating the composition of spectrally similar PFTs, e.g., Alder, Willow, and Poplar trees.
- UAS-based upscaling is superior to traditional spectral mixing-based mapping of vegetation composition

Shawn Serbin & Daryl Yang

Assessing the variability of aircraft remote sensing products (CFIS and AVIRIS-NG) within flux tower footprints

- Question: What is the hyperspectral variability around flux towers at 14 sites within ABoVE domain?
- Looked at both radii contours (50-200m) and weighted averages of flux tower footprints

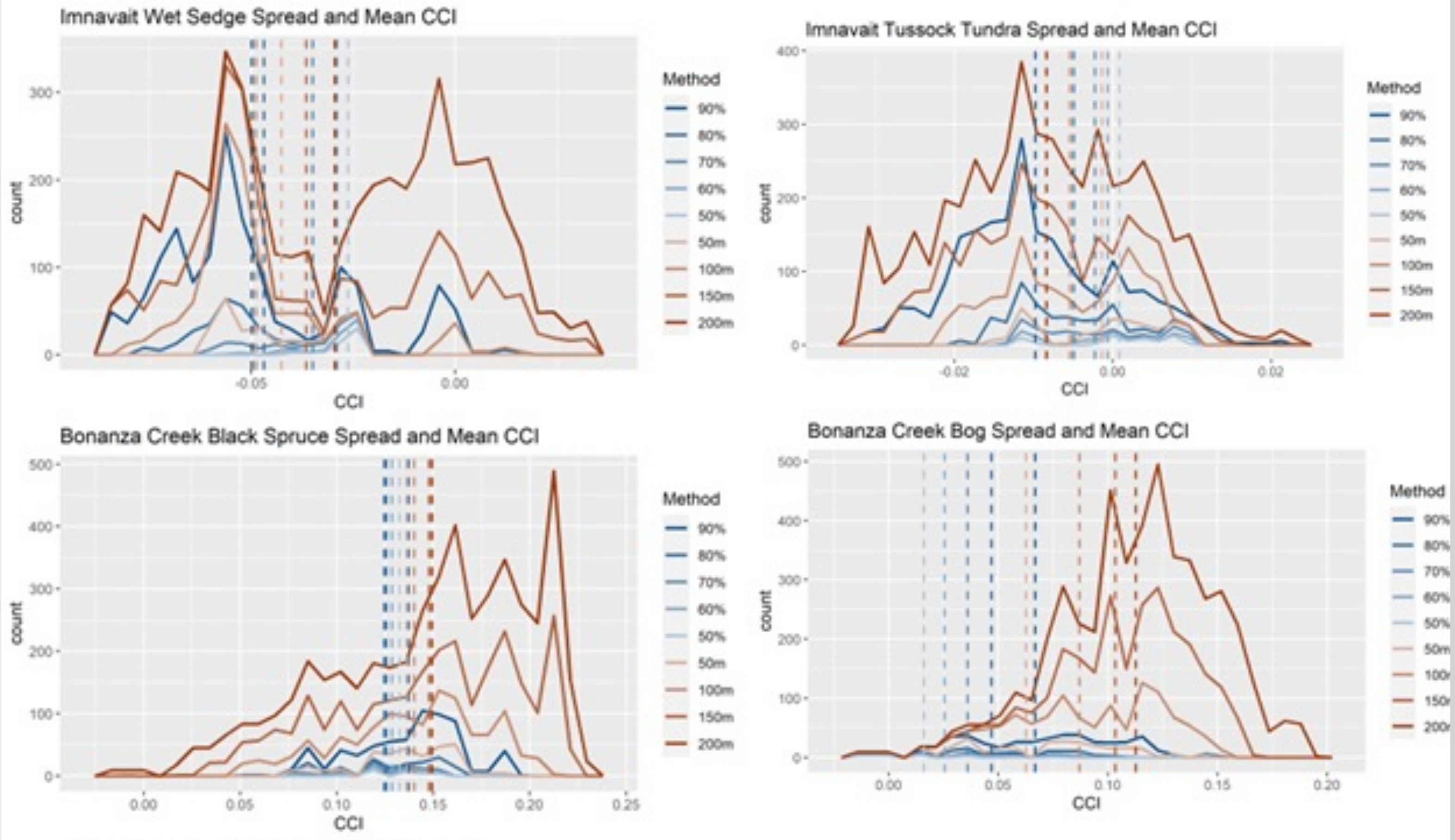




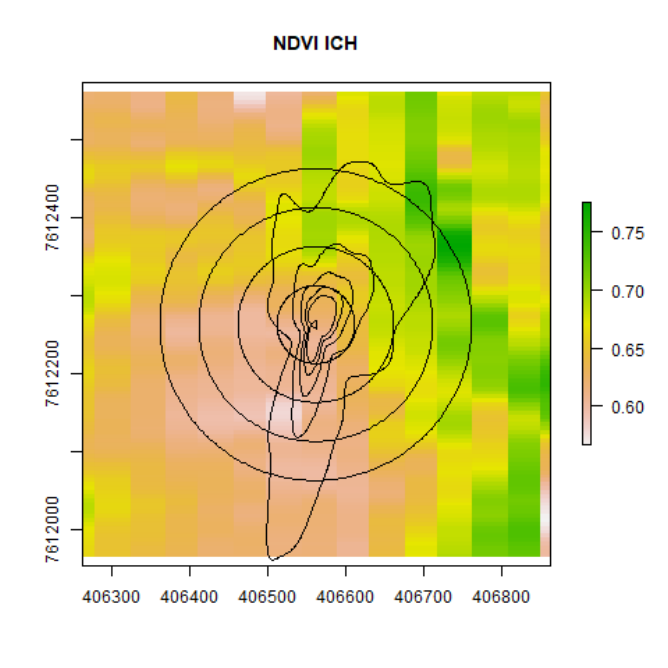
Erica L. Orcutt*, Christian Frankenberg, Housen Chu, Kyle A. Arndt, Eugenie S. Euskirchen, Gabriel Hould Gosselin, Manuel Helbig, Hiroki Ikawa, Hideki Kobayashi, Andrew J. Maguire, Philip Marsh, Gesa Meyer, Walter C. Oechel, Ryan Pavlick, William L. Quinton, Adrian V. Rocha, Christopher Schulze, Oliver Sonnentag, Donatella Zona, & Troy S. Magney

An example from 4 sites shows pixel counts using different footprints.

Take home: How you compare flux tower data to remote sensing data matters. Recommend using weighted footprints.



% contour or radii distance from tower



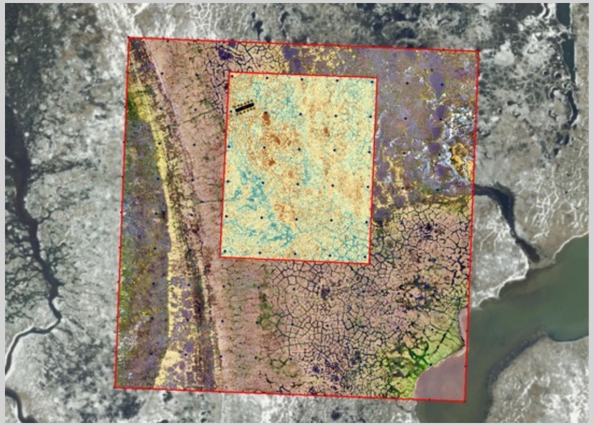
Erica Orcutt

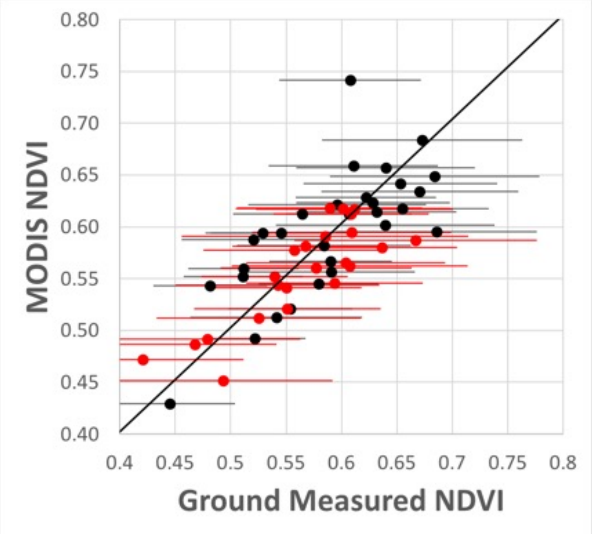
Scaling Tundra NDVI Green-up from Plot to MODIS

K.F. Huemmrich (UMBC), P. Campbell (UMBC), S. Vargas (UTEP), C. Tweedie (UTEP), R. Hollister (GVSU)

MODIS and ground measured NDVI for a subset of Circumpolar Active Layer Monitoring (CALM) grid

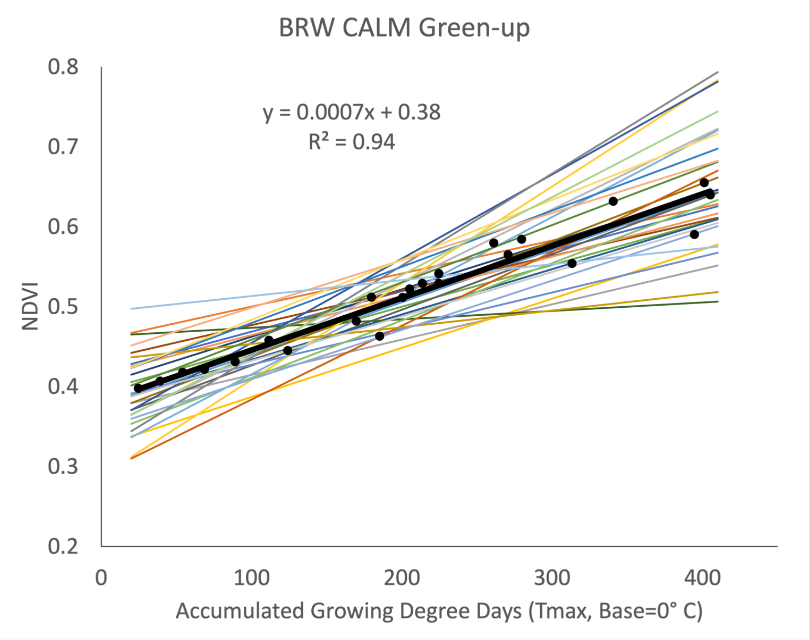
- Ground sampling of 30 points (~1 m^2 plots, 5x6 grid, 100 m between points), collected over 10 years

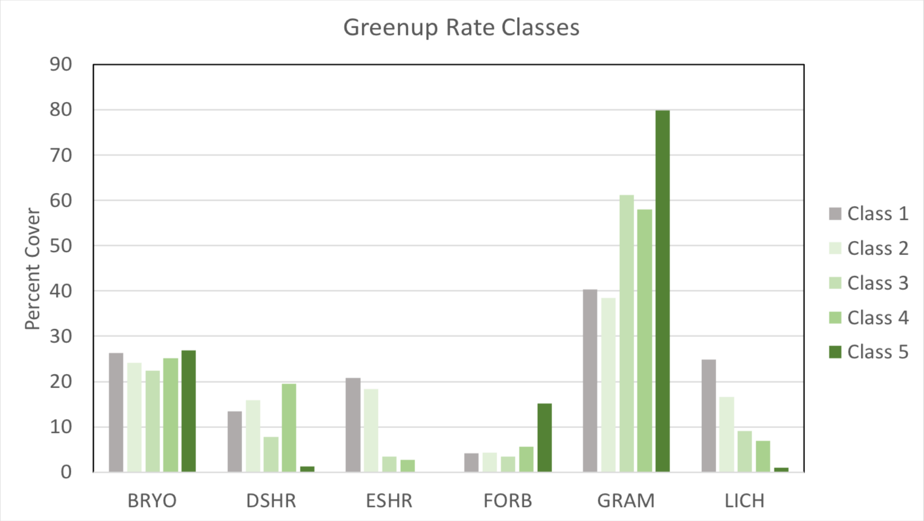




Average ground NDVI matches MODIS NDVI

Within pixel variability in springtime greening response to warmth (accumulated Growing Degree Days) related to cover type





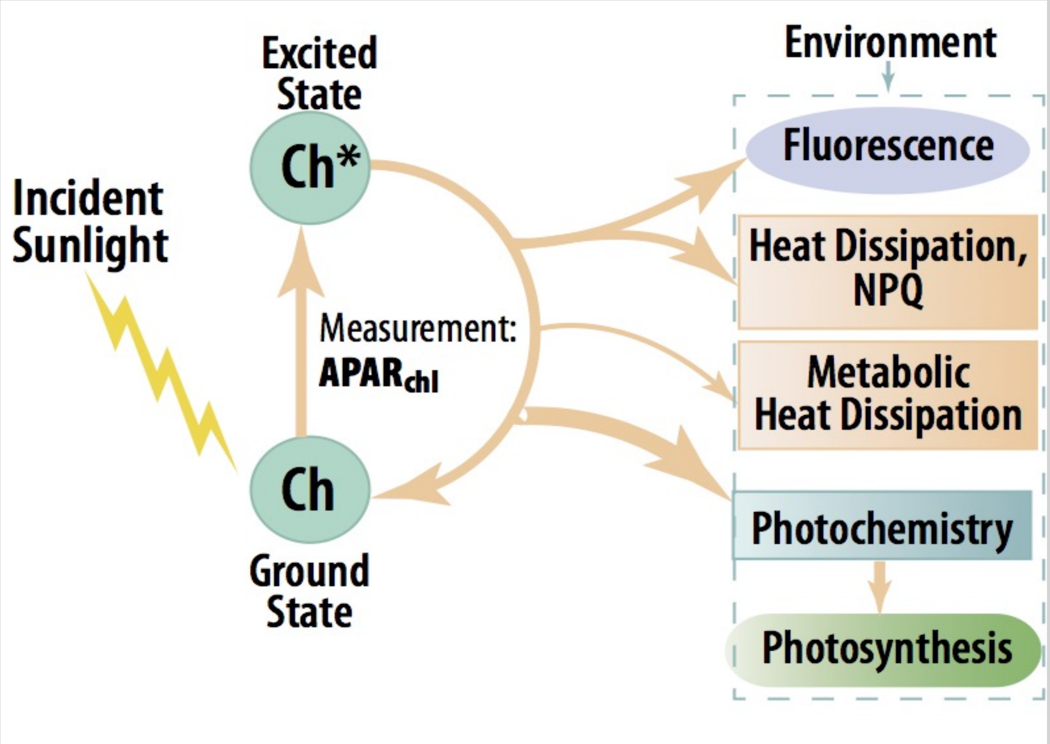
This work is supported by NASA (grant # NNX17AC58A)
We thank the Inupiaq communities whose land we are studying

Solar Induced Fluorescence (SIF) in ABoVE

Chlorophyll fluorescence (F) at leaf level is closely linked to photosynthesis.

Canopy solar induced fluorescence (SIF) can be remotely sensed and has the potential to link to the leaf-level processes and estimate productivity at different temporal and spatial scales.

Within ABoVE investigators are examining SIF at a range of spatial and temporal scales.

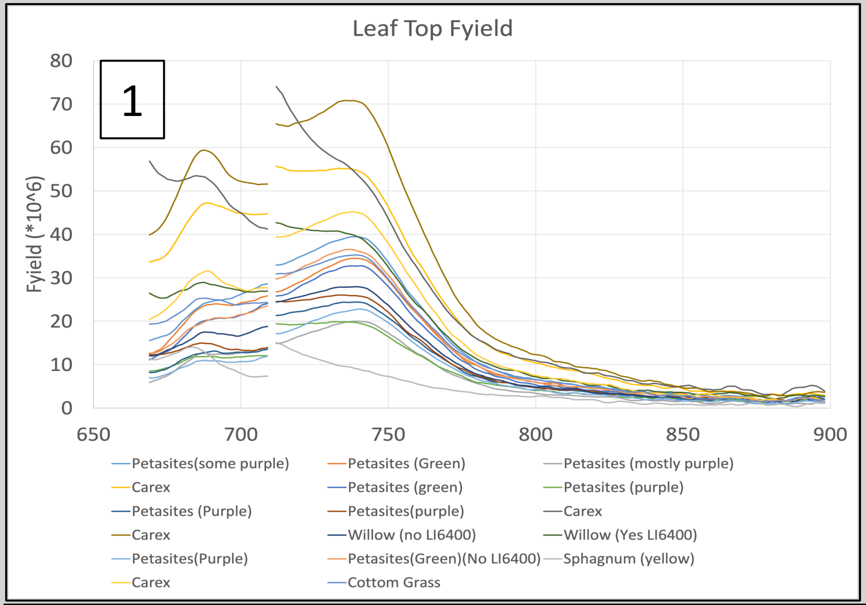


ABoVE 9th SCIENCE TEAM MEETING

WYNDHAM SAN DIEGO BAYSIDE 23-26 JANUARY 2023

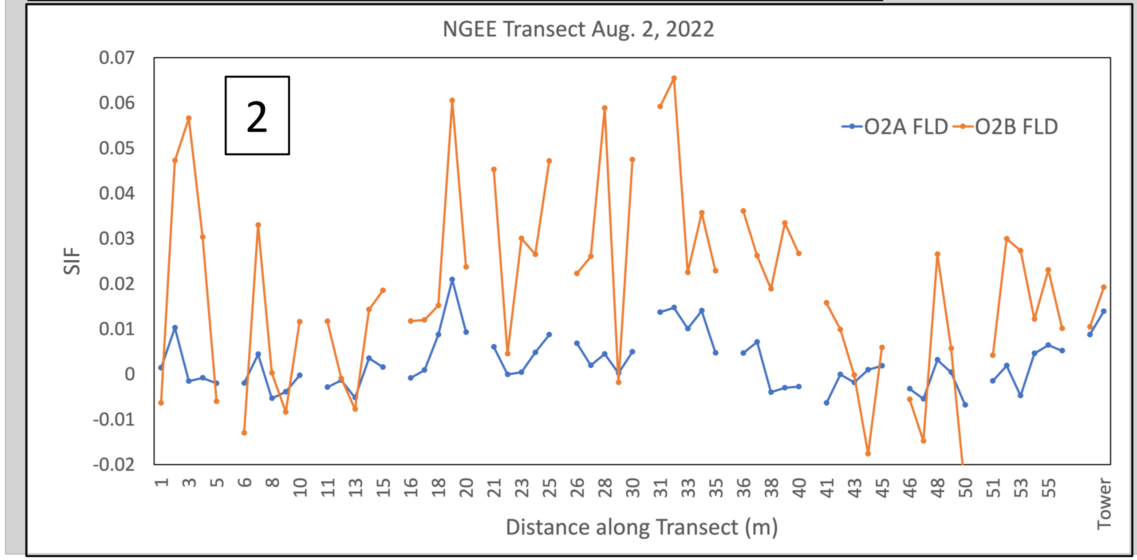
Field Measurements of Tundra Solar Induced Fluorescence (SIF)

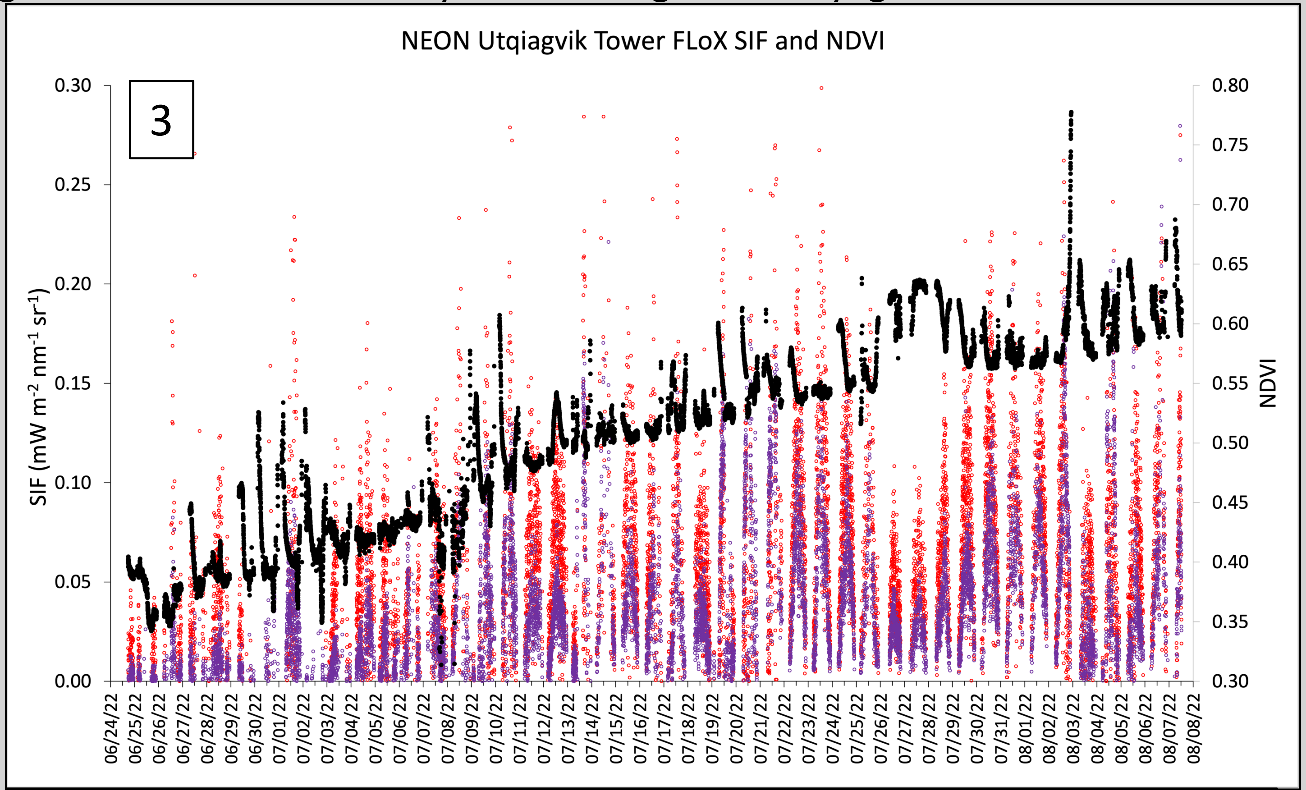
K.F. Huemmrich, P. Campbell, S.A. Vargas Z., C. Tweedie, M. Mora, B. Almanza



Field measurements of tundra in Utqiagvik show important scaling factors for SIF

1) At the leaf level, both between and within species variation in magnitude of red and far red Fyield peaks
2) Large spatial variability at the meter scale along transect from flux tower
3) Over time, significant diurnal variability even during 24 hr. daylight





This work is supported by NASA grant 80NSSC19M0110. We are grateful to the Inupiaq communities whose land we are studying

JGR Biogeosciences

RESEARCH ARTICLE
10.1029/2021JG006588

Key Points:

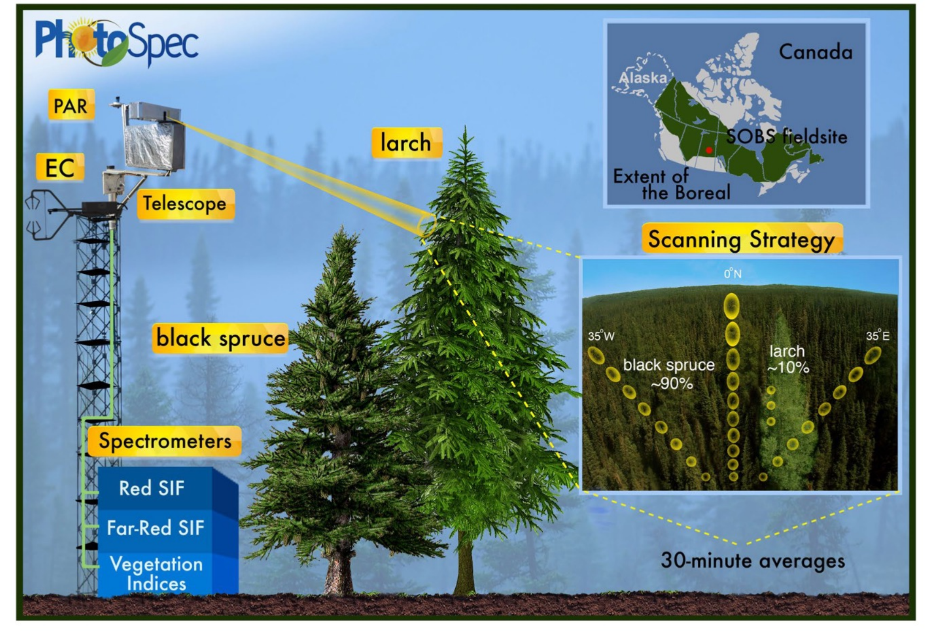
- Tower-based solar-induced chlorophyll fluorescence (SIF) closely tracks gross primary productivity (GPP) over two years in a mixed-species boreal forest
- Light saturation of photosynthesis drives non-linearity between SIF and GPP
- The SIF-GPP relationship is seasonally variant due to dynamics between LUE_F and LUE_P

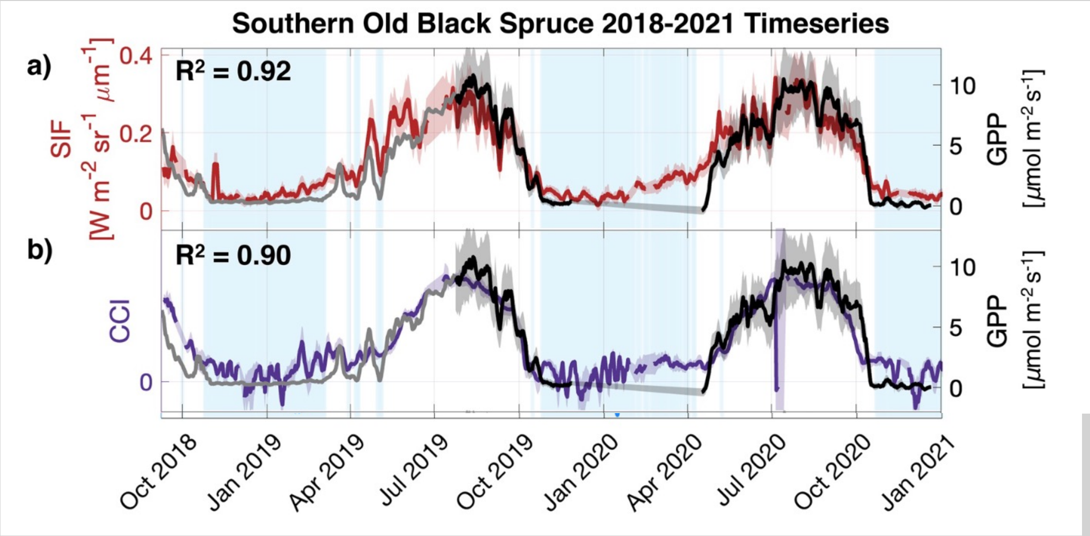
Diurnal and Seasonal Dynamics of Solar-Induced Chlorophyll Fluorescence, Vegetation Indices, and Gross Primary Productivity in the Boreal Forest

Zoe Pierrat[1], Troy Magney[2], Nicholas C. Parazoo[3,4], Katja Grossmann[5], David R. Bowling[6], Ulli Seibt[1], Bruce Johnson[7], Warren Helgason[7], Alan Barr[7], Jacob Bortnik[1], Alexander Norton[3], Andrew Maguire[3], Christian Frankenberg[4], and Jochen Stutz[1]

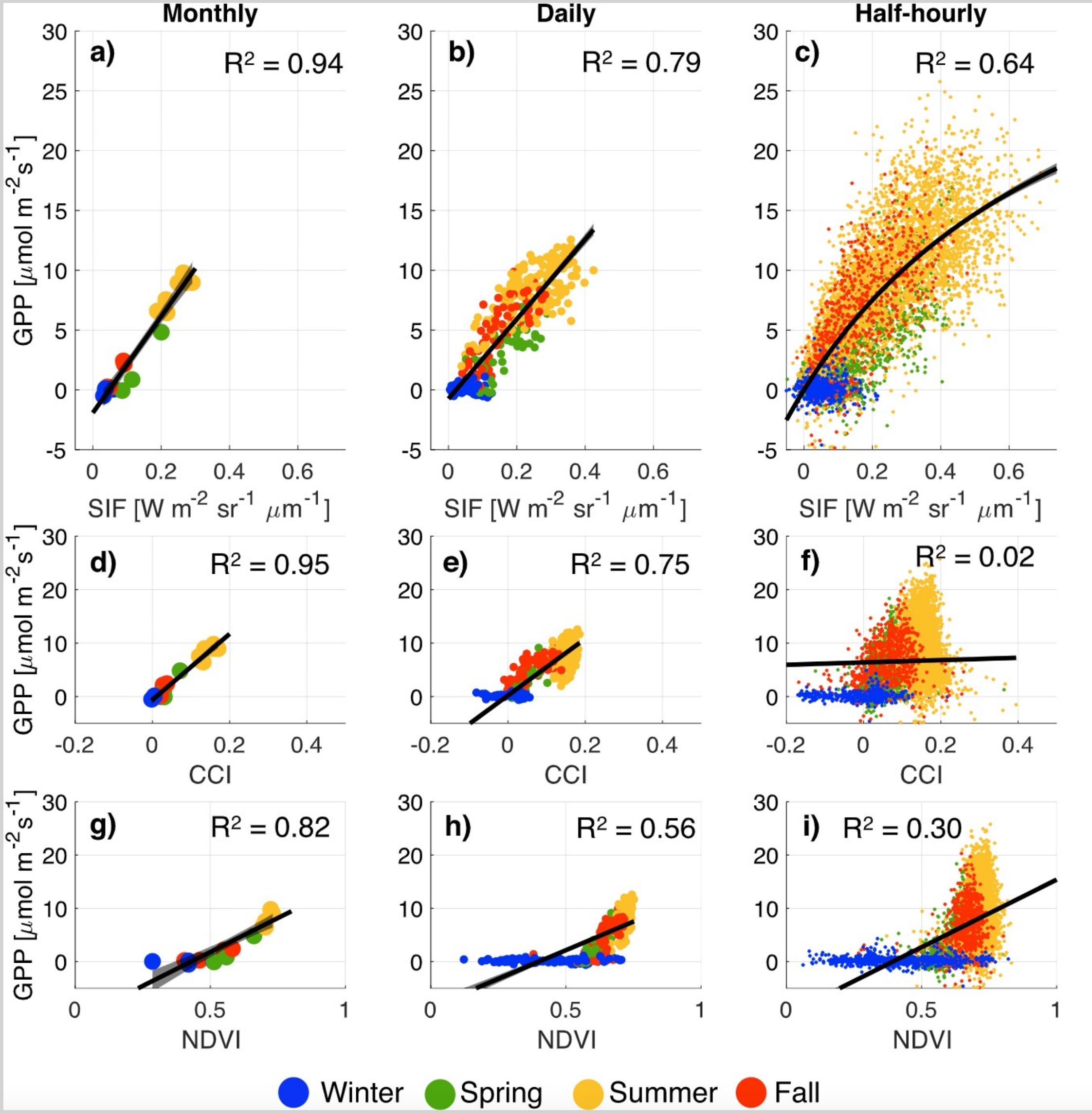
[1]University of California Los Angeles, Los Angeles, CA, USA, [2]University of California Davis, Davis, CA, USA, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, [4]California Institute of Technology, Pasadena, CA, USA, [5]University of Heidelberg, Heidelberg, Germany, [6]University of Utah, Salt Lake City, UT, USA, [7]University of Saskatchewan, Saskatoon, SK, Canada

- Used high resolution tower spectral data to look at temporal dynamics of VIs and SIF at the Southern Old Black Spruce site in Saskatchewan





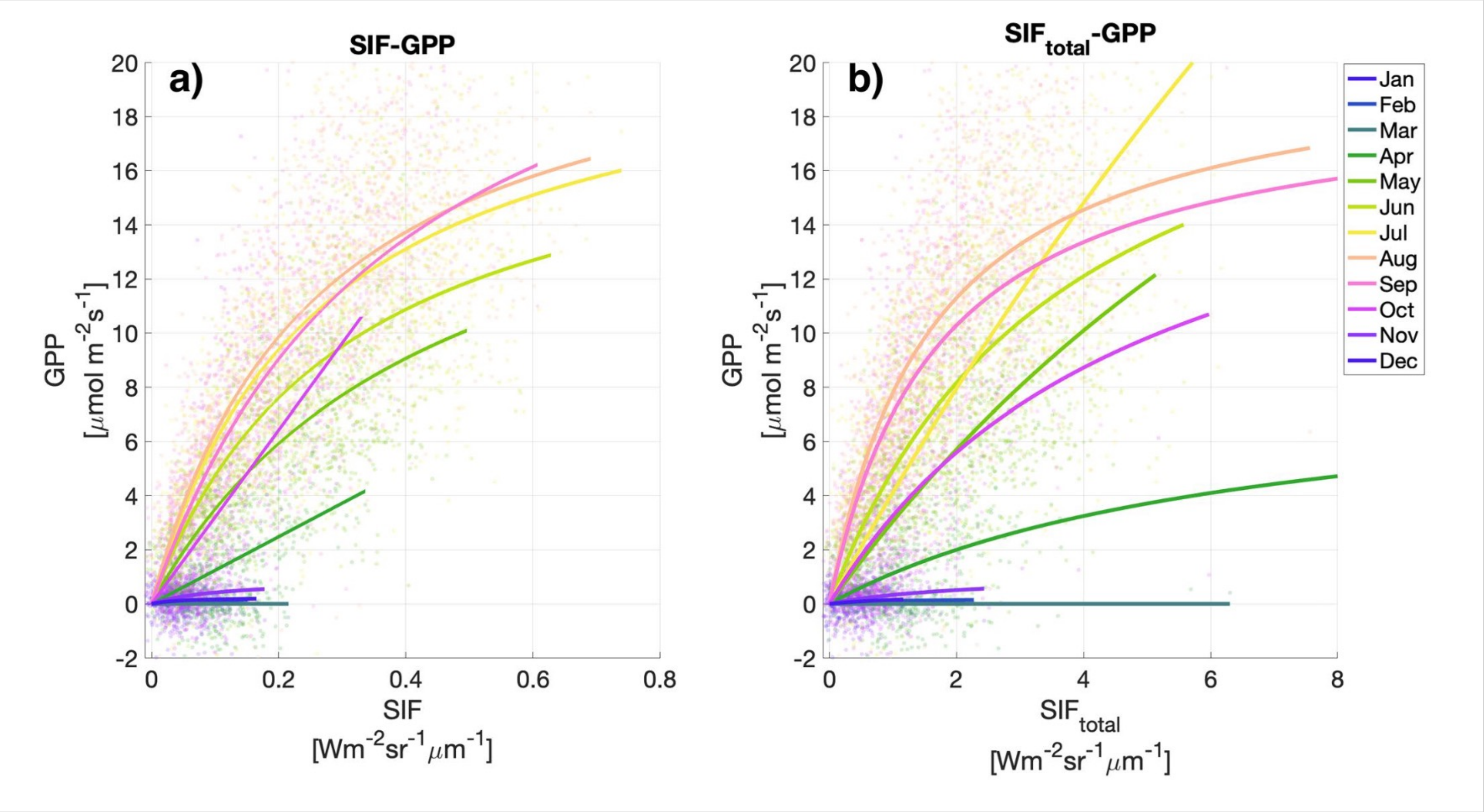
Zoe Pierrat



- Relationships between NDVI, CCI and SIF at Monthly, Daily and Half-hourly time scales
- Observed non-linearity in SIF at the half-hourly time scale due to GPP saturation at high light
- CCI and NDVI show no relationship at the half-hourly time scale with improvements in temporal aggregration

Zoe Pierrat

The SIF:GPP relationship is non linear at half-hourly intervals and the nature of the relationship changes on a monthly basis.



Zoe Pierrat

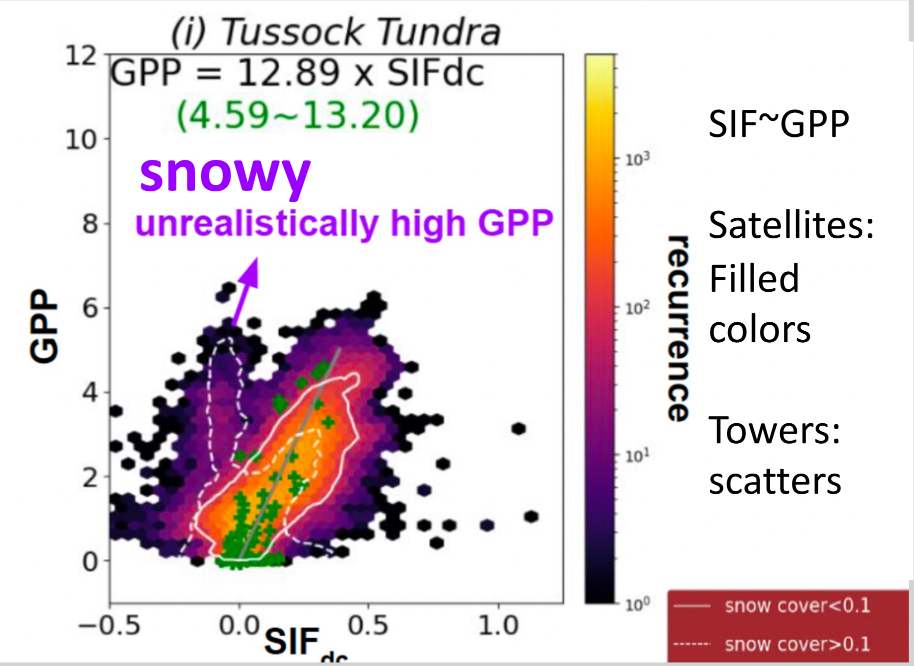
Challenges in comparing GPP derived from SIF and reflectance across spatial scales (tower vs. satellite)

Cheng, R., Magney, T. S., Orcutt, E. L., Pierrat, Z., Köhler, P., Bowling, D. R., ... & Frankenberg, C. (2022). Evaluating photosynthetic activity across Arctic-Boreal land cover types using solar-induced fluorescence. *Environmental Research Letters*, *17*(11), 115009.

- subpixel heterogeneity
  (inconsistant land cover types across scales)

Name	30m	0.0833° 10km	IGBP	PI's definition
CA-HPC	*Fen*	*Woodland*	*ENF*	*Woodland*
CA-Obs	—	—	*ENF*	*Evergreen Forest*
CA-SMC	*Woodland*	*Water*	*ENF*	*Evergreen Forest*
CA-TVC	*Herbaceous*	*Low Shrub*	*OSH*	*Low Shrub*
DEJU	*Evergreen Forest*	*Woodland*	*ENF*	*Evergreen Forest*
US-An1	*Sparsely Vegetated*	*Tussock Tundra*	*OSH*	*Sparsely Vegetated*
US-An3	*Tussock Tundra*	*Tussock Tundra*	*OSH*	*Tussock Tundra*
US-Atq	*Low Shrub*	*Sparsely Vegetated*	*WET*	*Tussock Tundra*
US-BZB	*Woodland*	*Deciduous Forest*	*WET*	*Fen*
US-BZF	*Low Shrub*	*Deciduous Forest*	*WET*	*Fen*
US-BZS	*Woodland*	*Deciduous Forest*	*ENF*	*Evergreen Forest*
US-ICh	*Low Shrub*	*Tussock Tundra*	*OSH*	*Low Shrub*
US-ICs	*Tussock Tundra*	*Tussock Tundra*	*WET*	*Fen*
US-ICt	*Tussock Tundra*	*Tussock Tundra*	*OSH*	*Tussock Tundra*
US-Ivo	*Herbaceous*	*Low Shrub*	*WET*	*Tussock Tundra*
US-Prr	*Woodland*	*Woodland*	*ENF*	*Evergreen Forest*

- snow



And
- Surface water
- topography
- extrapolation
- ...

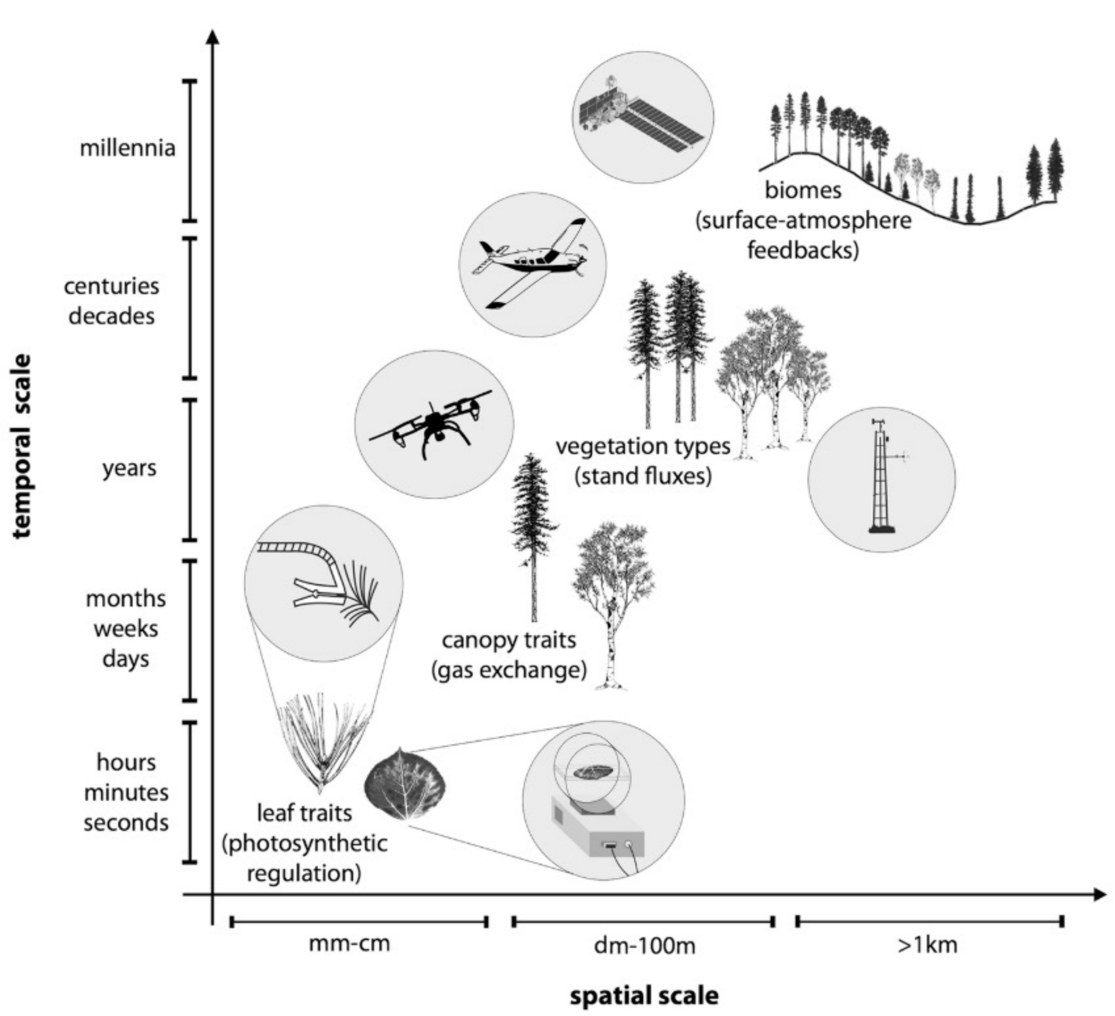
Check out our paper

Rui Cheng

Next Steps

Organize our discussions and findings on scaling in optical remote sensing for high latitudes leading to another group paper

We have been having monthly meetings, all are welcome, just join the working group to get on the mailing list



Gamon et al., 2019