NGEE Arctic
Next-Generation Ecosystem Experiments

Enhancing collaborations between NGEE-Arctic and NASA ABoVE

Shawn Serbin
and the NGEE-Arctic team

Next-Generation Ecosystem Experiments: Arctic
Ecosystem Processes
Modeling, Prediction
Systems Understanding

U.S. DEPARTMENT OF ENERGY | Office of Science

OAK RIDGE National Laboratory

Los Alamos NATIONAL LABORATORY

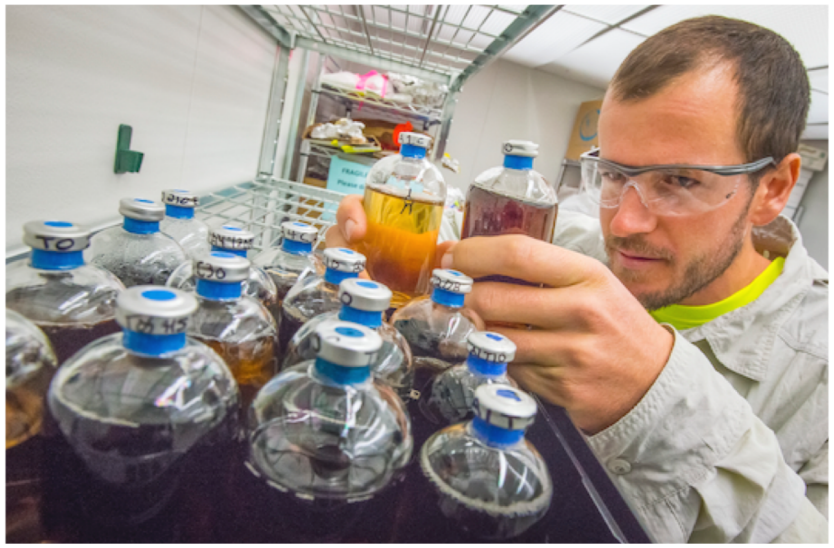
BERKELEY LAB

BROOKHAVEN NATIONAL LABORATORY

UAF UNIVERSITY OF ALASKA FAIRBANKS

NGEE-Arctic

Deliver a process-rich ecosystem model, extending from bedrock to the top of the vegetative canopy/atmospheric interface, in which the evolution of Arctic ecosystems in a changing climate can be modeled at the scale of a high-resolution Earth System Model (ESM) grid cell.



Climate Feedbacks in Arctic Ecosystems

Permafrost Thaw

Permafrost contains 1700 Pg C

A large fraction of that permafrost could thaw by 2100 (*Slater and Lawrence, 2013*)

Microbial decomposition could represent a positive feedback to climate warming through CO_2 and CH_4 emissions

Shrub Expansion

Trend observed for shrub expansion in Northern Alaska (*Tape et al, 2005*)

Changes in albedo could mediate feedbacks to climate, but the magnitude is uncertain

Emphasis on plant traits and shrub dynamics

Climate Feedbacks in Arctic Ecosystems

Hydrology and Water Distribution Across Changing Landscapes

A synthesis of field observations, remote sensing and modelling documents that polygon degradation across the Arctic has important hydrological implications (*Liljedahl et al., 2016*)

Differential ground subsidence at a few tens of centimeters may be perceived as small locally, but has the potential to significantly impact the regional ecosystem, as ice-rich permafrost may underlie up to two-thirds of the terrestrial Arctic.

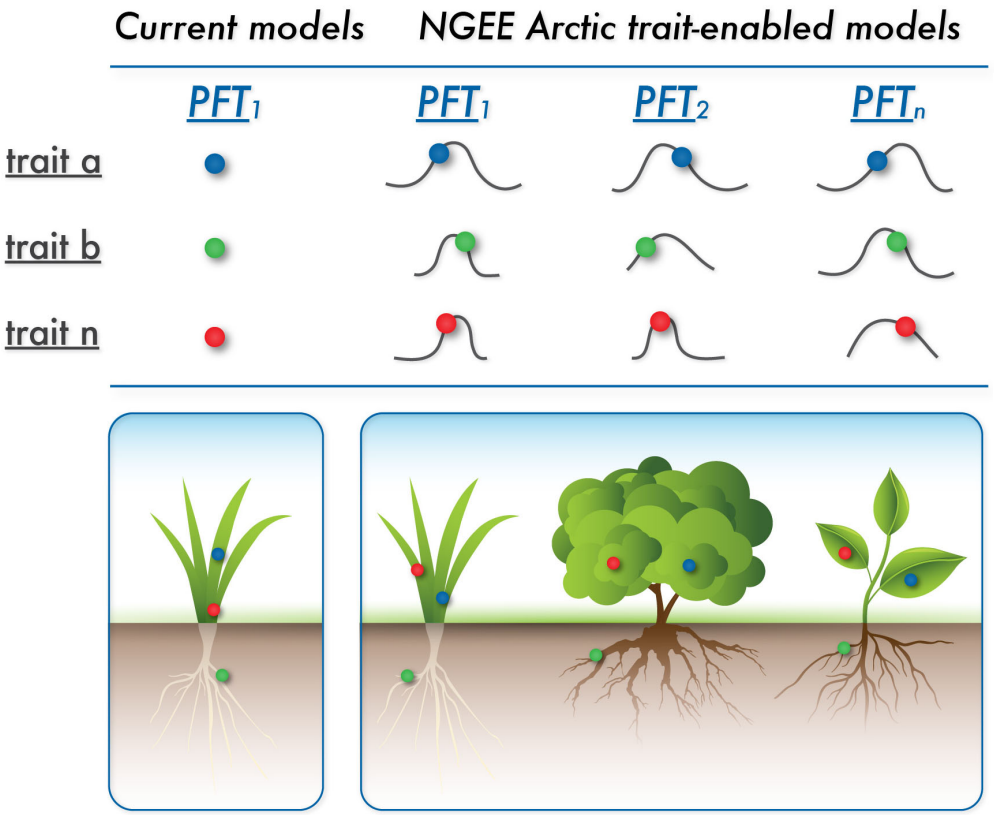
Whether the Arctic will become wetter or drier in light of an evolving landscape is an unresolved question.

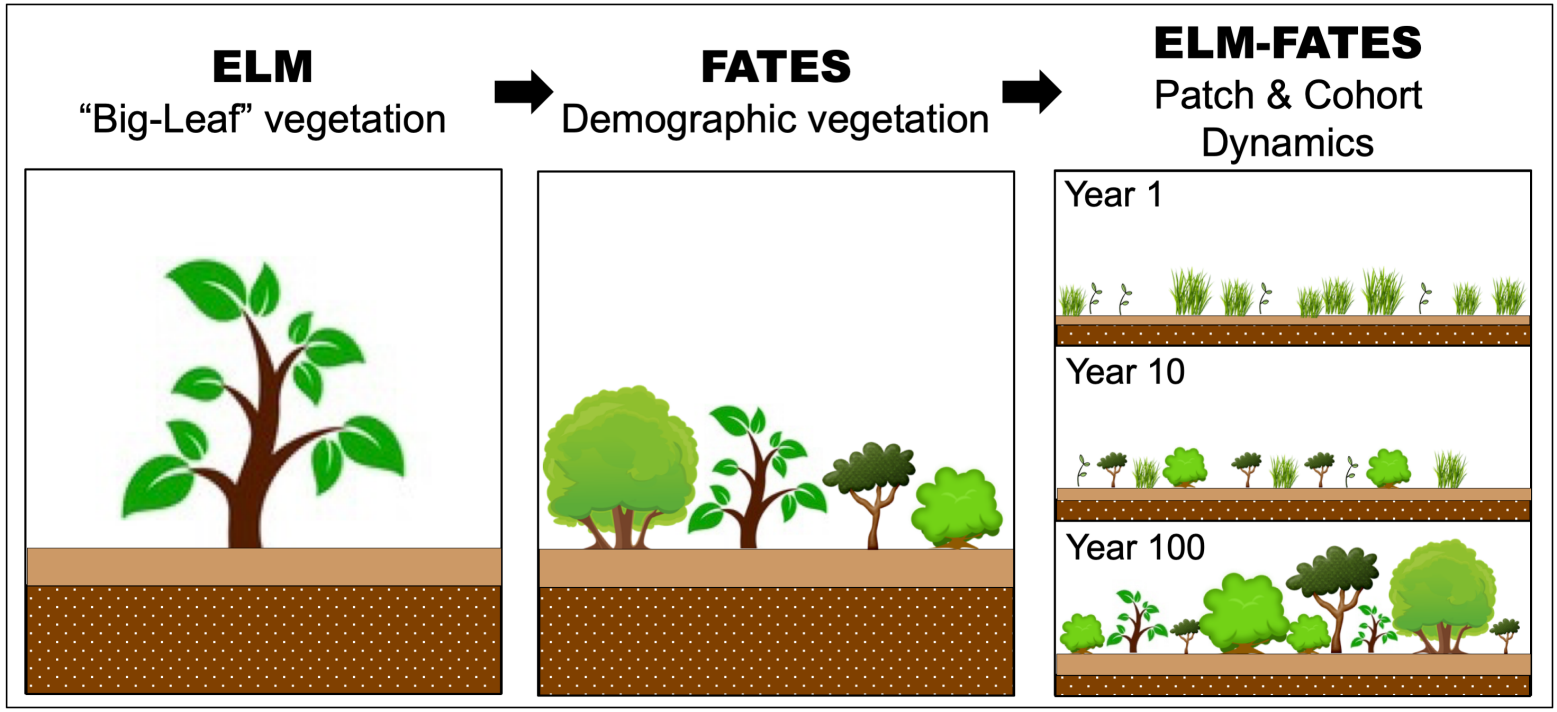
E3SM
Energy Exascale Earth System Model

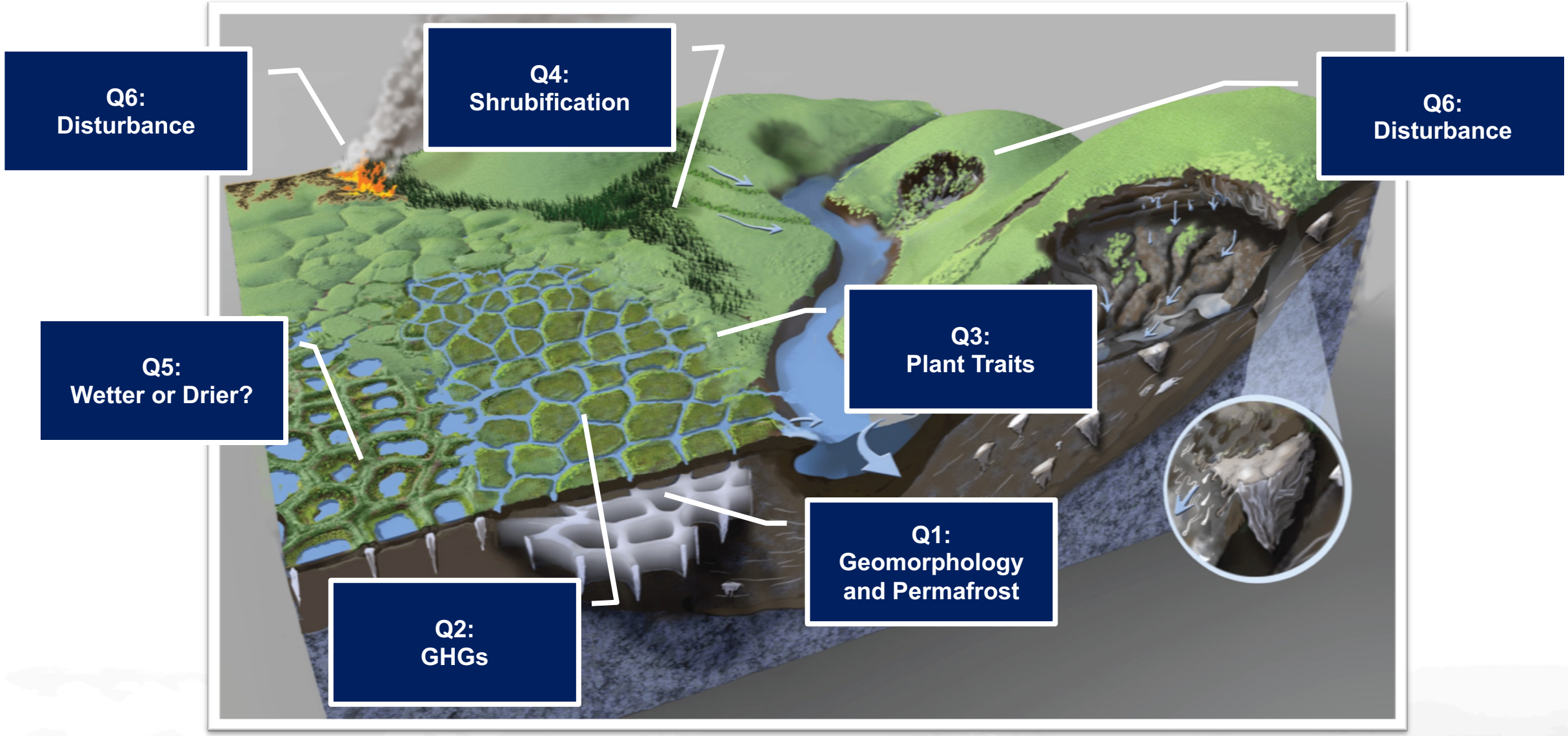
Pan-Arctic capabilities that that address:

- ***Landscape heterogeneity*** in surface and subsurface properties and processes, and the distribution of features across the landscape,
- ***Biogeochemical feedbacks*** due to thawing permafrost, landscape change, and consequences for microbial dynamics that drive CO_2 and CH_4 emissions,
- ***Biophysical feedbacks*** due to shrubs and shrub expansion, and regional changes in energy balance for evolving landscapes, and
- ***Hydrology at watershed scales*** and importance of snow-shrub interactions, active layer, permafrost, and bedrock interactions that drive water distribution.

Dynamic Vegetation



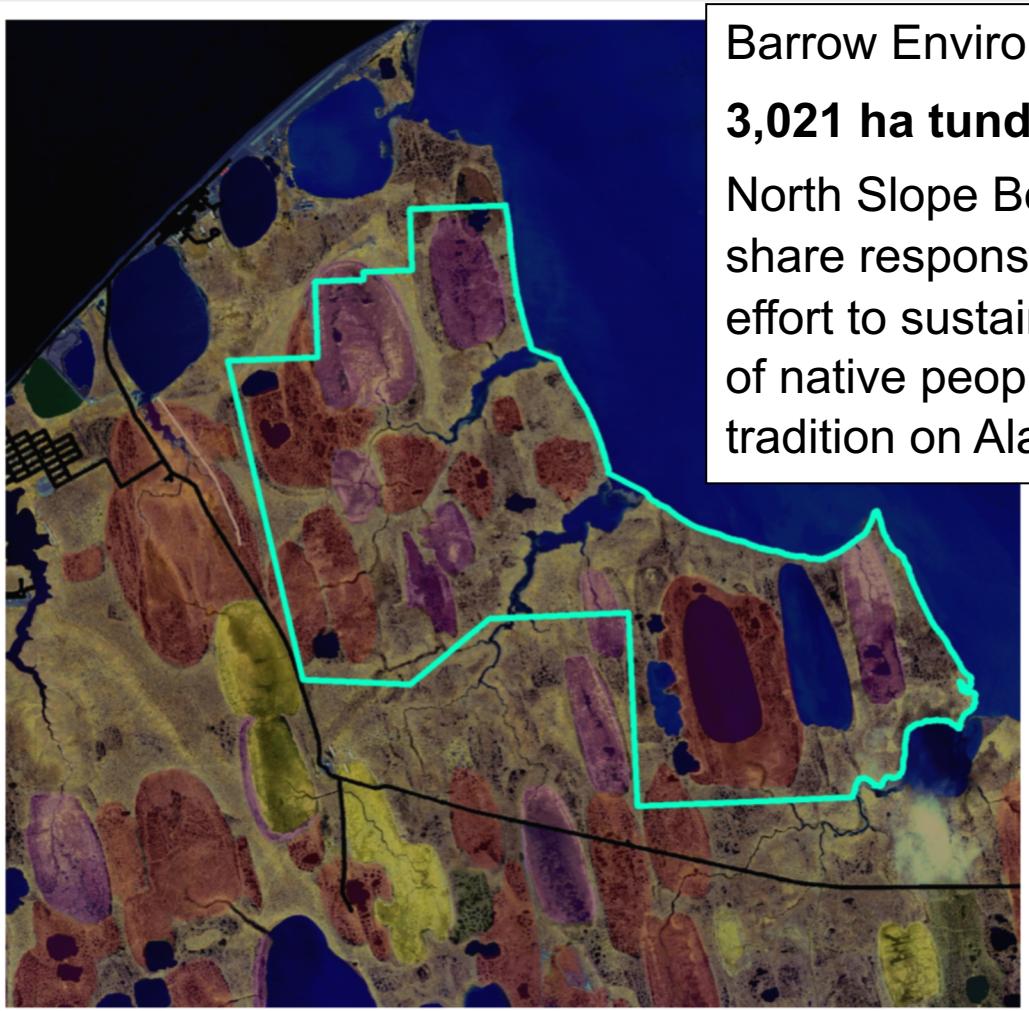




Schuur and Mack (2018). Annu. Rev. Ecol. Evol. Syst. 49: 279-301.

NGEE Arctic Field Sites (Phase 1)

Utqiagvik, Alaska

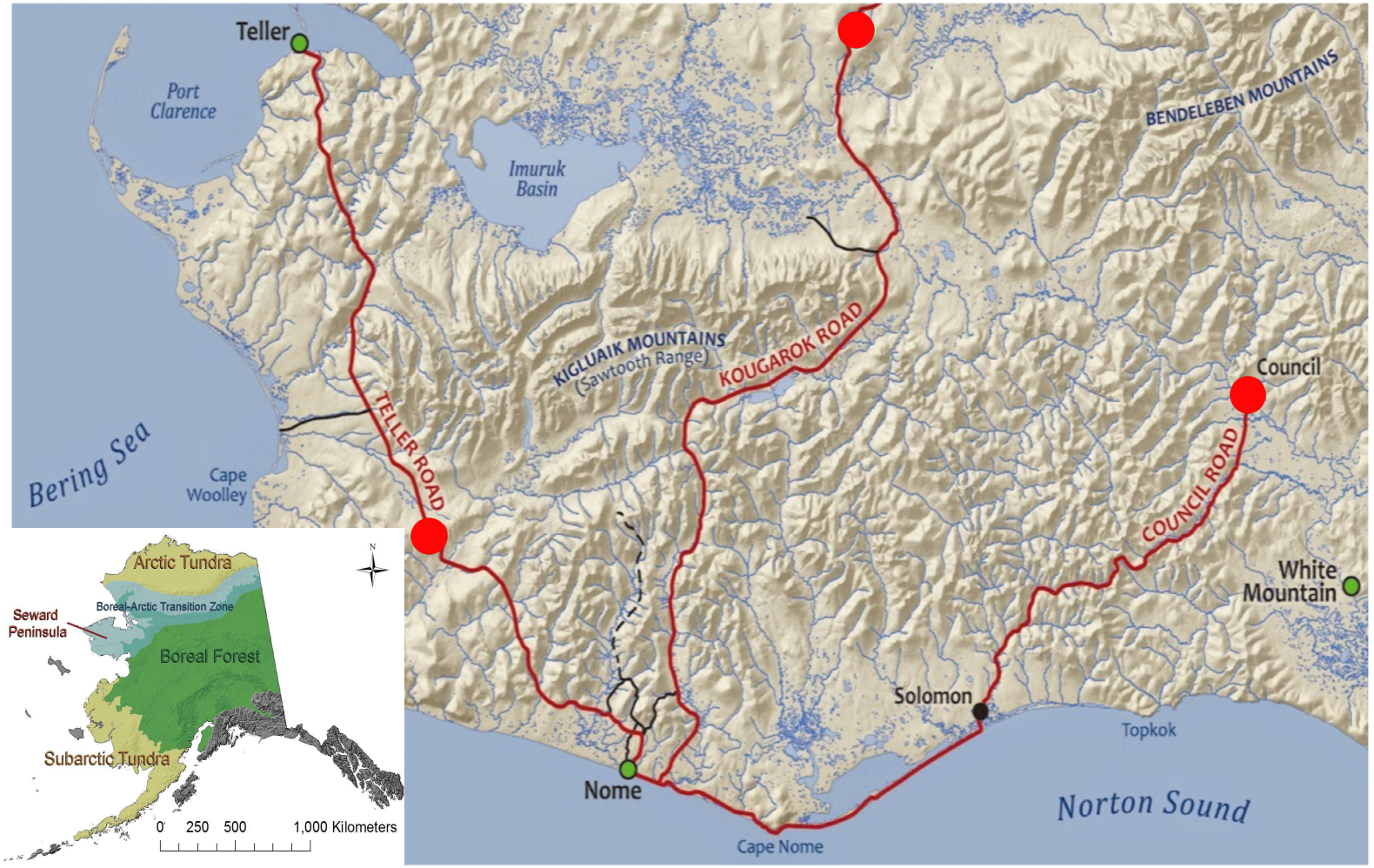


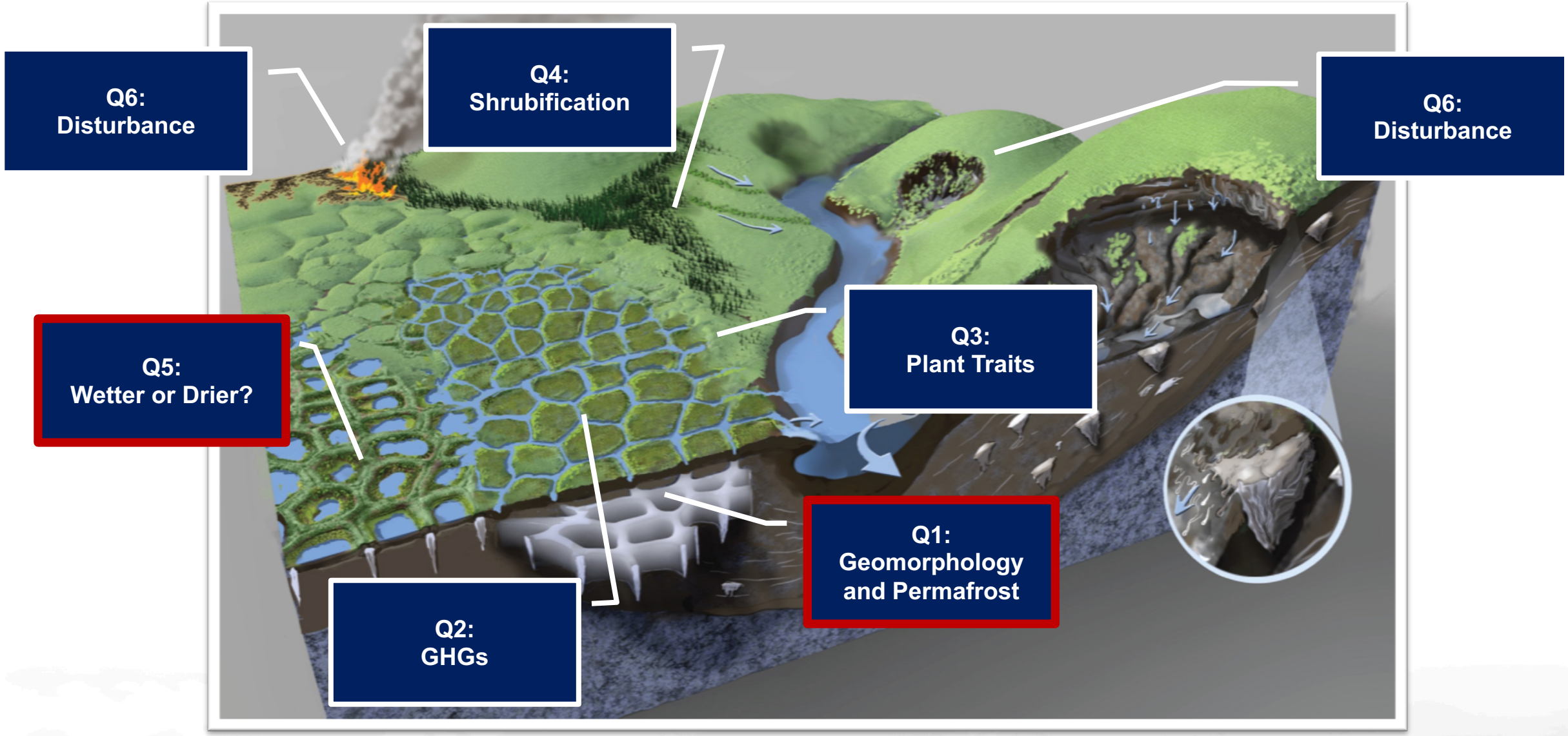
Barrow Environmental Observatory (BEO)

3,021 ha tundra preserve

North Slope Borough and UIC Science share responsibilities for the BEO in an effort to sustain the long-term commitment of native people to the scientific research tradition on Alaska's North Slope.

NGEE Arctic Field Sites (Phase 2)





Schuur and Mack (2018). Annu. Rev. Ecol. Evol. Syst. 49: 279-301.

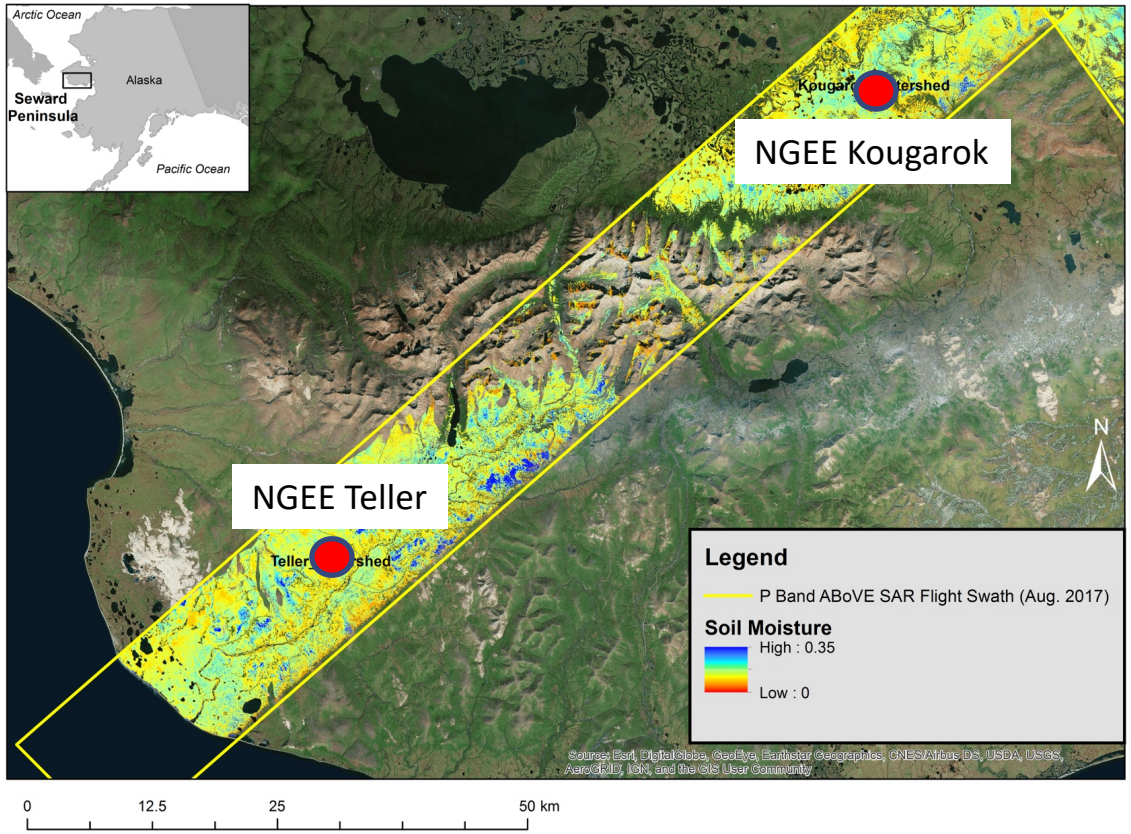
NGEE-ABoVE Soil Moisture Mapping

- Measured *in-situ* soil moisture and ALT during 2017 ABoVE P-band (Seward Peninsula) and L-Band (Utqiagvik) surveys.
- Data and soil samples were collected and analyzed at 4 sites at Teller, 3 sites at Kougarok and 2 sites at Council NGEE watersheds.
- Data is DOI'd and available on the NGEE Arctic Data Portal.

Teller Site TL_SAR_41

ABoVE Autumn 2017 P-Band

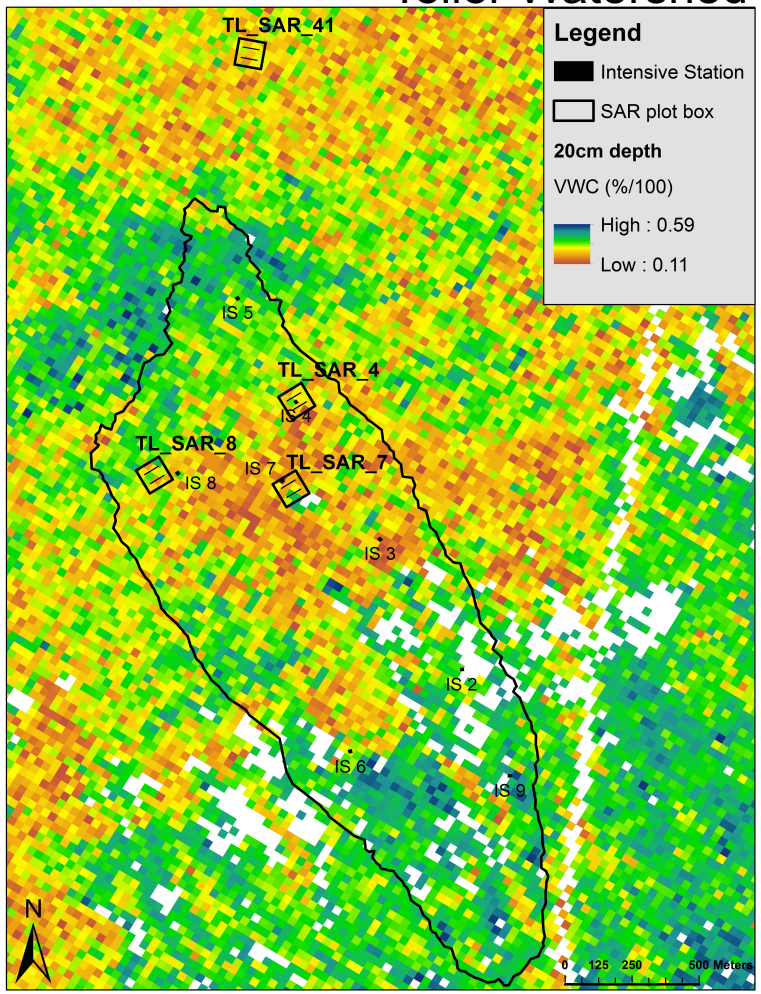
Seward Peninsula

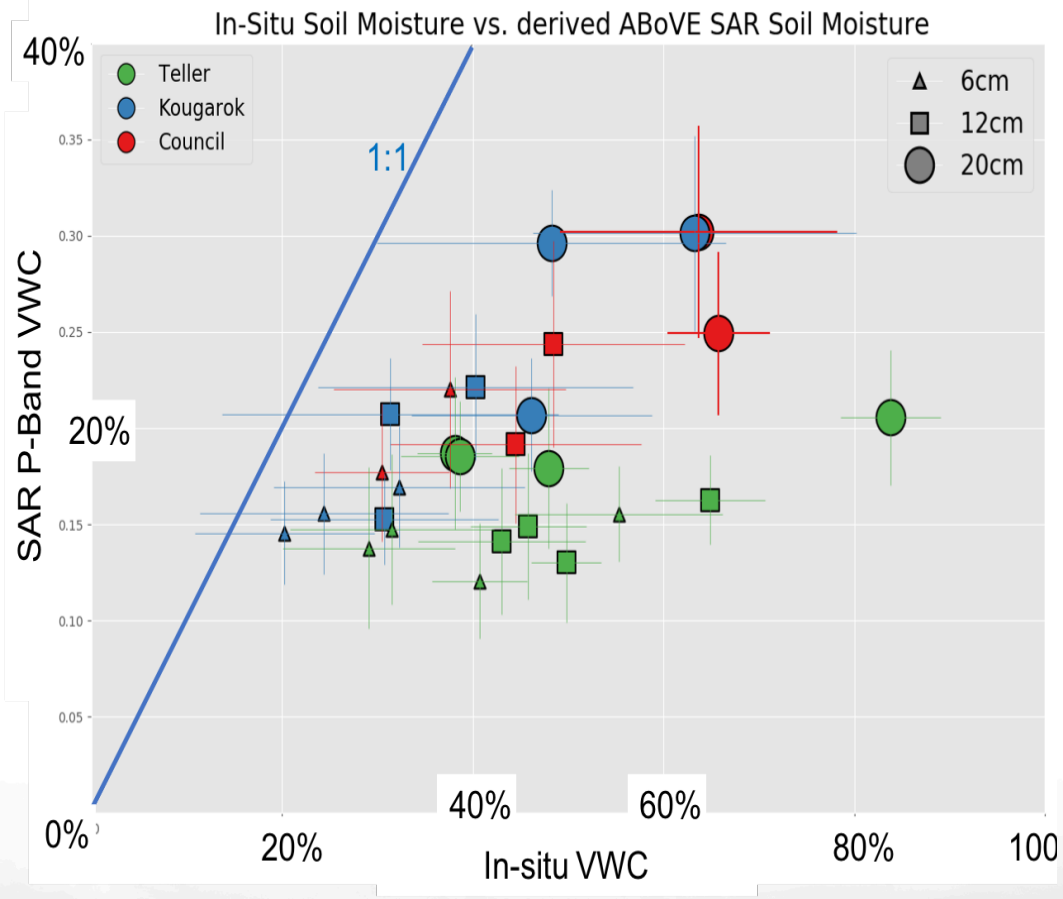


Providing Calibration Data for ABoVE SAR

- *In-situ* data will be used to help calibrate ABoVE SAR soil moisture, deformation and thaw depth data.
- SAR data matches wet and dry areas across Teller watershed.
- Across watersheds, base SAR VWC product shows significant mismatch with *in-situ* data
- SAR VWC should improve with calibration.

Teller Watershed

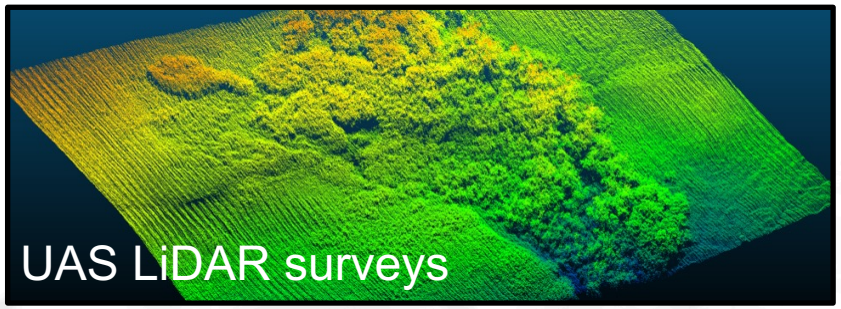




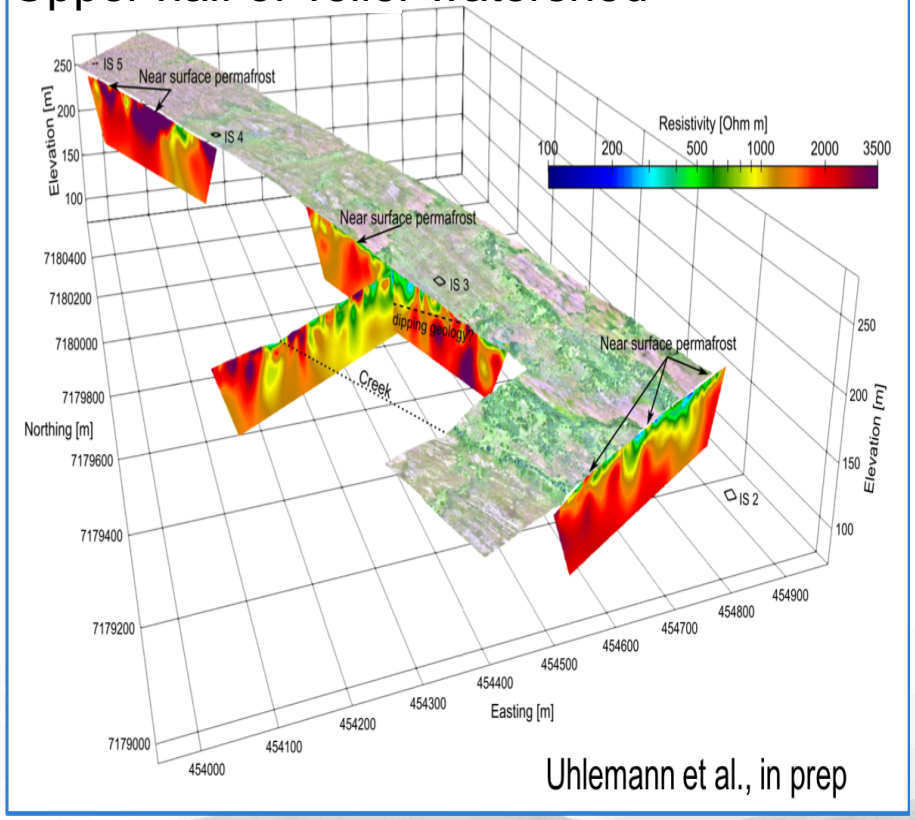
NGEE-Arctic Snow Research

We are collecting, analyzing and modeling data that demonstrates the role of tall shrub patches in deep snow trapping and permafrost thaw.

- Develop “physics informed” snow redistribution model for Earth System Models.
- Understand interactions between snow, vegetation, permafrost and hydrology.
- Predict how interactions will change with climate.

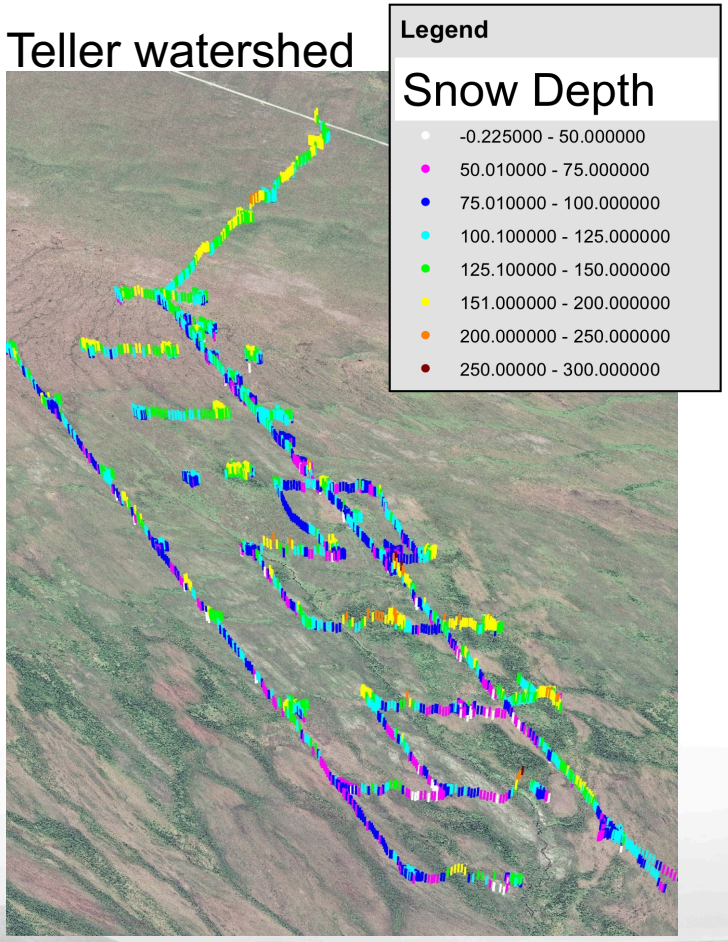


Upper half of Teller watershed



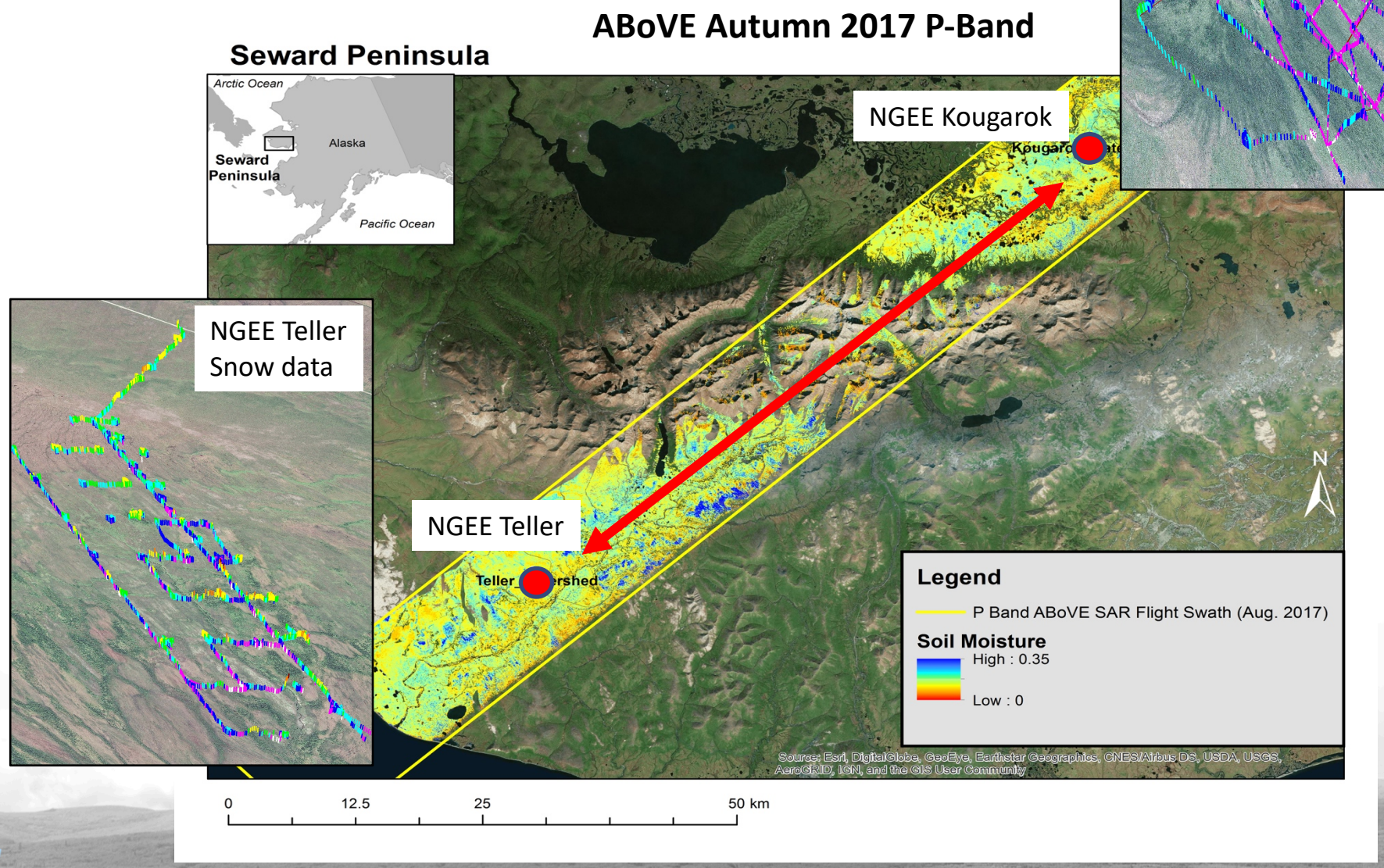
Teller geophysical survey data points to talik features under tall shrub patches

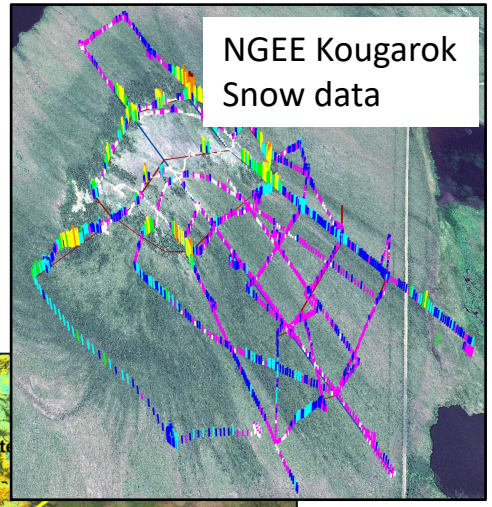
Teller watershed

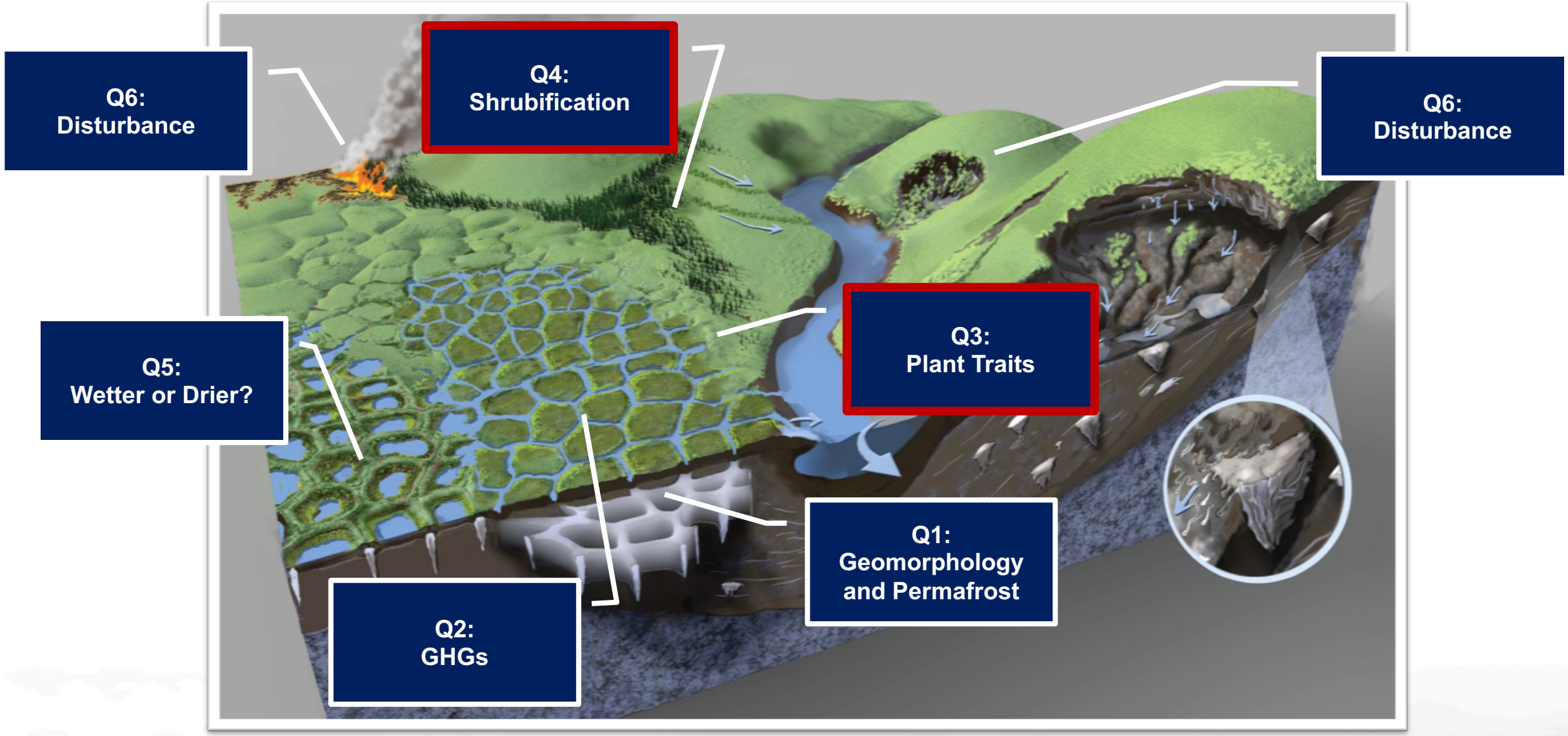


NGEE-SnowEX-ABoVE Opportunity

- NGEE goal: Bridge data gap between Teller and Kougarok sites
- SnowEx and L-band flights along line including our watersheds would be of extremely high value!



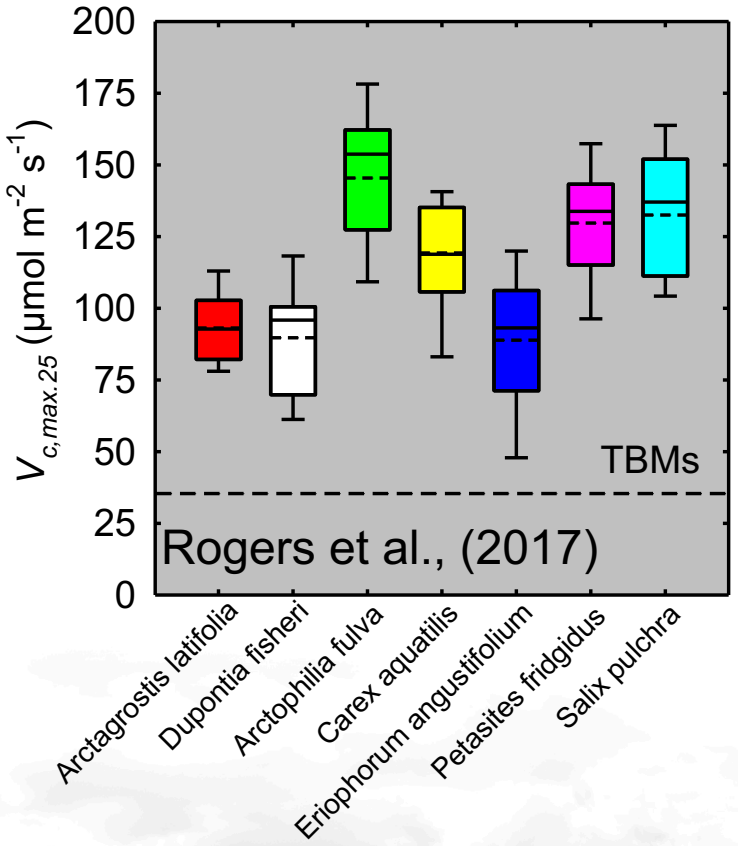




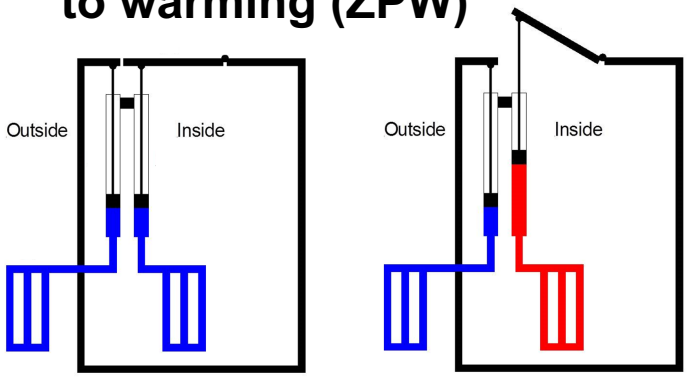
Schuur and Mack (2018). Annu. Rev. Ecol. Evol. Syst. 49: 279-301.

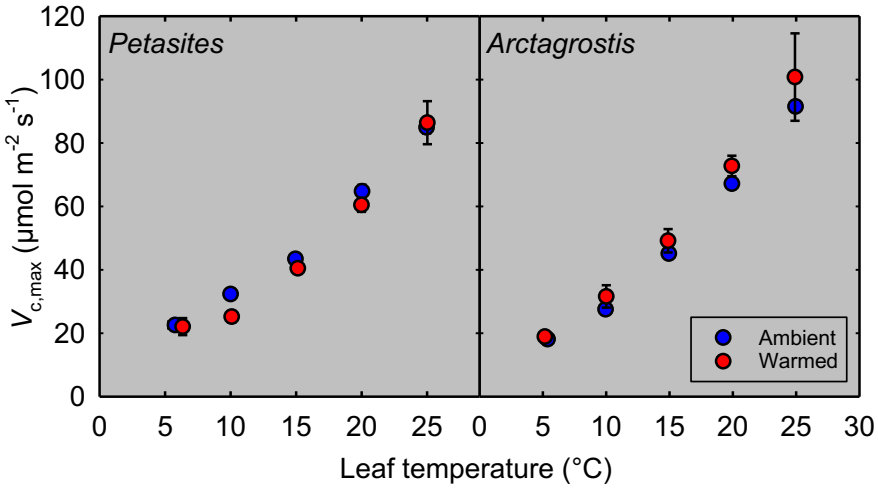
Improving the representation of C uptake in TBMs

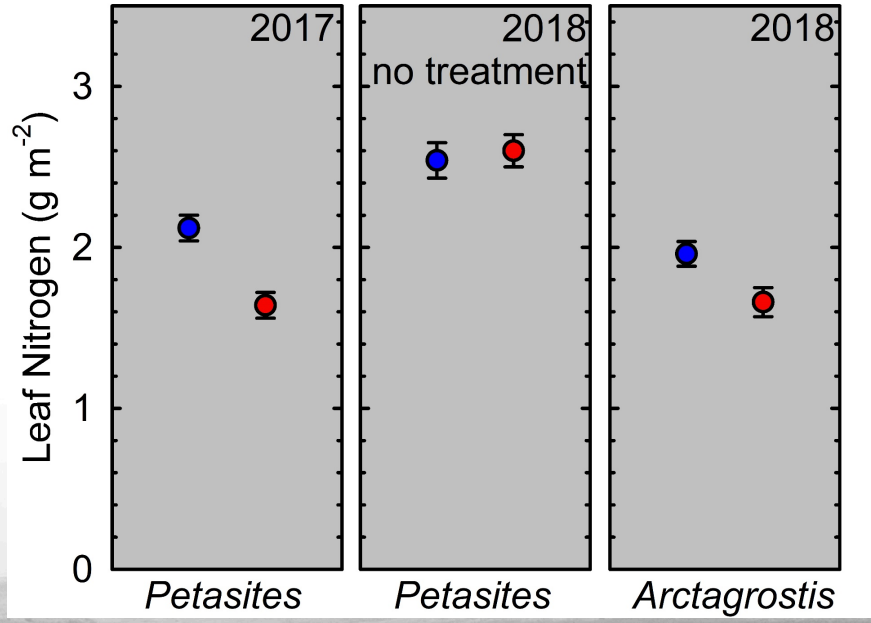
TBMs underestimate $V_{c,max}$ and J_{max}



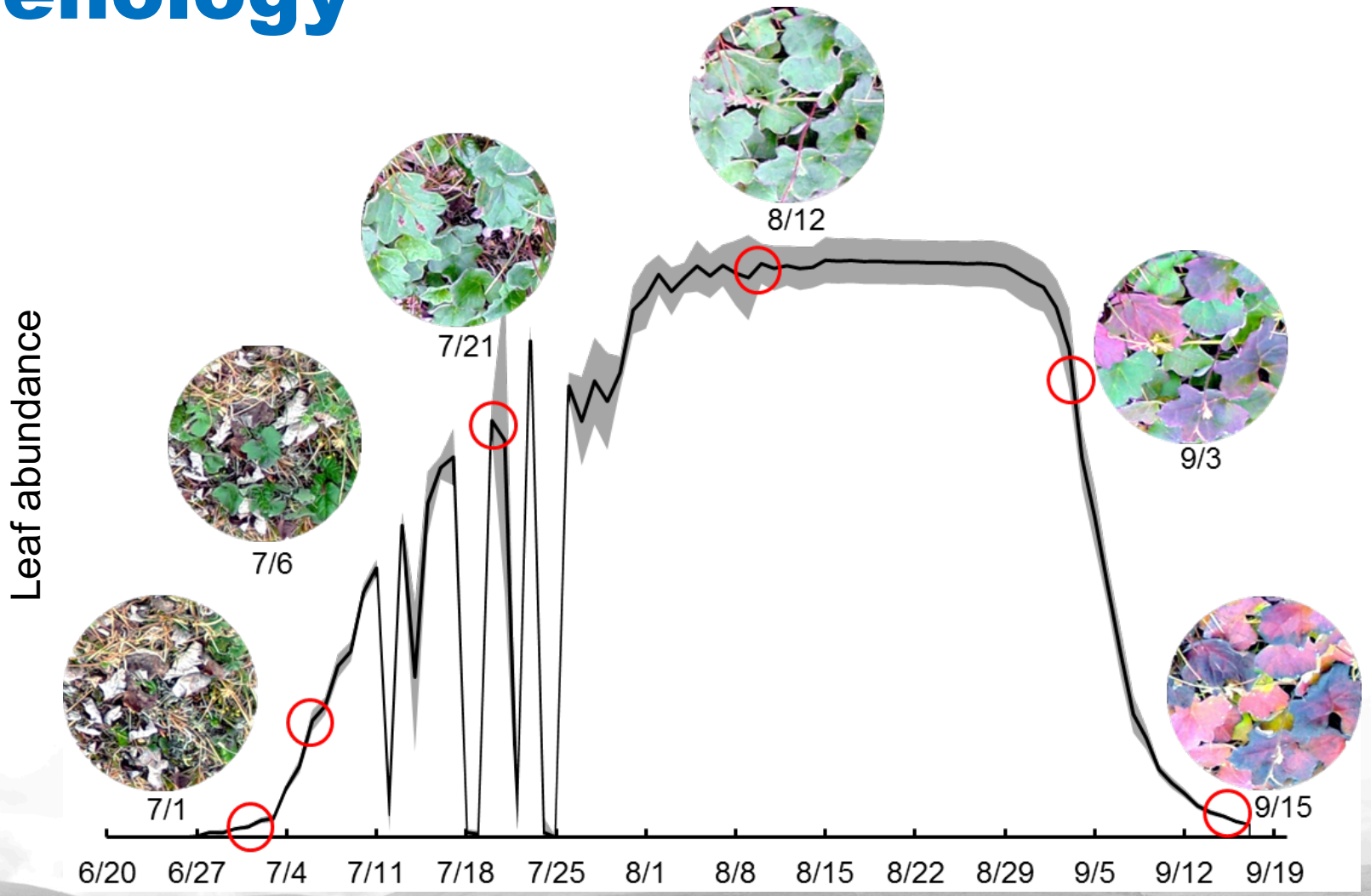
Arctic vegetation responses to warming (ZPW)



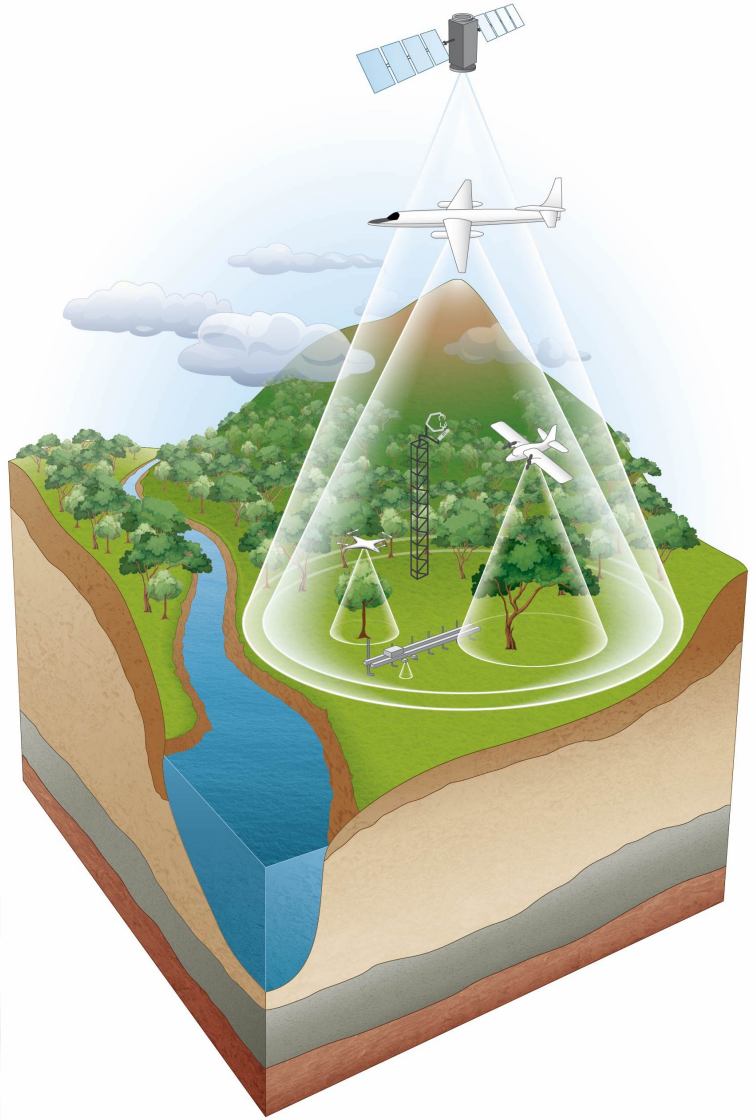




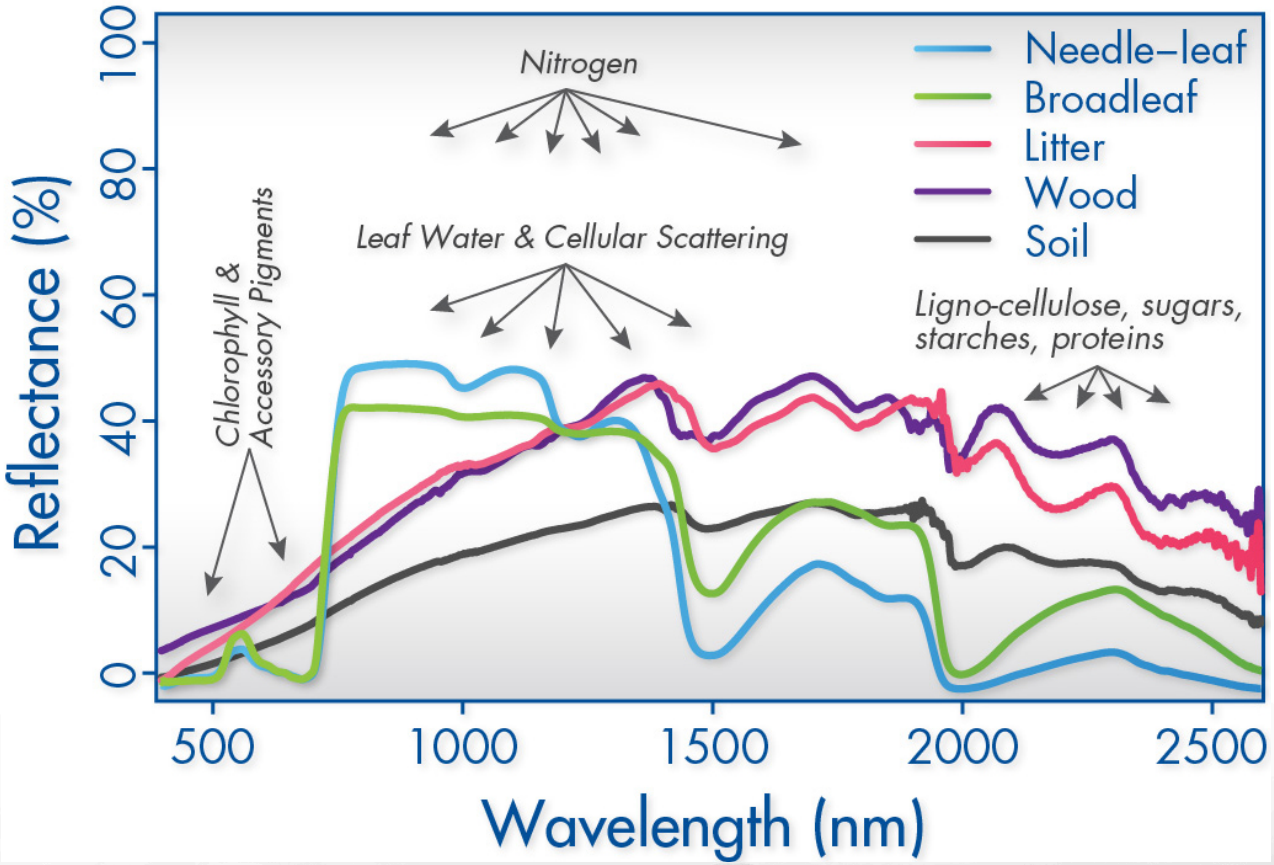
Warming impacts on vegetation greenness and phenology



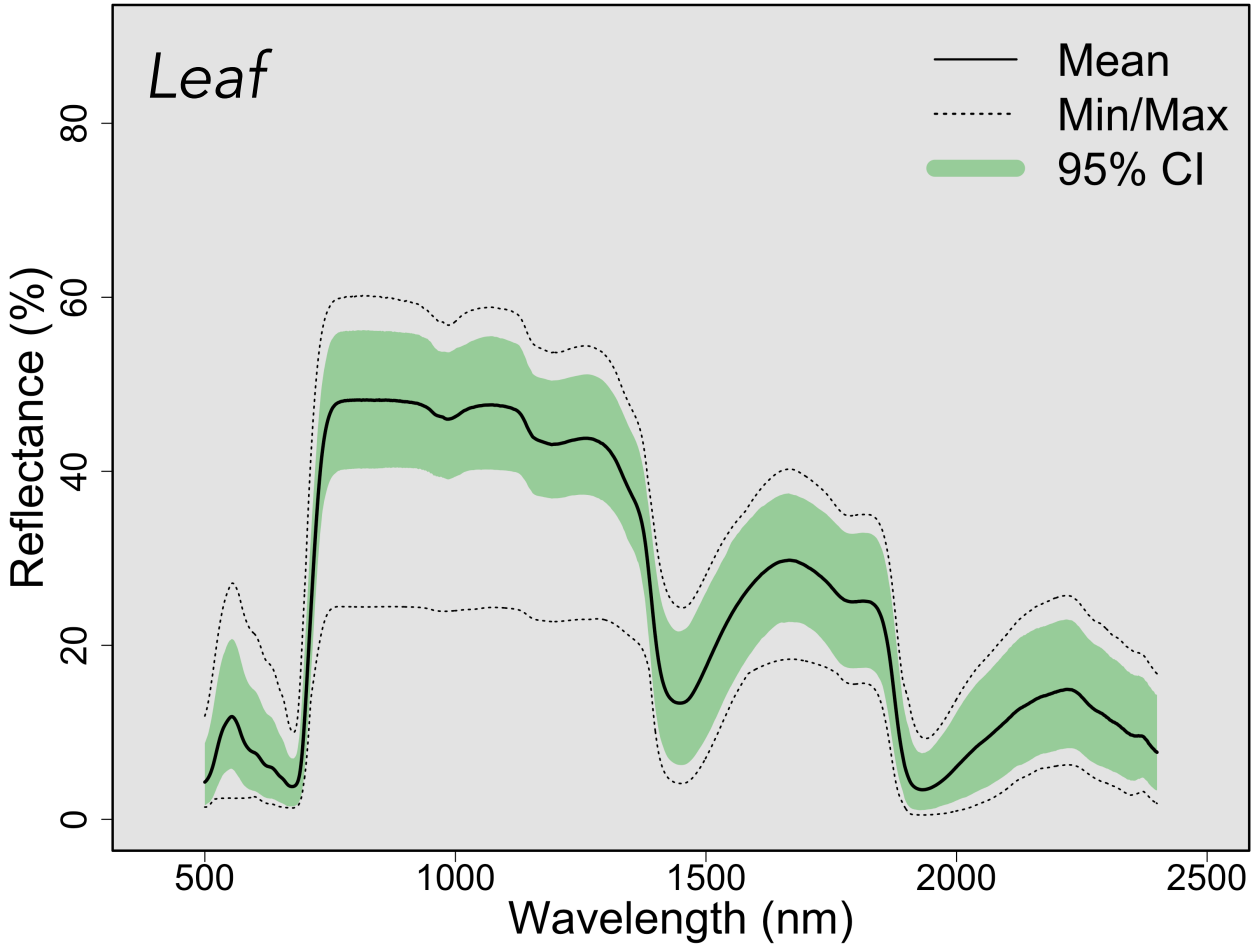
Multi-scale remote sensing of Arctic vegetation

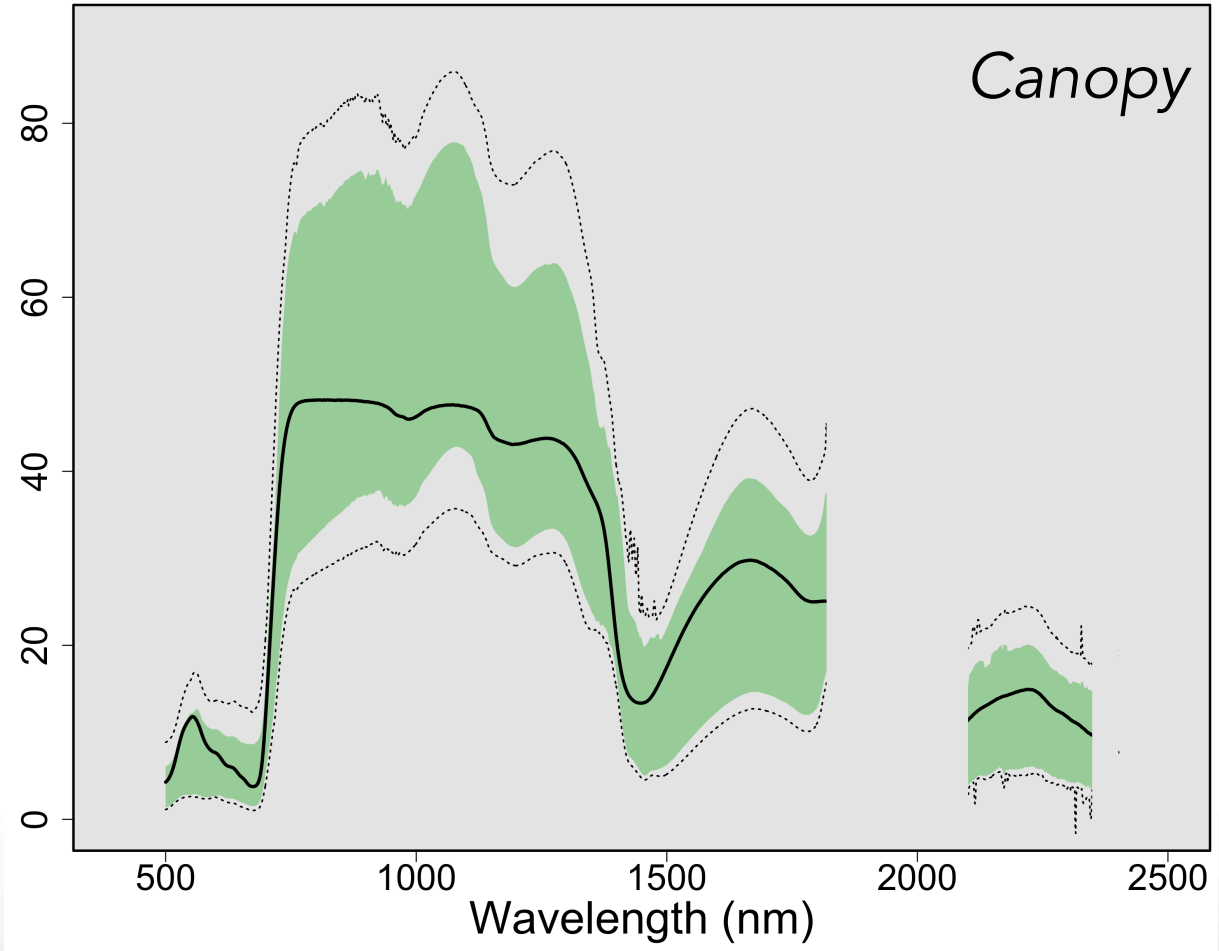


Leaf → Canopy → Tram → UAS → ABoVE → Orbital

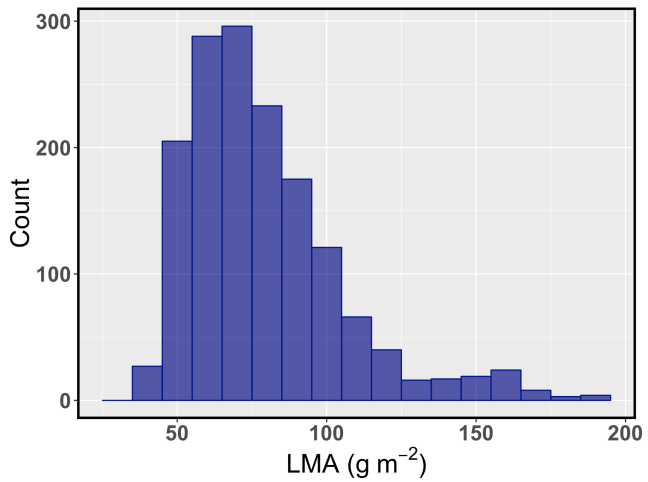


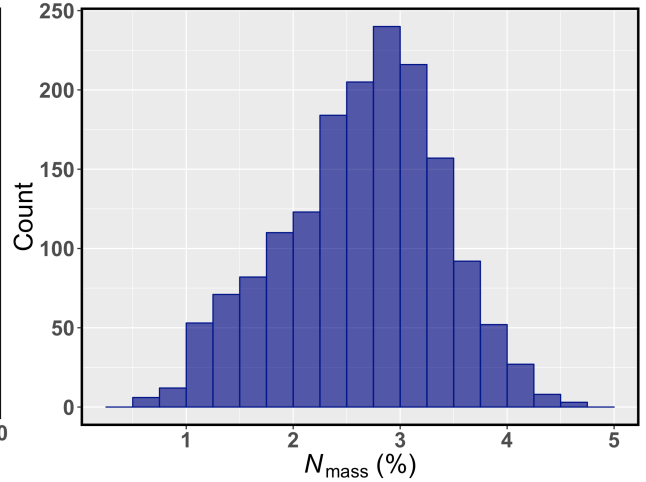
NGEE-Arctic vegetation spectroscopy

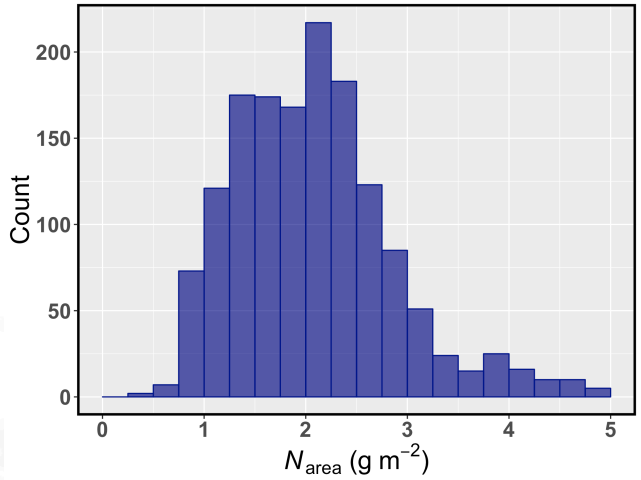


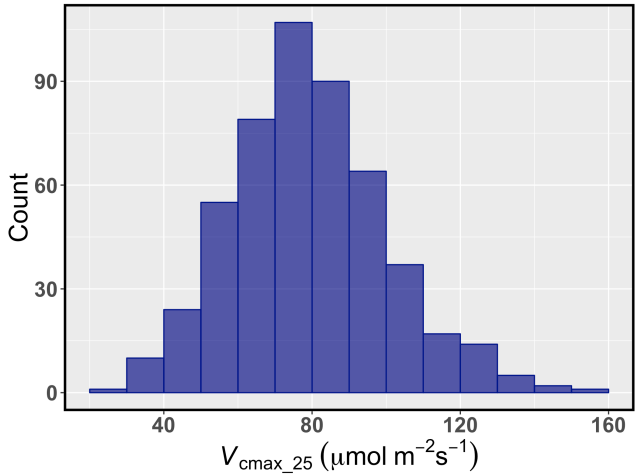


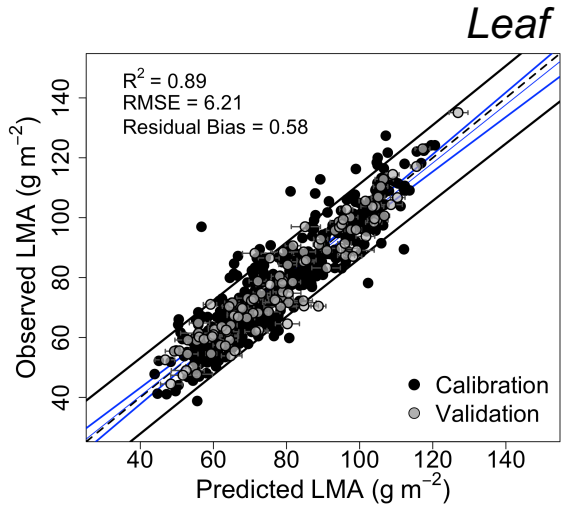
Spectral scaling of plant functional traits

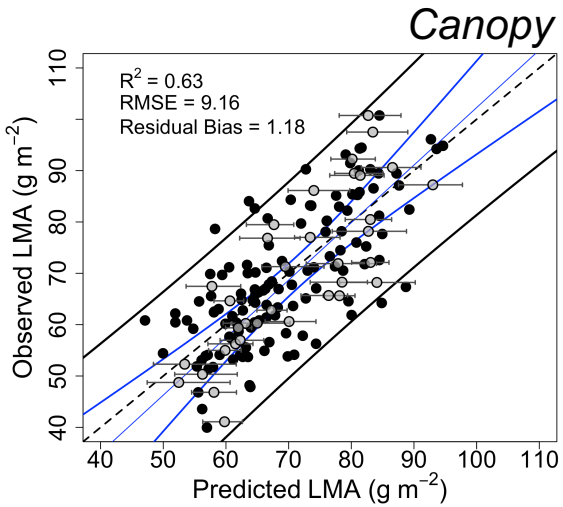


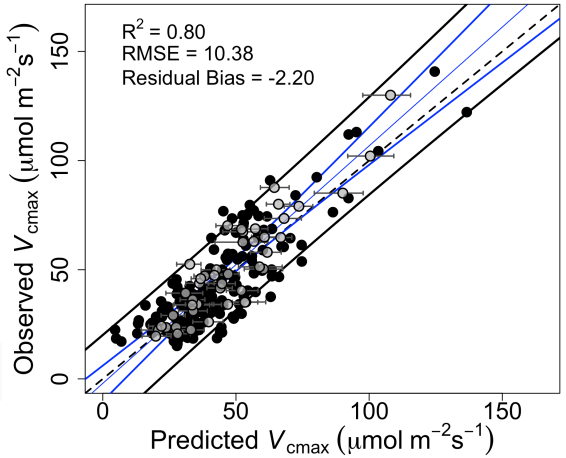


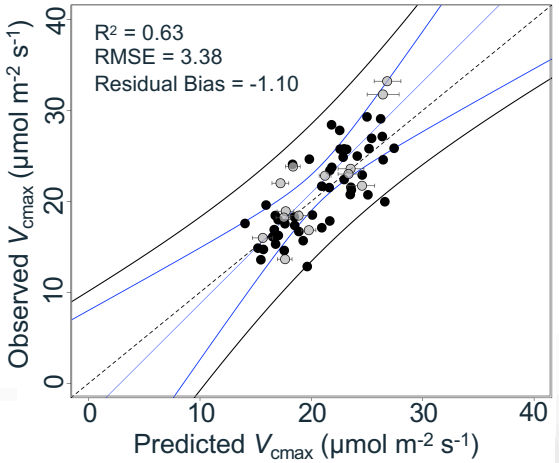






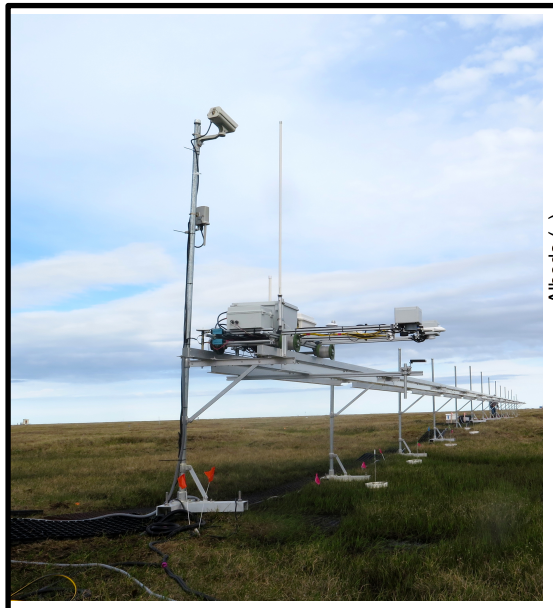


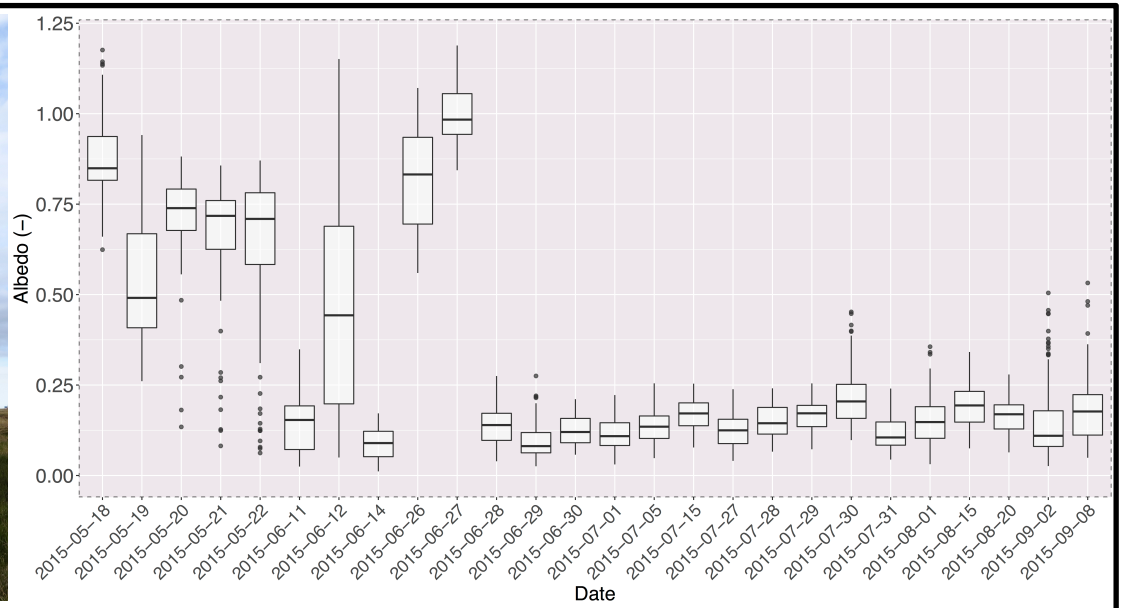


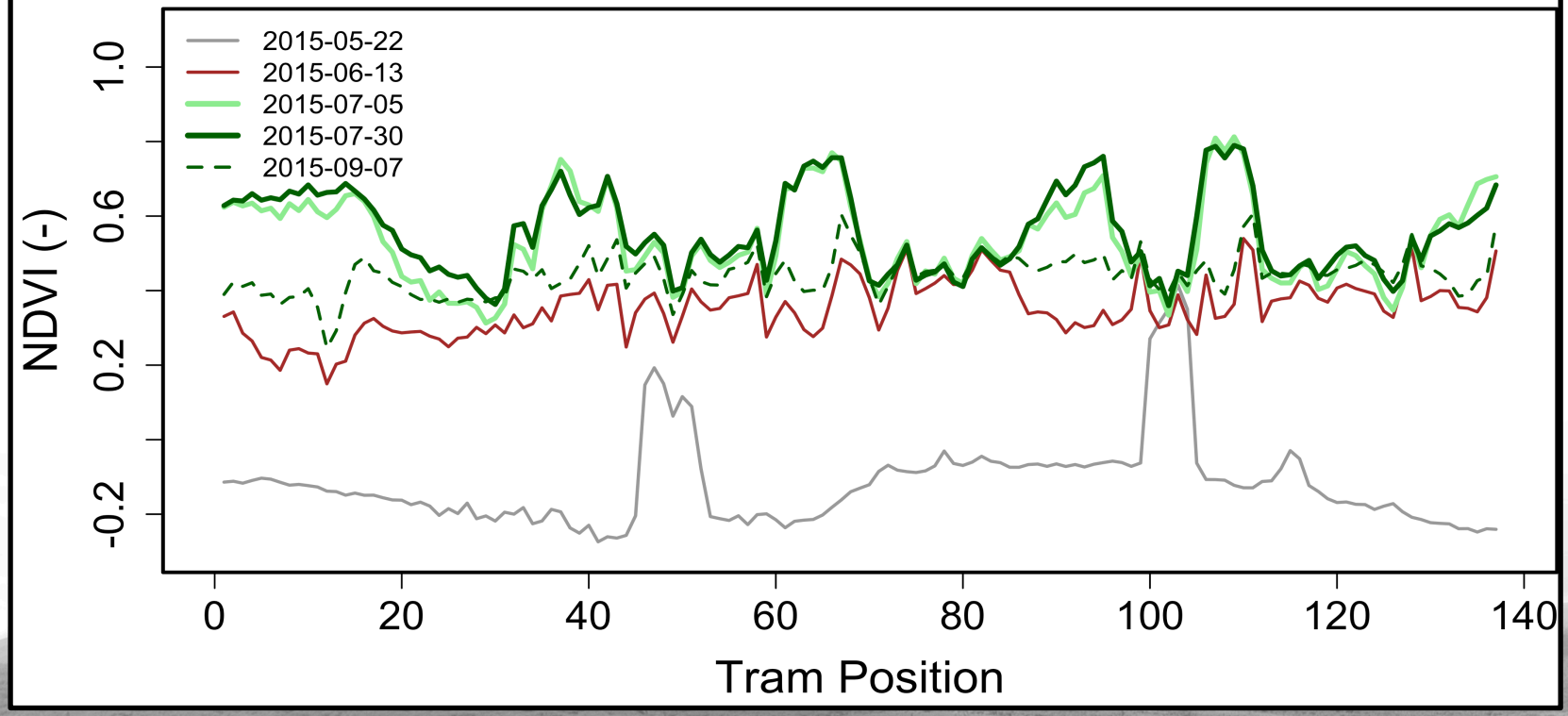


NGEE-Tram

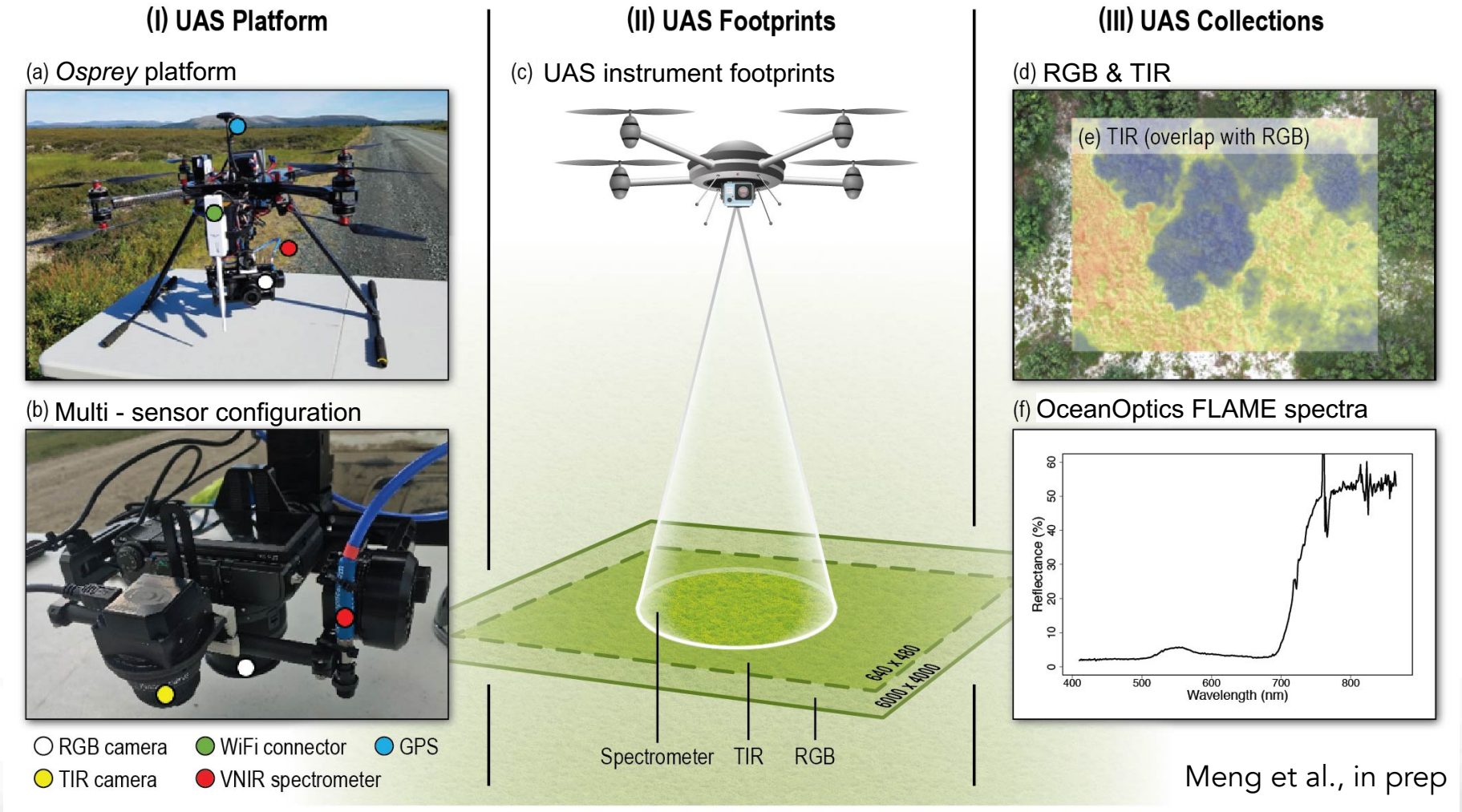
Tram Sensor	Purpose
Net Radiometer	Albedo, LW, SW
IR Surface Temperature	Skin temperature of land surface
PAR, Incident & Reflected	Fraction of absorbed PAR
Spectral Red/NIR, Incident & Reflected	NDVI – Normalized Difference Vegetation Index
Spectroradiometer	Near-surface remote sensing (350-1100nm)
Thermal Camera	Spatial distribution of surface temperature
Sonic Distance Sensor	Snow and water depth
Digital RGB Camera	Photo of sensor footprint

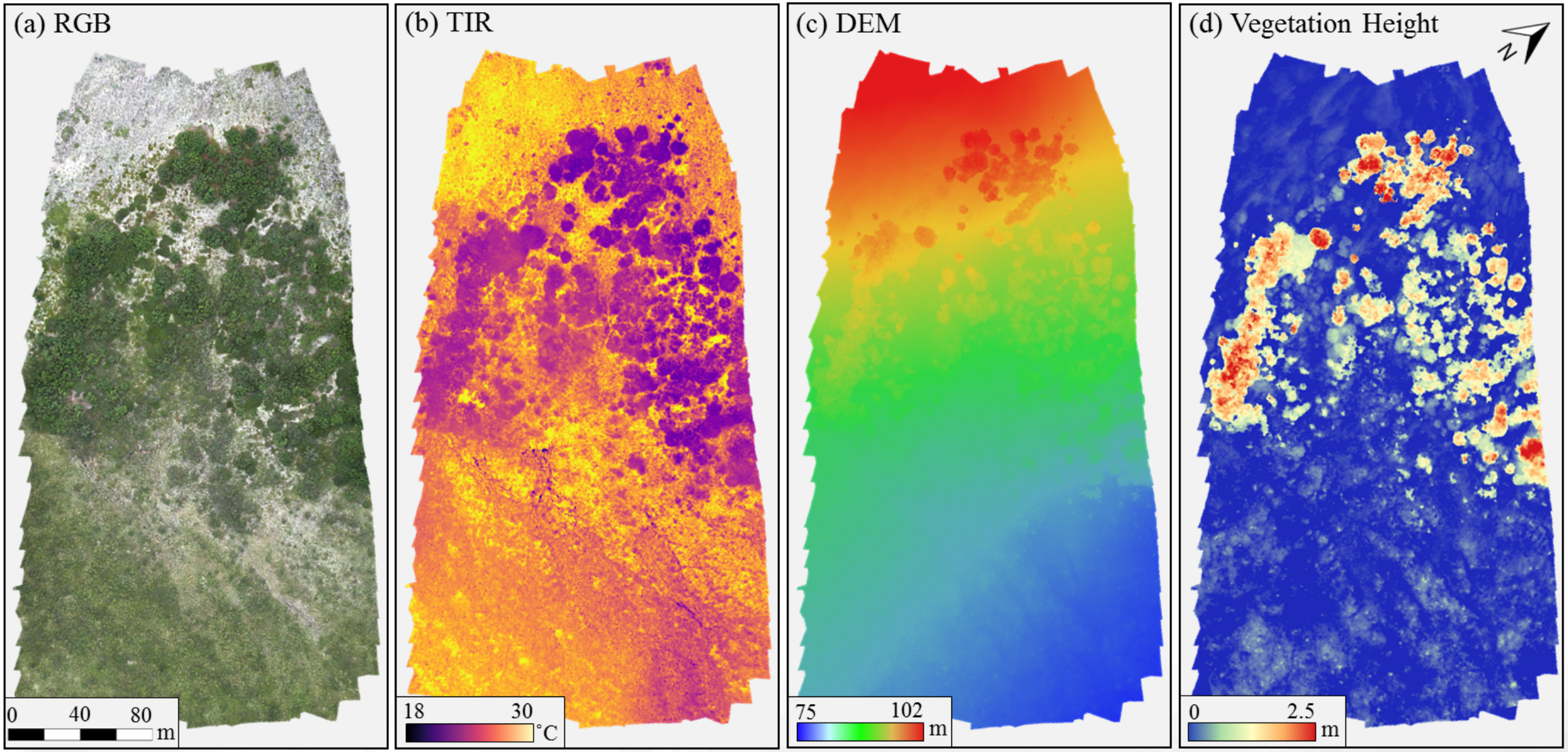




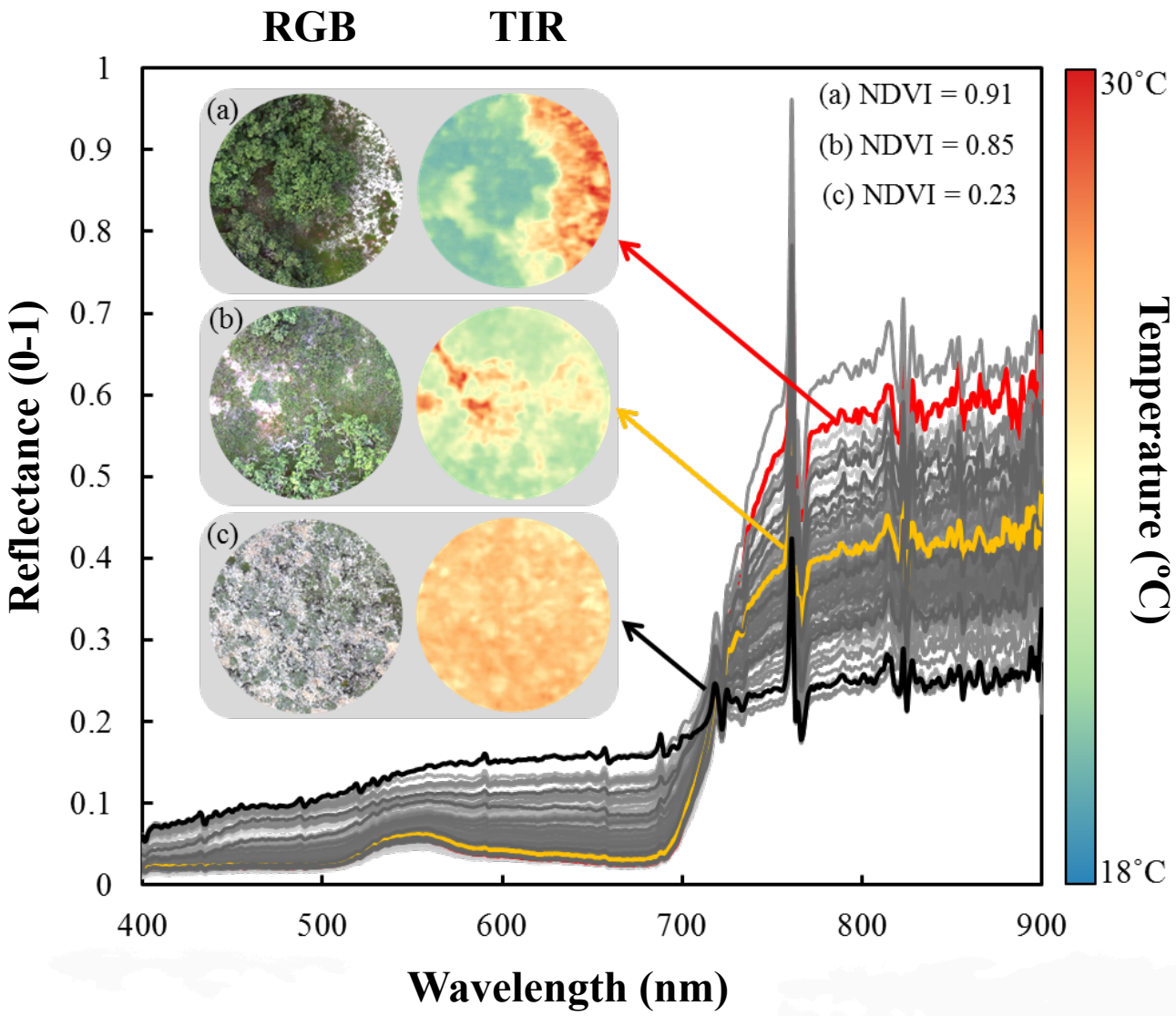


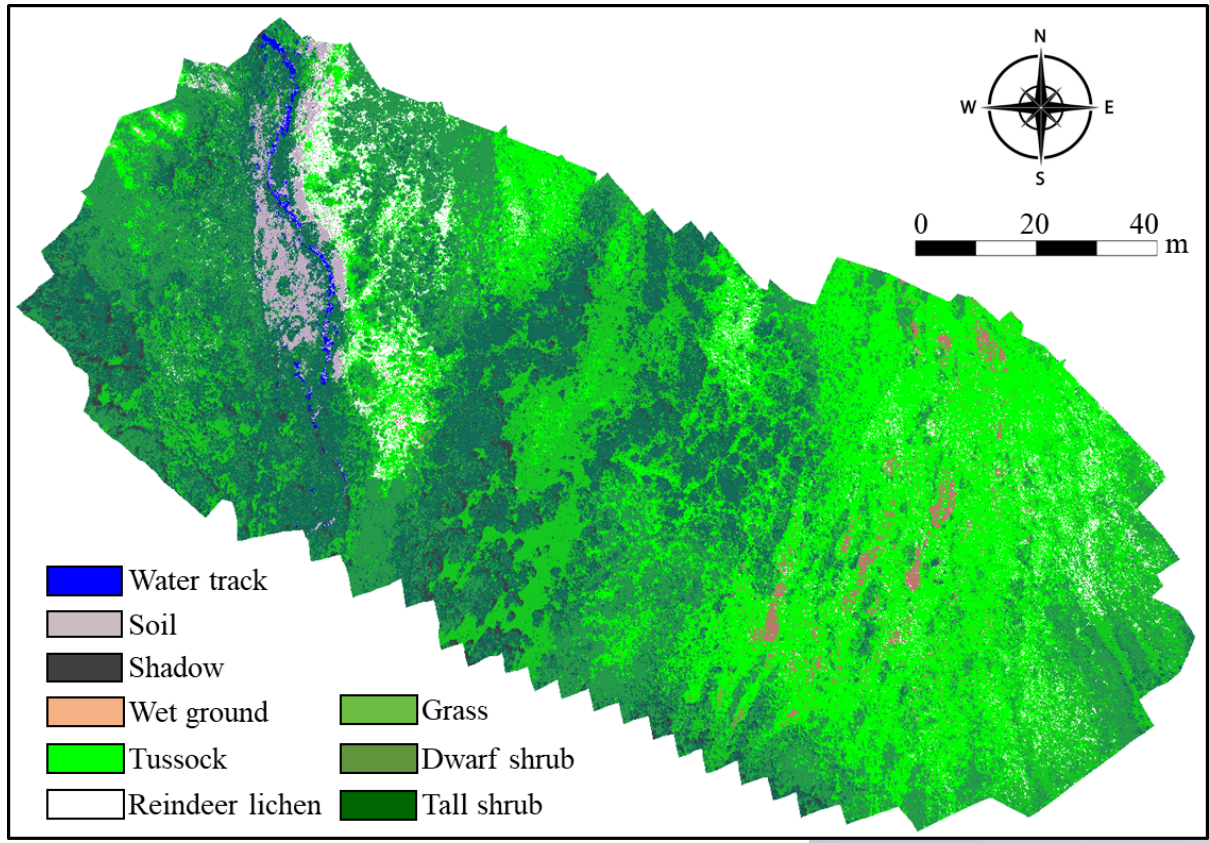
NGEE-Arctic UAS campaigns





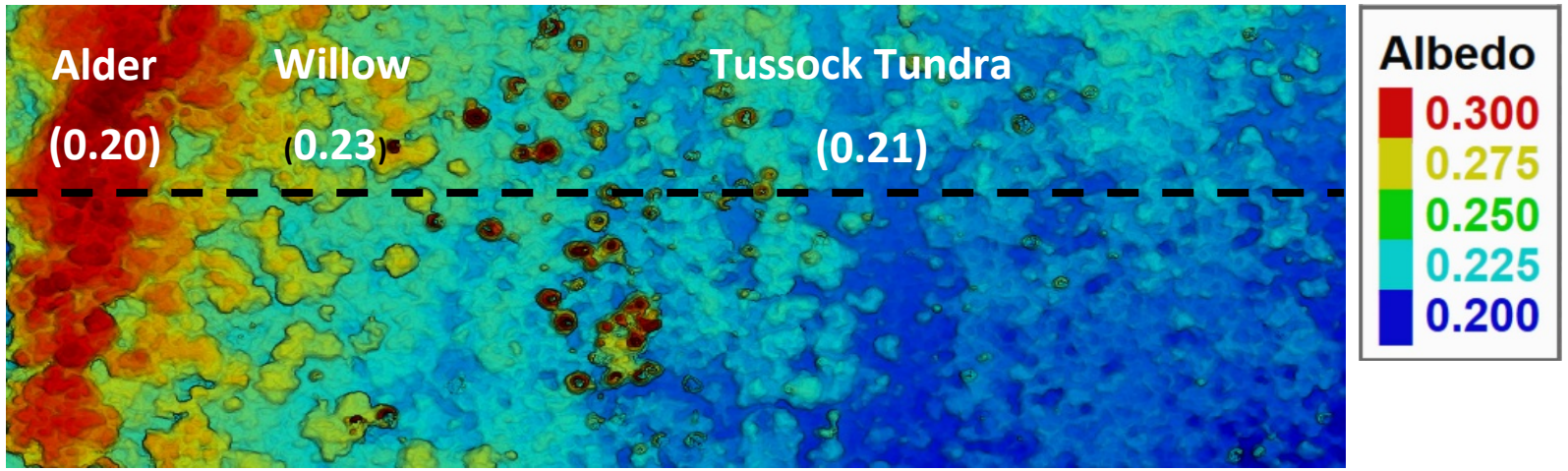
Meng et al., in prep

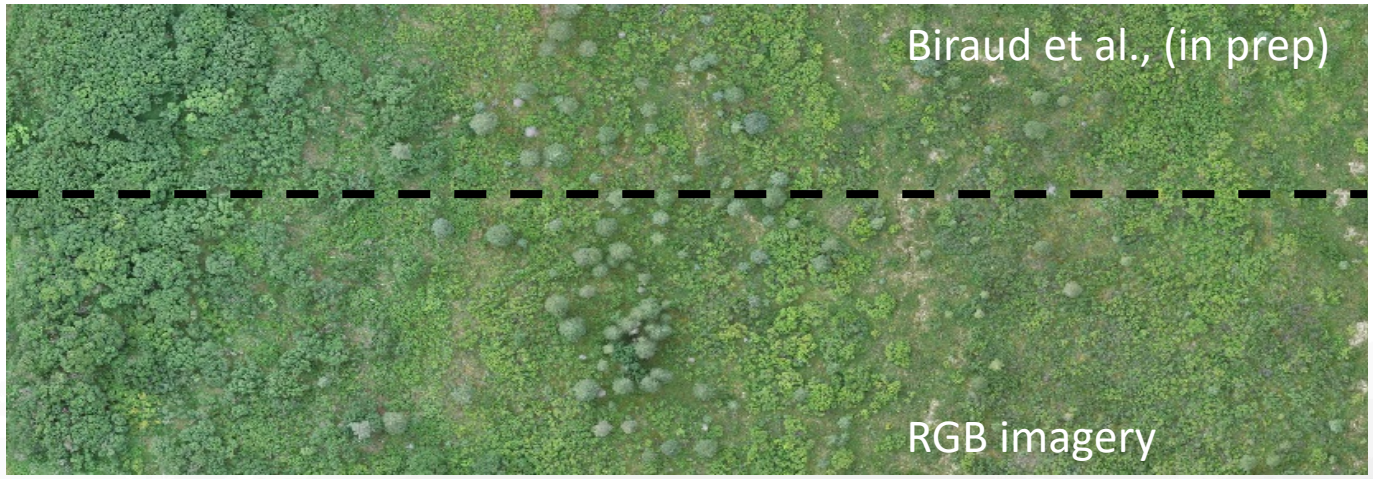




Meng et al (in prep)

Vegetation albedo



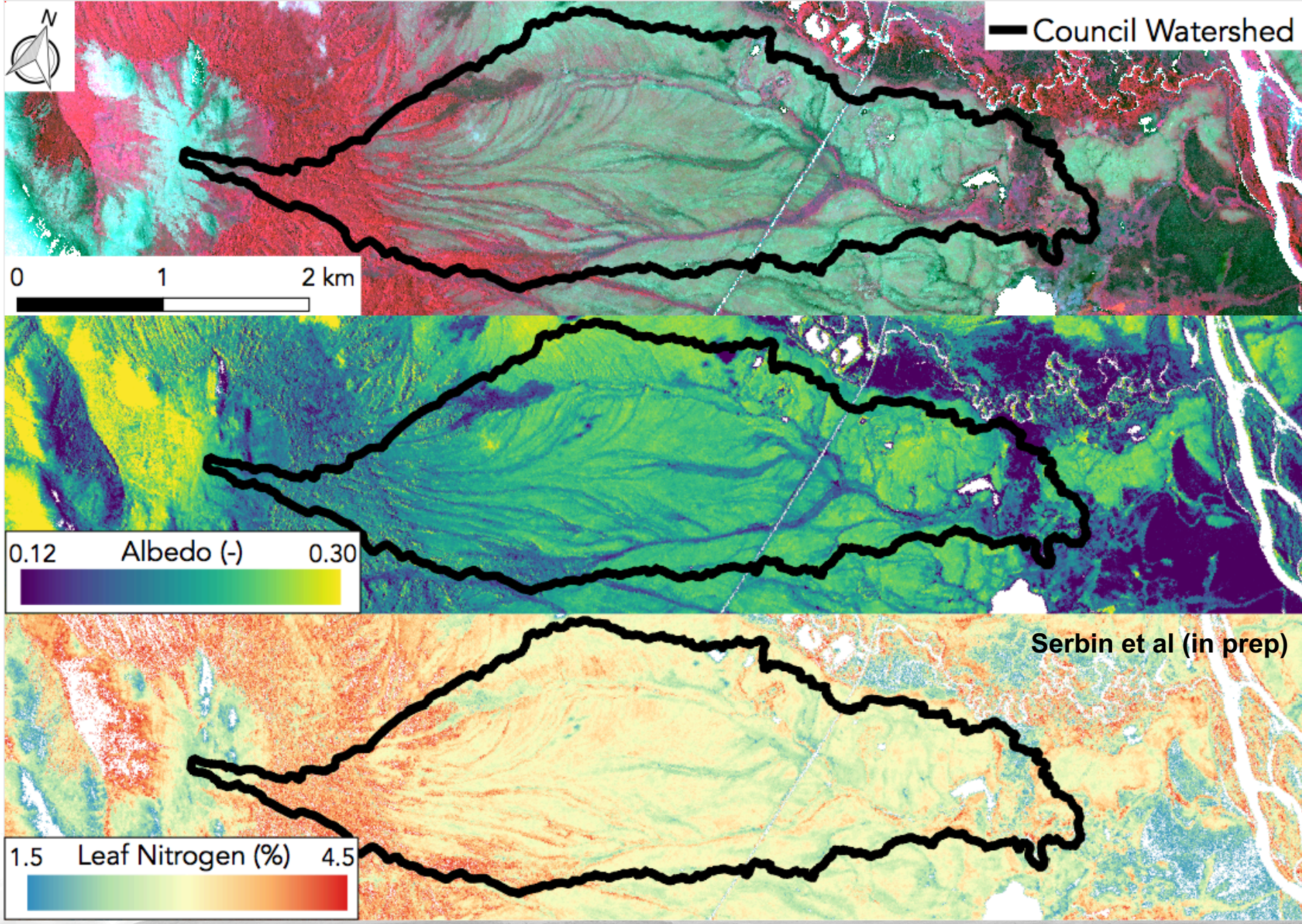


Utilizing multiple groups and platforms to scale up and characterize fine-scale variation to link with ABoVE imagery

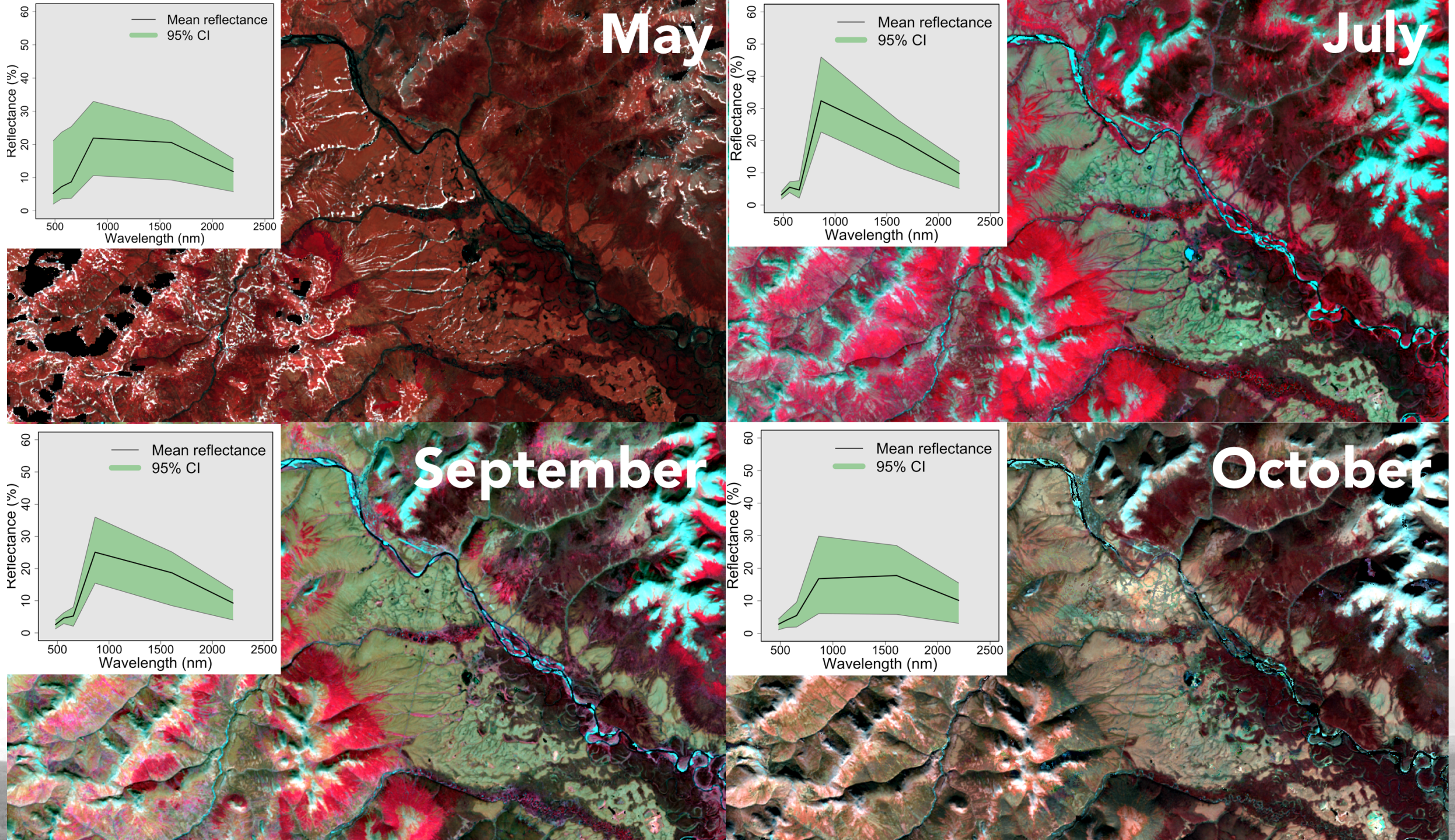
Upscaling

NASA AVIRIS imagery

- Derive albedo
- Map foliar traits, connect with field/UAS datasets
- Connect vegetation properties to watershed features
- Links with modeling



NASA ABoVE Airborne Campaign data


May
Mean reflectance
95% CI
Reflectance (%)
Wavelength (nm)
July
Mean reflectance
95% CI
Reflectance (%)
Wavelength (nm)
September
Mean reflectance
95% CI
Reflectance (%)
Wavelength (nm)
October
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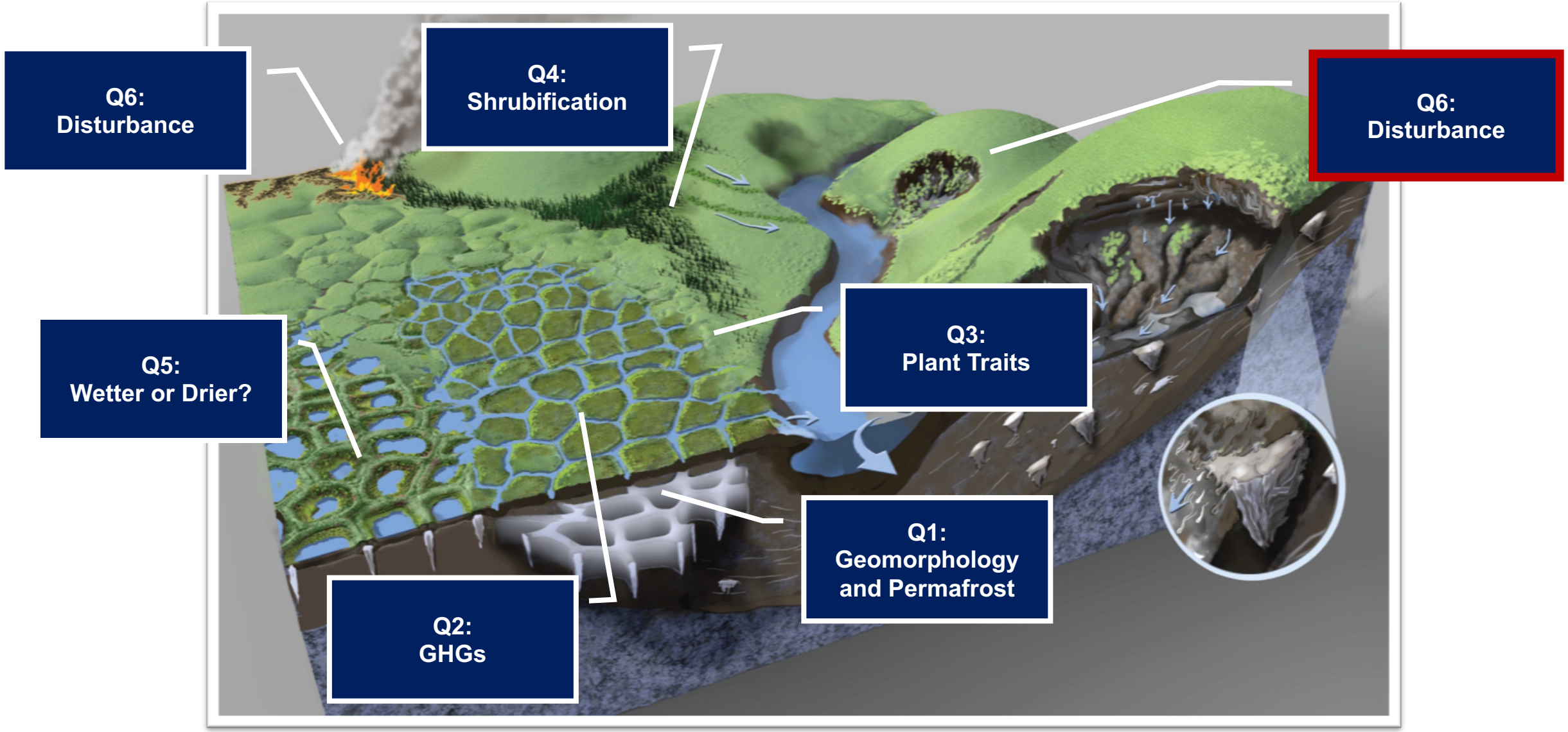
95% CI
Reflectance (%)
Wavelength (nm)



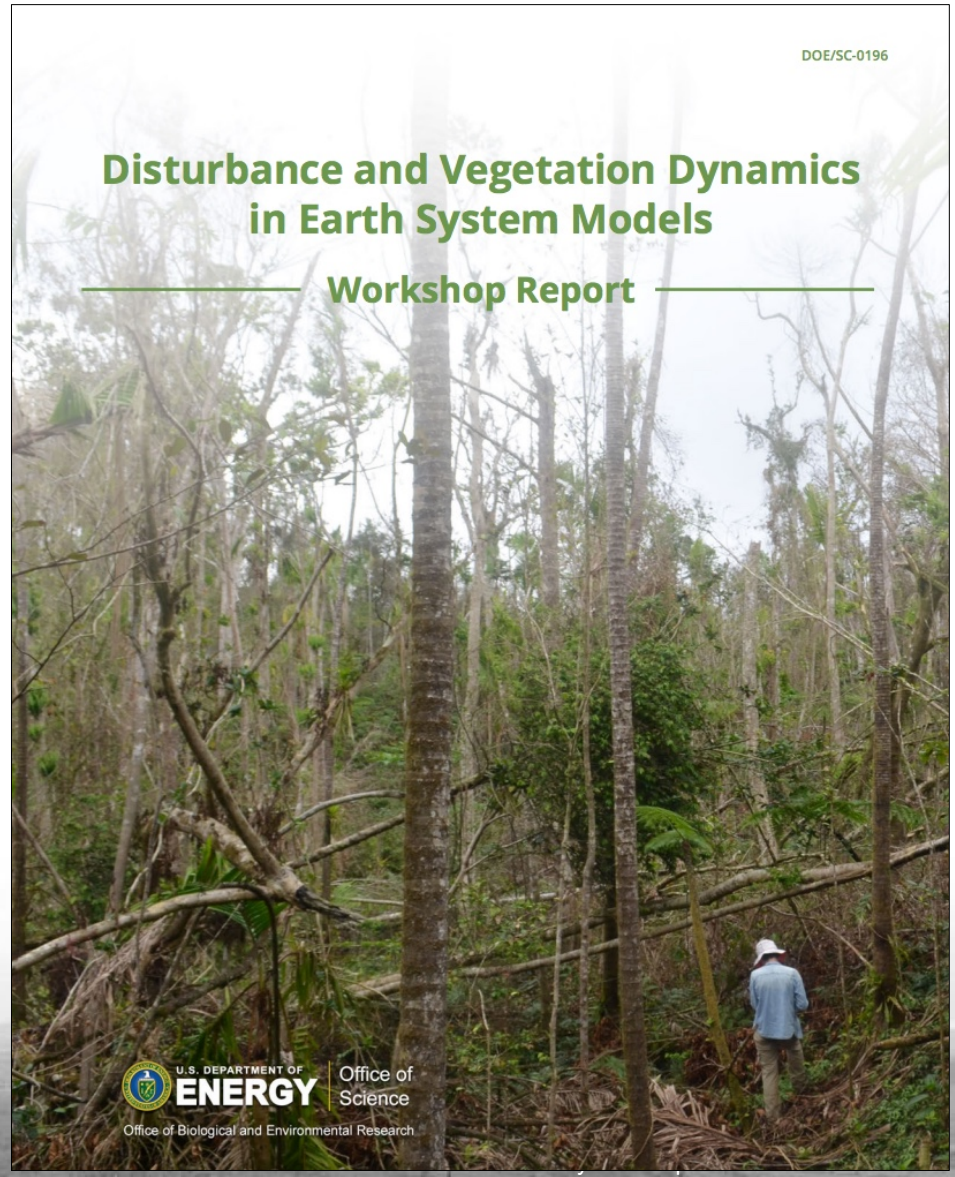
Schuur and Mack (2018). Annu. Rev. Ecol. Evol. Syst. 49: 279-301.

Arctic disturbance dynamics and ecosystem response

Motivation & key priority needs addressed:

- New empirical data that better quantify **climate-disturbance-ecosystem interactions** to constrain vegetation model projections
- New modeling approaches that adequately represent **both process-based vegetation dynamics and disturbances**

We focus on **wildfire & thermokarst disturbance** utilizing observations from the ground to the satellite.

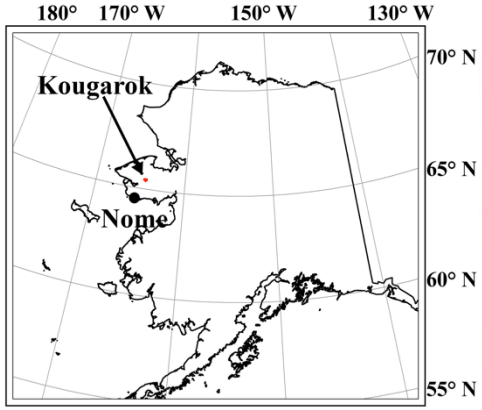


Primary tasks & PI to contact to collaborate:

- Establish a chronosequence network of disturbance-affected landscapes to co-locate observations characterizing recovery patterns (Breen, UAF)
- Manipulate growing season precipitation via rainfall simulators in disturbed and undisturbed watersheds to quantify the relationship between fluxes and hydrological forcing (Rowland, LANL)
- Identify dominant controls on past disturbance and where on the landscape is most vulnerable to future disturbance (Kumar, ORNL & Iwahana, UAF)
- Utilize the ATS model to quantify how changes in surface properties due to disturbance alter the thermal and hydrological state of permafrost (Painter, ORNL & Jafarov, LANL)
- Develop & test DOE's ELM-FATES model including a high latitude fire module and implementation of dynamic Arctic shrub functional types (Riley, LBNL)

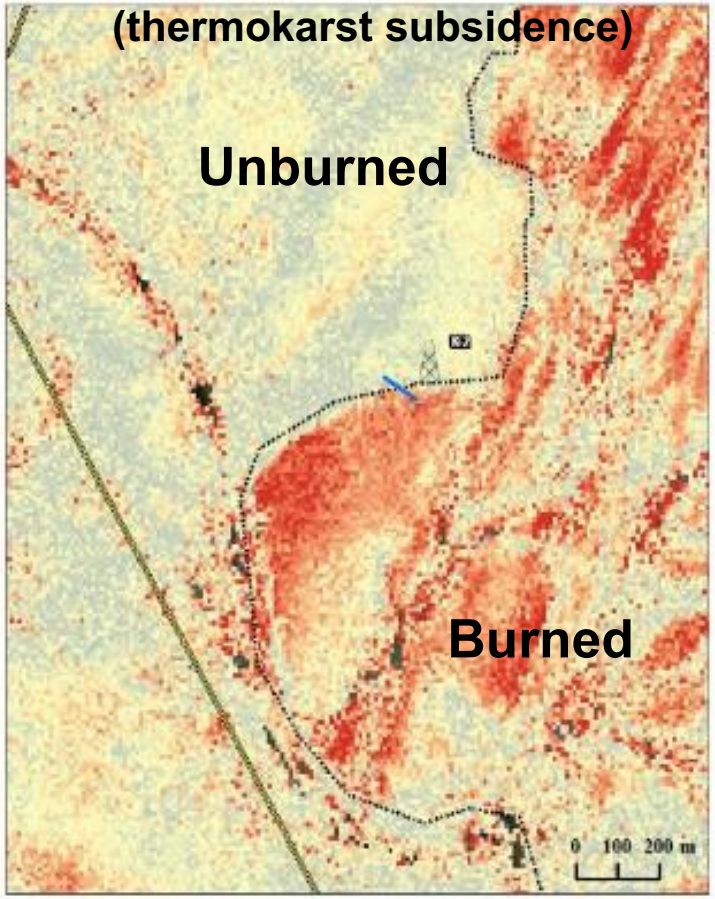
Arctic disturbance dynamics and ecosystem response

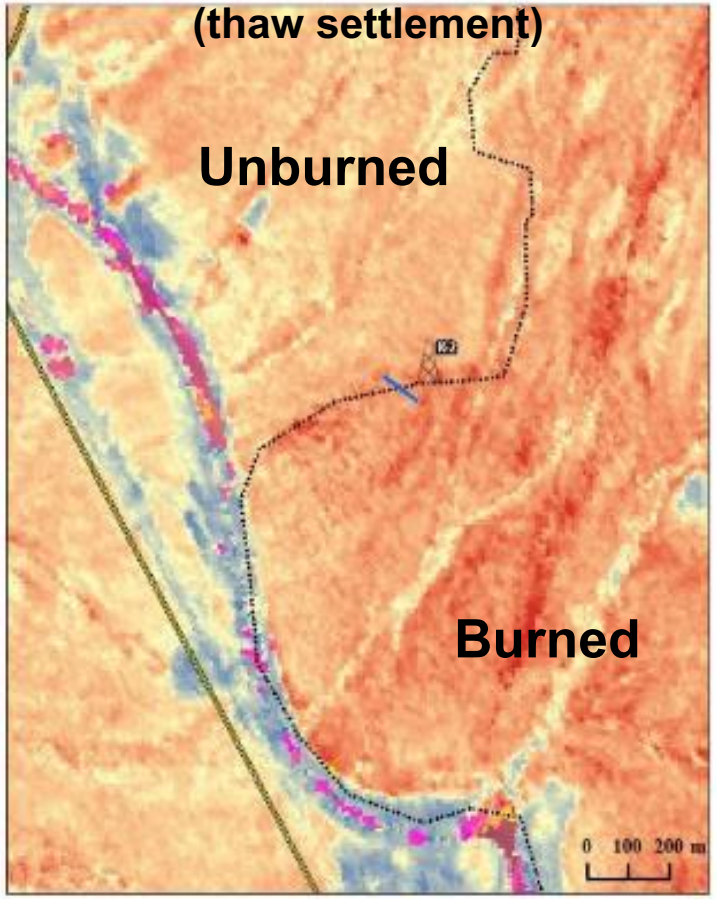
Identifying dominant controls on past disturbance



Inter-annual ground displacement (thermokarst subsidence)

Seasonal ground displacement (thaw settlement)





We are examining the intensity of past thermokarst subsidence and its relationship to:

- landscape position
- severity & timing of wildfire
- surface physical conditions (soil moisture, ice content, vegetation, etc.)

Max. difference in displacement = ~40cm
Blue - Red

Max. difference in displacement = ~30 cm
Blue - Red

ALOS2

UAV-SAR

Iwahana, In Prep.

Areas for continued or expanded NGEE-Arctic & NASA ABoVE collaboration

- **Scaling:** NGEE-Arctic and NASA ABoVE have been closely coordinating airborne campaigns efforts and have developed scaling algorithms. Expect to continue this tight coordination into NGEE Phase III and ABoVE Phase II
- **Evaluation/validation:** NGEE scientists have collected data to help validate ABoVE data products (e.g. soil moisture, plant traits, vegetation structure & function), how should expand or further leverage these connections?
- **Disturbance:** Our Phase III disturbance efforts will provide detailed process-rich information useful for informing ABoVE remote sensing and modeling efforts
- **Modeling and forecasting:** NGEE is developing approaches to inform models and model predictions with ABoVE data, how do we also coordinate with ABoVE modeling teams? Can we coordinate parameterization efforts (e.g. NGEE Phase III has a strong Arctic PFT component). Standardize classification schemes?

Skookum Pass (Mile, 53 Council Road), Seward Peninsula, Alaska