

Understanding the Pattern and Drivers of Plant Communities across the Arctic Tundra Landscape

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Greening Trend in Arctic



Since the late 20th century, tundra regions have been greening in response to changing climate and an accelerated disturbance regime [??].

Credits: NASA's Goddard Space Flight Center/Cindy Starr

Implications for Arctic Biogeochemistry



Transitioning plant communities have important implications for C and N cycling within tundra ecosystems that have historically been nutrient-limited [??]

Image provided by Lawrence Berkeley National Laboratory
Edited by: Verity G. Salmon

Objectives

- Create high-resolution, watershed-scale plant community maps – **where?**



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- Understand the drivers (climatological, topographic and hydrologic) of plant community distribution – **why?**



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- Create high-resolution, watershed-scale plant community maps – **where?**
- Understand the drivers (climatological, topographic and hydrologic) of plant community distribution – **why?**
- With the help of Remote Sensing and Machine Learning
– **how?**

Objective 1

Watershed-scale plant community mapping



Intensively Studied Watersheds at Seward, AK

Teller



Kougarok



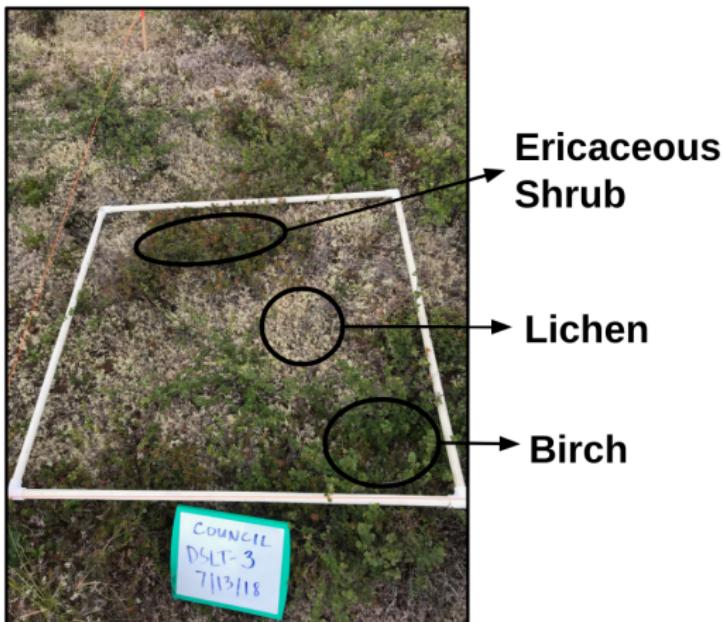
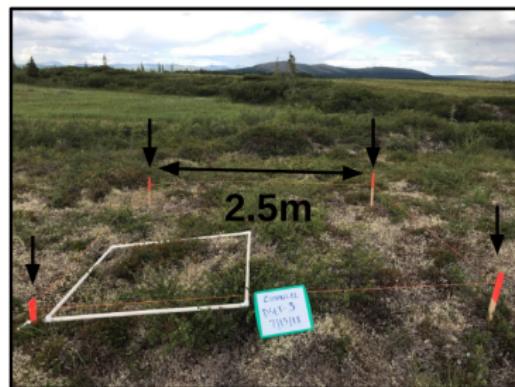
Council



Field vegetation surveys conducted across all watersheds

Plant Community: A collection of plant species within a geographical area, which form a relatively uniform patch

Birch-Ericaceous-Lichen



Field Vegetation Survey (contd.)

12 Plant Communities

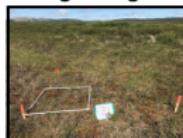
Willow-Birch



Mesic Graminoid-Herb Meadow



Wet Sedge Bog-Meadow



Dryas-Lichen Dwarf Shrub Tundra



Wet Meadow Tundra



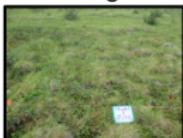
Birch-Ericaceous-Lichen Shrub Tundra



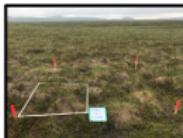
Sedge-Willow Dryas Tundra



Mixed Shrub-Sedge Tussock Tundra



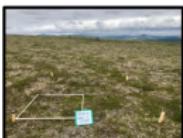
Tussock-Lichen tundra



Willow Shrub



Ericaceous-Lichen Dwarf Shrub Tundra



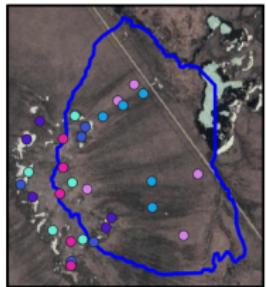
Alder-Willow Shrub



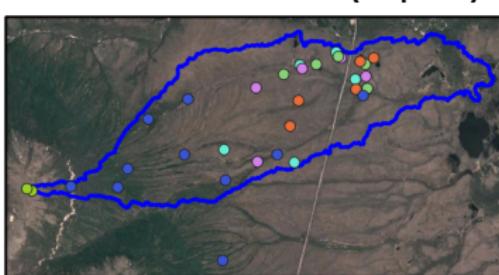
Field Vegetation Survey (contd.)



Teller
(36 plots)



Kougarok
(30 plots)



Council
(32 plots)

Legend	
●	Alder-Willow Shrub
●	Birch-Ericaceous-Lichen Shrub Tundra
●	Dryas-Lichen Dwarf Shrub Tundra
●	Ericaceous Dwarf Shrub Tundra
●	Mesic Graminoid-Herb Meadow
●	Mixed Shrub-Sedge Tussock Tundra
●	Sedge-Willow-Dryas Tundra
●	Tussock-Lichen Tundra
●	Wet Meadow Tundra
●	Wet Sedge Bog-Meadow
●	Willow Shrub
●	Willow-Birch Shrub

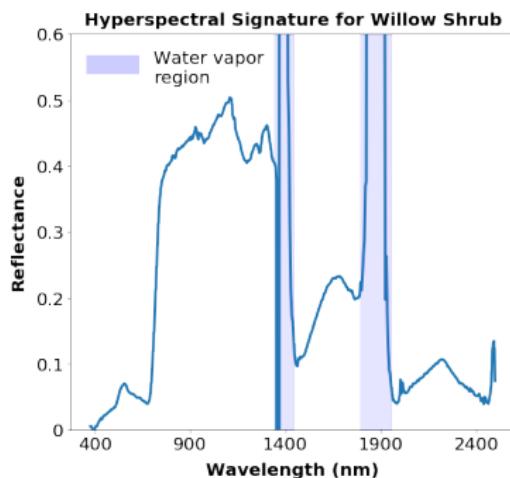
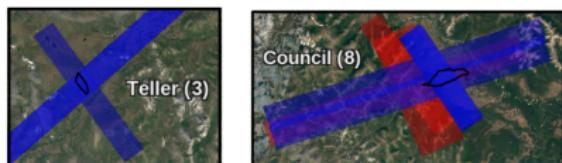
Total number of surveys = 98

Airborne Remote Sensing from NASA ABOVE AVIRIS-NG

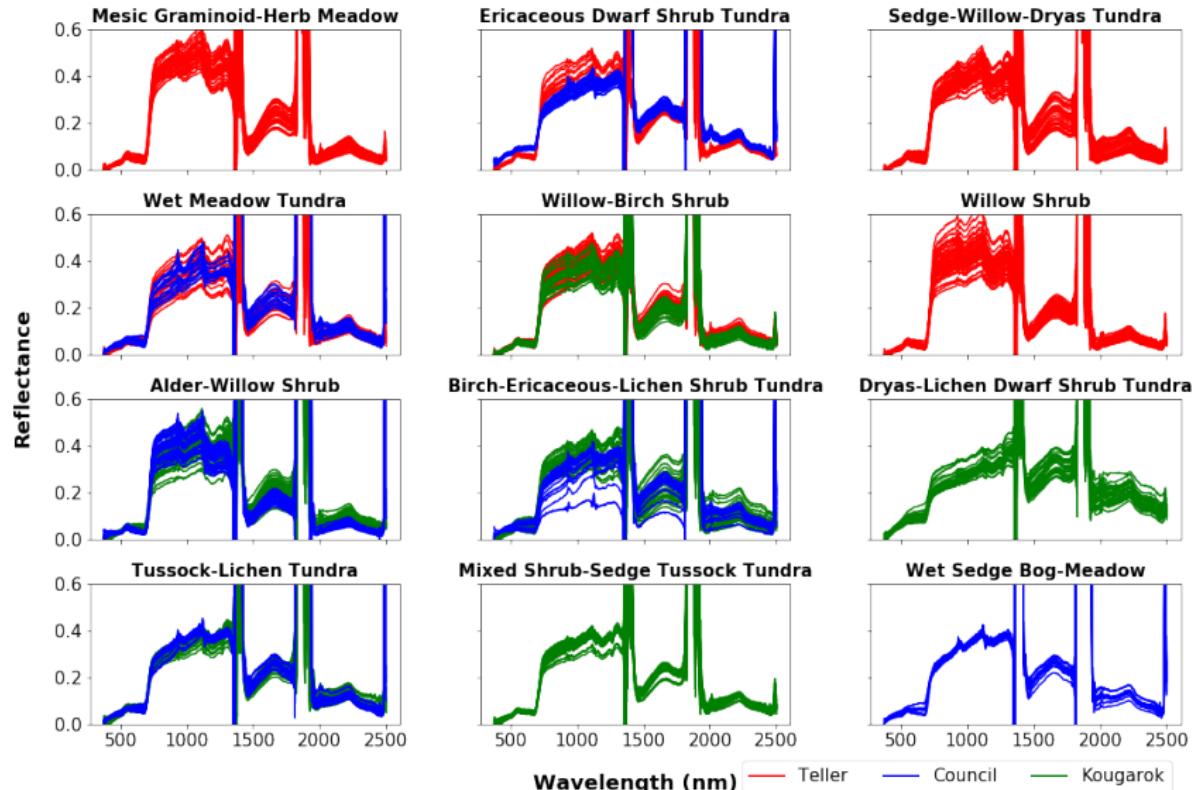


Sensor Specifications

Parameter	Value
Wavelength	380 - 2510 nm
No. of Bands	425
Spatial Res	5 m

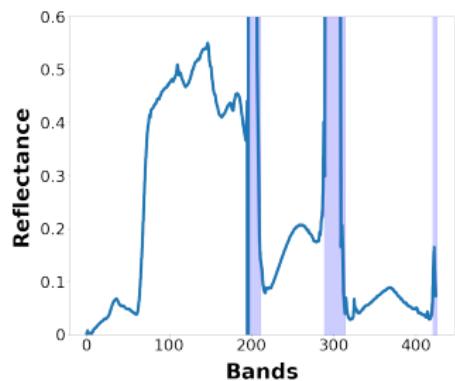


Spectral signatures of vegetation communities across sites



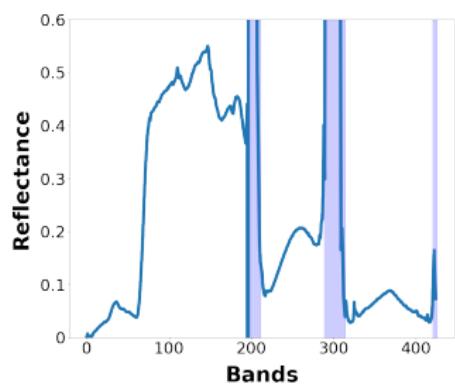
Deep Neural Network-based classifier

For every 5m pixel,

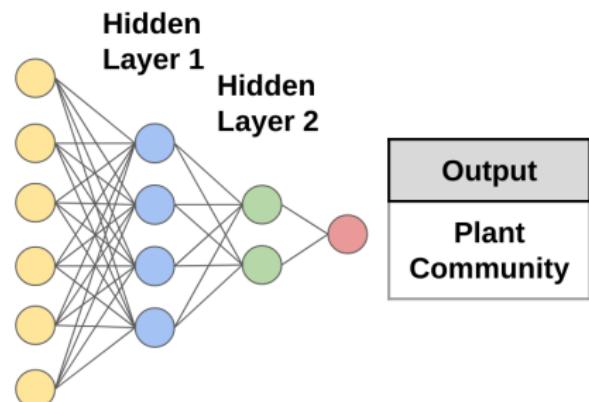


Deep Neural Network-based classifier

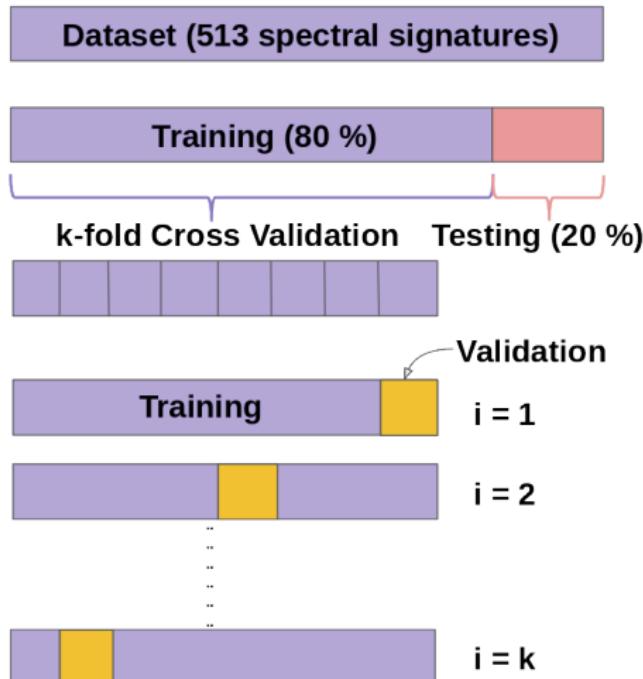
For every 5m pixel,



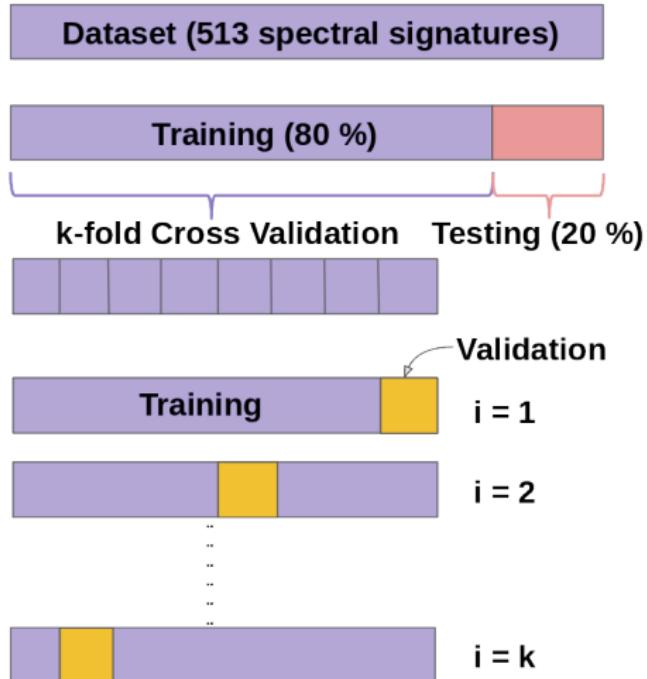
Inputs (378)
Band 1
Band 2
..
..
Band 418
Band 419



Classification Results

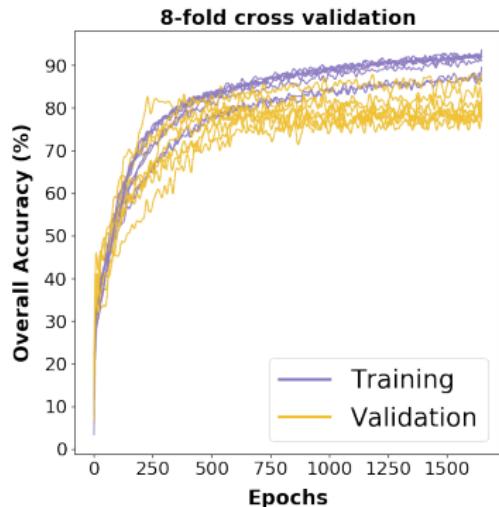


Classification Results



Hyperparameters:

- Number of Hidden Layers: 3
- Number of Units: 200, 100, 50
- Regularization: Dropout (0.1) and L1



Accuracy on the test set: **80.58%**

Errors in Prediction

- Values along the diagonal represent the number of instances when the model predicted correctly.
- Off-diagonal values show errors.

OBSERVED	PREDICTED														Recall (%)
	Ald-Wil	Bir Eric	Dry Lic	Eric Dwrf	Mes Gram	Mix Shrb	Sed-Wil	Tuss Lich	Wet Mead	Wet Sed	Wil Shrb	Wil Bir	-	-	
Ald-Wil	12	2	-	-	-	-	-	-	-	-	-	-	1	-	80
Bir Eric	-	6	-	-	1	-	-	-	1	1	-	-	-	-	67
Dry Lic	-	-	5	-	-	-	-	-	-	-	-	-	-	-	100
Eric Dwrf	-	-	-	5	-	-	-	-	-	-	-	-	2	-	71
Mes Gram	-	-	-	-	5	-	-	-	-	-	-	2	-	-	71
Mix Shrb	-	-	-	-	-	6	-	-	-	-	-	-	-	-	100
Sed-Wil	-	-	-	-	-	-	6	-	2	-	1	-	-	-	67
Tuss Lich	-	-	-	-	-	-	-	9	-	-	-	-	-	-	100
Wet Mead	-	1	-	-	-	-	-	-	5	-	-	-	-	-	83
Wet Sed	-	-	-	-	-	-	-	-	-	3	-	-	-	-	100
Wil Shrb	-	-	-	-	1	-	1	-	-	-	8	-	-	-	80
Wil Bir	2	-	-	-	-	-	-	-	-	-	2	13	-	-	76
Precision (%)	86	67	100	83	83	100	86	90	62	100	62	81	-	-	80.58

Birch-Ericaceous-Lichen Shrub Tundra

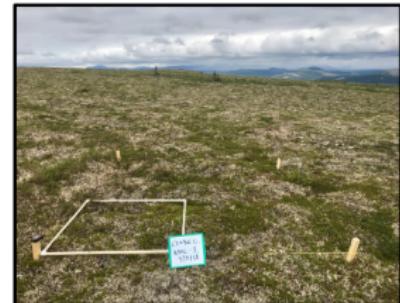
Confused with other plant communities

OBSERVED	PREDICTED												Recall (%)
	Ald-Wil	Bir Eric	Dry Lic	Eric Dwrf	Mes Gram	Mix Shrb	Sed-Wil	Tuss Lich	Wet Mead	Wet Sed	Wil Shrb	Wil Bir	
Ald-Wil	12	2	-	-	-	-	-	-	-	-	-	1	80
Bir Eric	-	6	-	-	1	-	-	-	1	1	-	-	67
Dry Lic	-	-	5	-	-	-	-	-	-	-	-	-	100
Eric Dwrf	-	-	-	5	-	-	-	-	-	-	-	2	71
Mes Gram	-	-	-	-	5	-	-	-	-	-	2	-	71
Mix Shrb	-	-	-	-	-	6	-	-	-	-	-	-	100
Sed-Wil	-	-	-	-	-	-	6	-	2	-	1	-	67
Tuss Lich	-	-	-	-	-	-	-	9	-	-	-	-	100
Wet Mead	-	1	-	-	-	-	-	-	-	5	-	-	83
Wet Sed	-	-	-	-	-	-	-	-	-	3	-	-	100
Wil Shrb	-	-	-	-	1	-	1	-	-	-	8	-	80
Wil Bir	2	-	-	-	-	-	-	-	-	-	2	13	76
Precision (%)	86	67	100	83	83	100	86	90	62	100	62	81	80.58

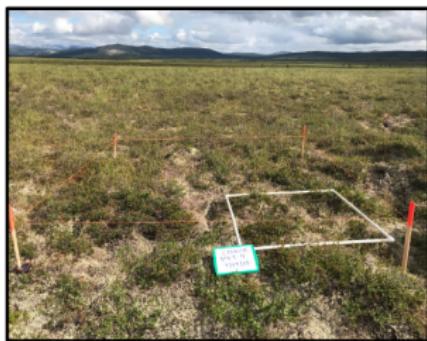
Reasons behind confusion

Overlap of constituent species with other plant communities

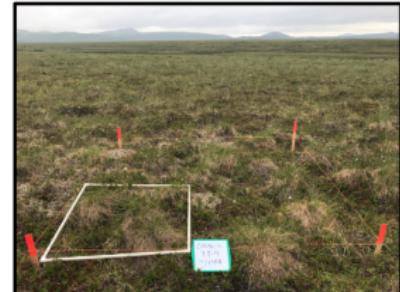
Ericaceous Dwarf Shrub Tundra



Birch-Ericaceous-Lichen Shrub Tundra



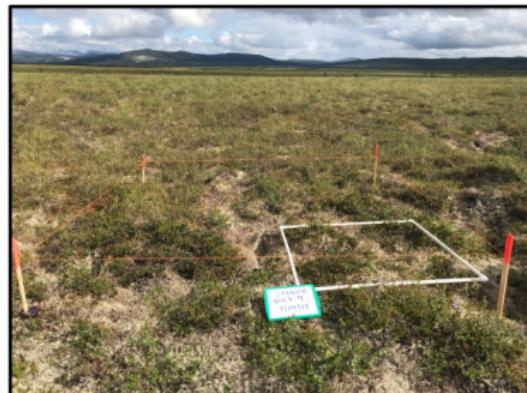
Tussock-Lichen Tundra



Reasons behind confusion

“Patchiness” of vegetation

Birch-Ericaceous-**Lichen** Shrub Tundra



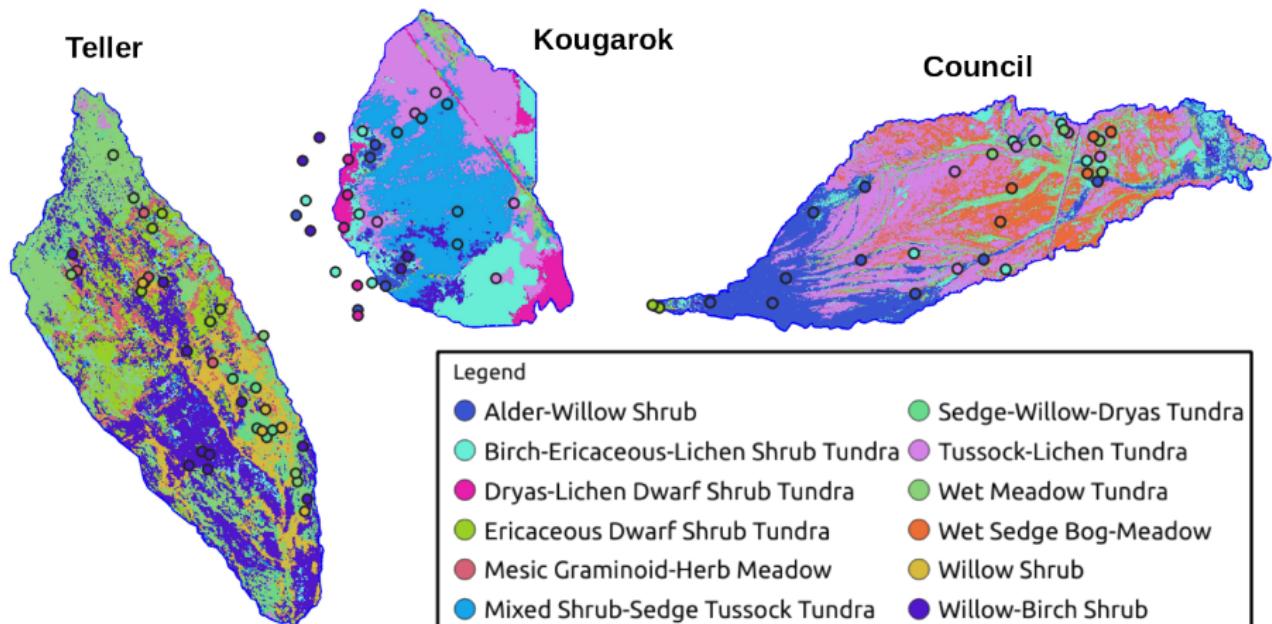
Alder-Willow Shrub



Alder Shrubland

Dwarf Shrub **Lichen** Tundra

5m Plant Community Maps for Watersheds



Objective 2

Understand the drivers of vegetation distribution



Environmental Variables

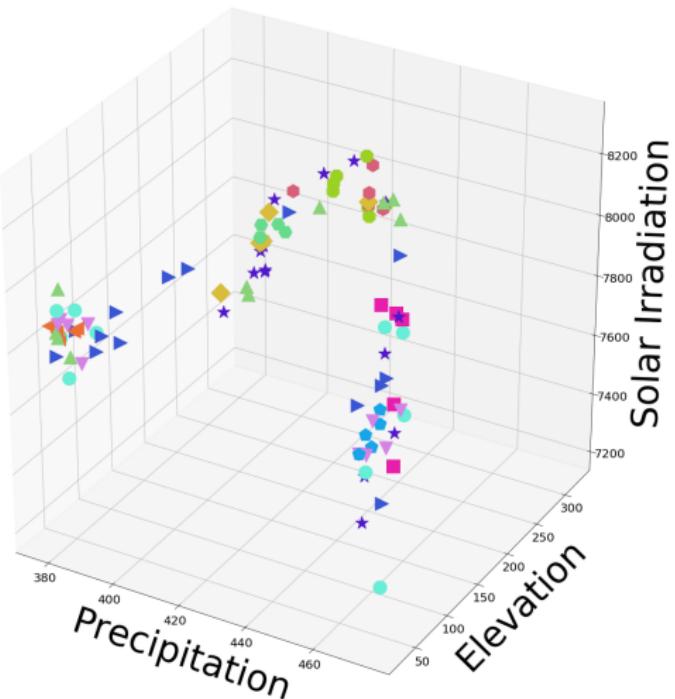
Type	Name	Units	Resolution	Source
Topography	Slope	degrees	5m	IfSAR
	Aspect	degrees		
	Elevation	meters		
	Avg. Summer Solar Irradiation*	Wh/m ² /day		
	Avg. Winter Solar Irradiation*	Wh/m ² /day		
	Topographic Convergence Index	-		
Climate (Decadal avg. 2000-09)	Distance to stream	meters	771m	SNAP [†]
	Avg. Summer Temperature*	°C		
	Avg. Winter Temperature*	°C		
	Precipitation	mm		
	Growing Season Length	days		
	Snowfall Equivalent	mm		

* Summer - June, July, August

Winter - December, January, February

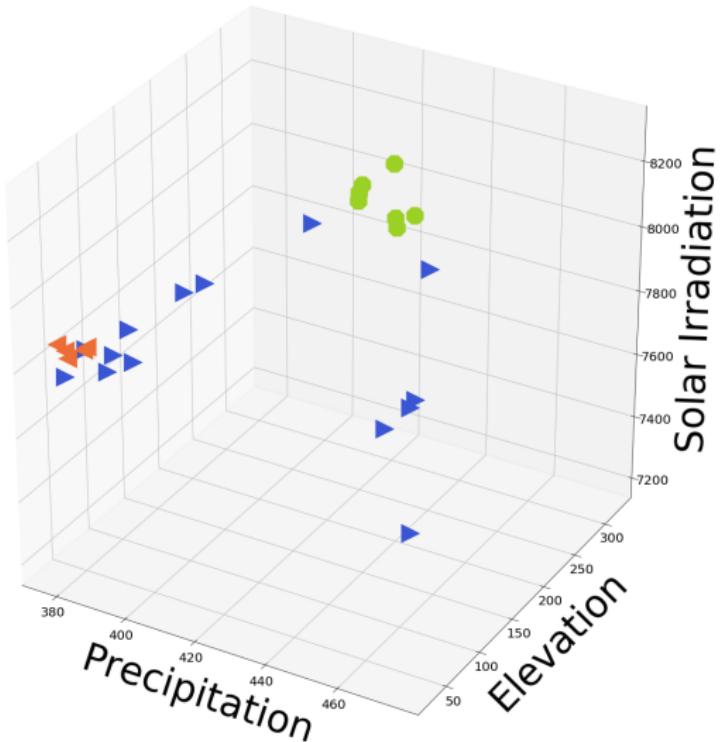
† SNAP (Scenarios Planning for Alaska Arctic planning) produces downscaled, historical climate data for sub-Arctic and Arctic regions of Alaska and Canada. Downscaled data come from one of 5 top-ranked GCMs or are calculated as a 5-model average.

Multidimensional Environmental Space



- Hexagon: Mesic Graminoid-Herb Meadow
- Pentagon: Willow-Birch Shrub
- Triangle: Wet Meadow Tundra
- Circle: Ericaceous Dwarf Shrub Tundra
- Inverted Triangle: Tussock-Lichen Tundra
- Diamond: Willow Shrub
- Plus: Mixed Shrub-Sedge Tussock Tundra
- Circle: Birch-Ericaceous-Lichen Shrub Tundra
- Right-pointing triangle: Alder-Willow Shrub
- Square: Dryas-Lichen Dwarf Shrub Tundra
- Hexagon: Sedge-Willow-Dryas Tundra
- Left-pointing triangle: Wet Sedge Bog-Meadow

Specialists v/s Generalists



- ▶ Alder-Willow Shrub
- Ericaceous Dwarf Shrub Tundra
- ◀ Wet Sedge Bog-Meadow

Summary

- Airborne hyperspectral remote sensing data allows mapping of plant communities at watershed scale.
- A Deep Neural Network-based classification of vegetation spectra achieved an accuracy >80%.
- Common reasons behind predictions errors:
 - Overlap of constituent species across vegetation communities
 - High heterogeneity of landscape (“patchiness”)
- Analysis of environmental drivers provides insights into preferential niche space where plant communities thrive.

Future Work

- Include topographic and environmental data to improve accuracy.
- Include 30m soil moisture data collected by NASA ABOVE.
- Estimate fractional cover of PFTs in each plant community.
- Predict which areas within the watershed satisfy the conditions of the species' niche.
- Estimate potential changes in niche distribution under predicted future climate.