



**Structural comparison of Arctic  
plant communities across the  
landscape  
and with experimental warming  
in Northern Alaska.**

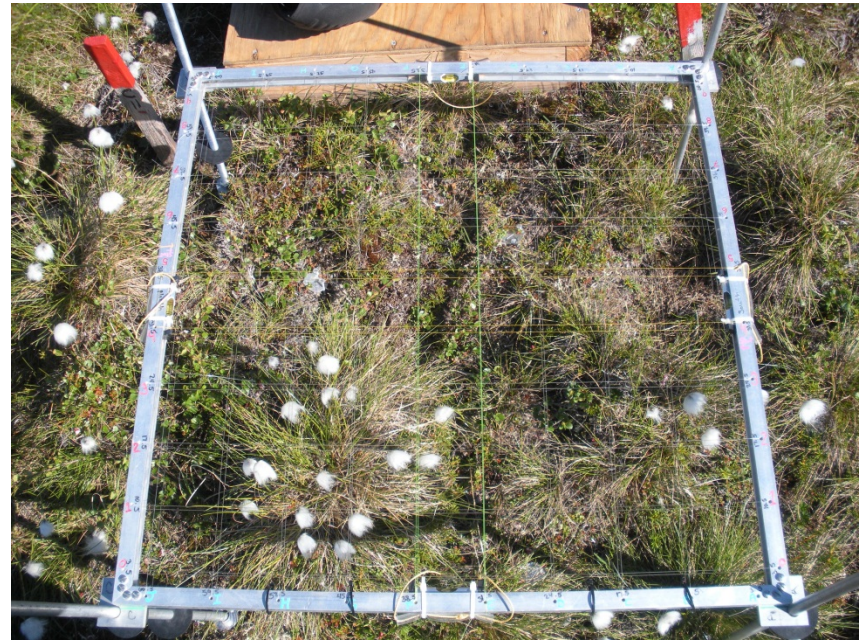
**Jessica L. Gregory  
Master's Thesis Defense  
Grand Valley State University  
November 20, 2014**



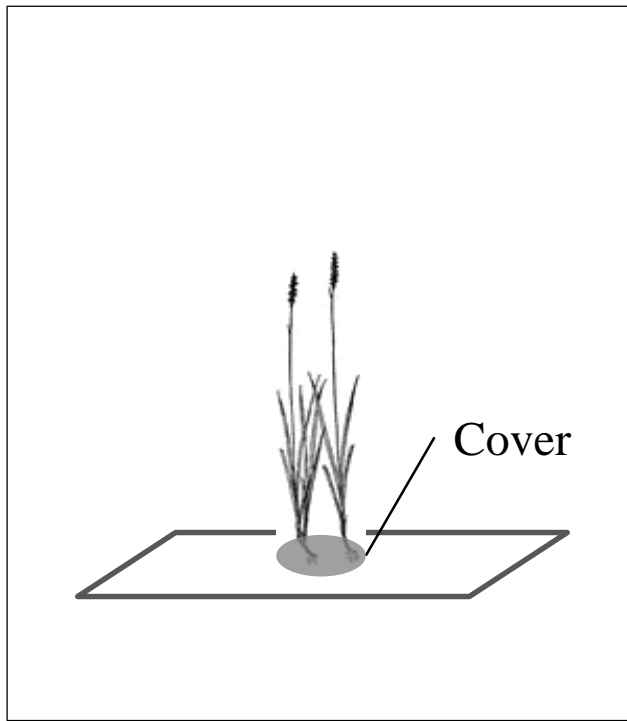
- Plants are important because they...
  - **Drive energy & nutrient flow through ecosystem**
    - Base of the food web
    - Influence energy balance (*albedo*)
    - Provide habitat structure
  - **Affect carbon balance**
    - Photosynthesis & ecosystem respiration via litter quality
  - **Are responsive to climate change**



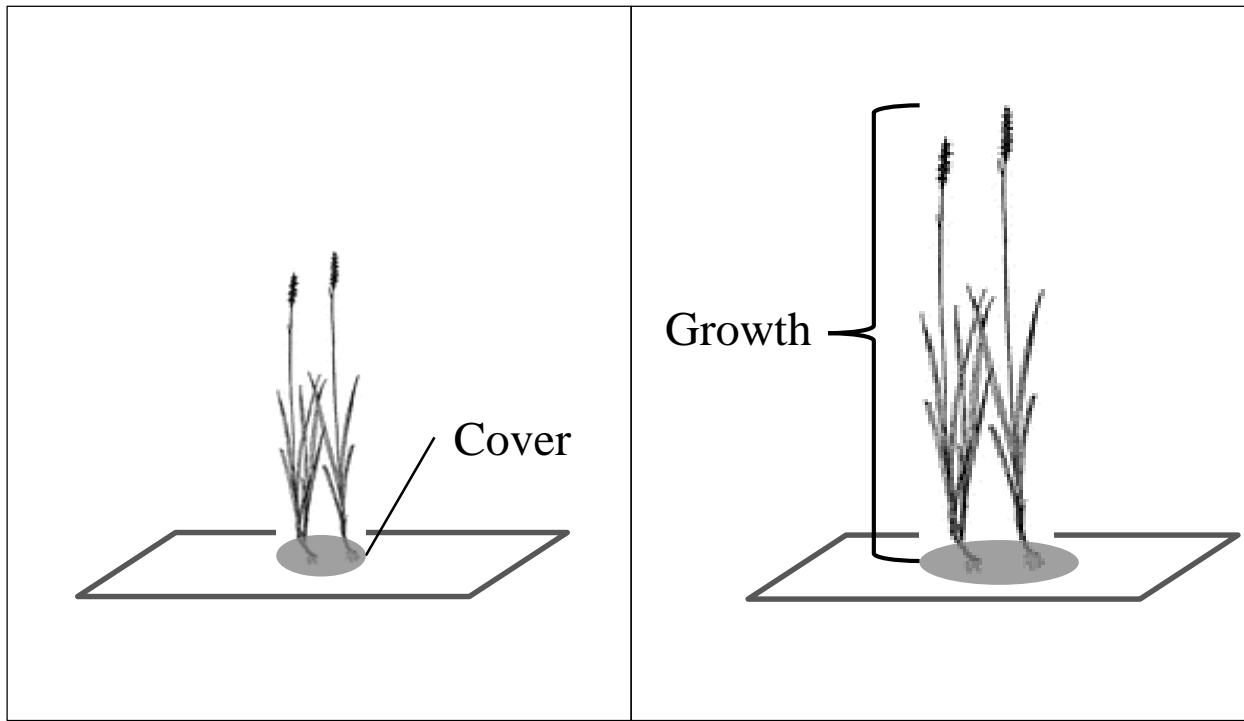
- Percent cover has been widely used to document vegetation change
- Point framing is a common method of determining percent cover
  - Particularly in the Arctic



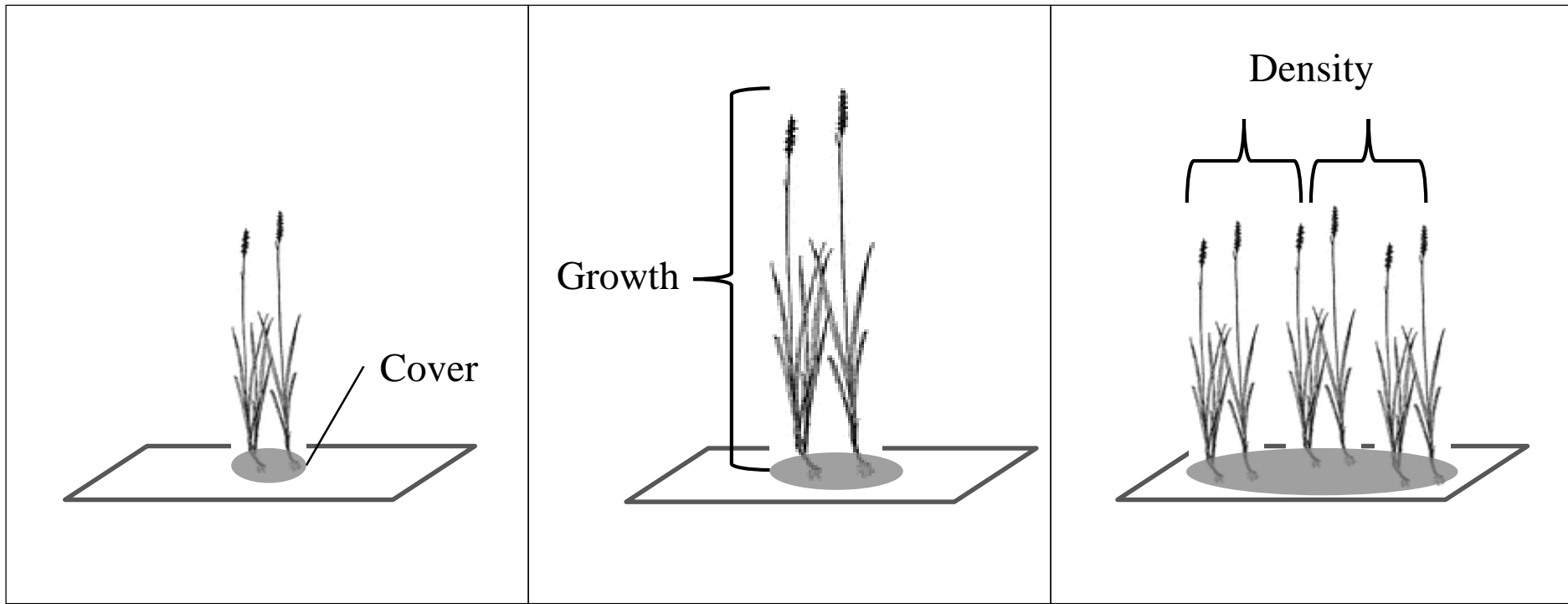
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  - Size of individual plants (Growth)

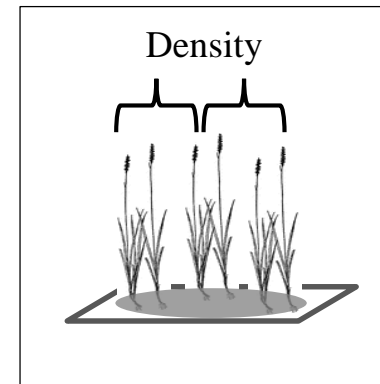
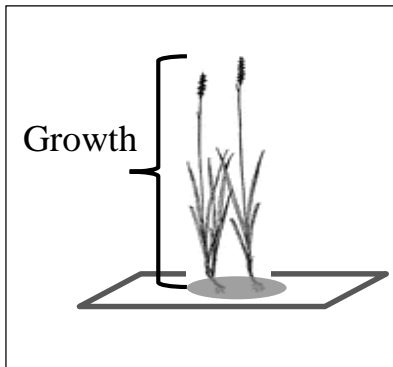


- Cover is influenced by canopy structure, which includes:
  - Size of individual plants (Growth)
  - Number of individual plants (Density)



# Significance of Research

- The balance between growth & density (and the influence on cover) may be critical for determining long-term changes in:
  - Community composition and diversity
  - Response to climate warming



# Project Objectives

- Document relationships between cover, growth and density
  1. Identify the impacts of abiotic variables on cover
  2. Pinpoint which traits are related to cover of dominant growth forms & species
  3. Determine the impact of experimental warming on these relationships
  4. Examine how relationships change across the landscape



# Study Site

- Atqasuk, Alaska (1996)

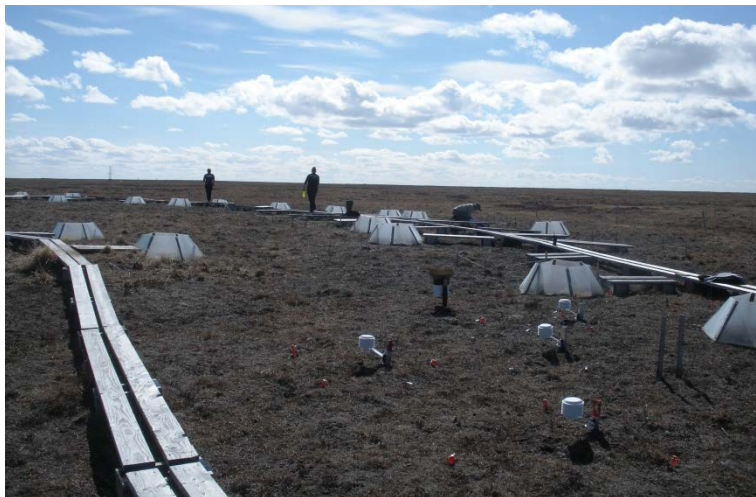




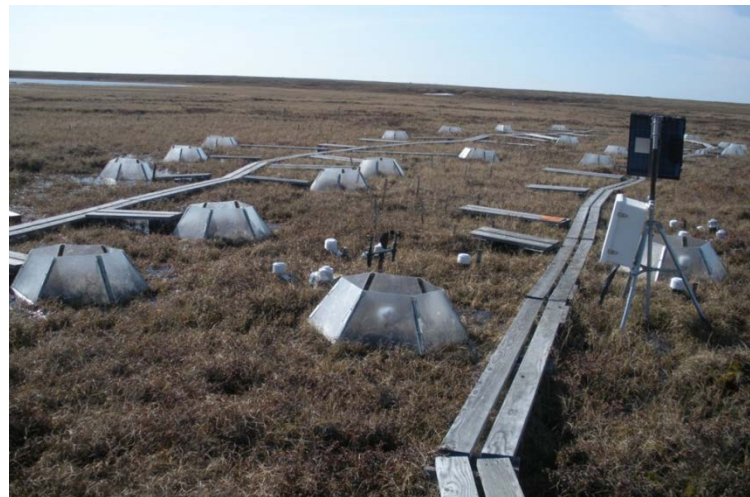
**Atqasuk Grid (AG)**



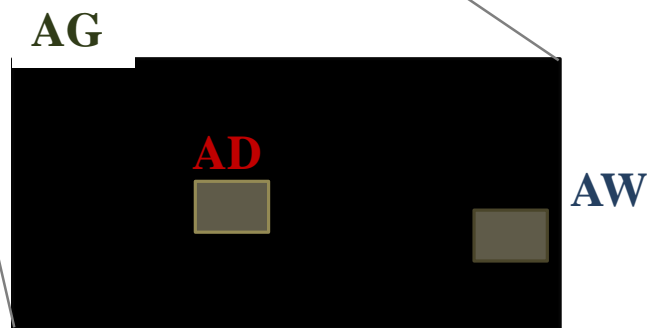
0 100 300 Meters



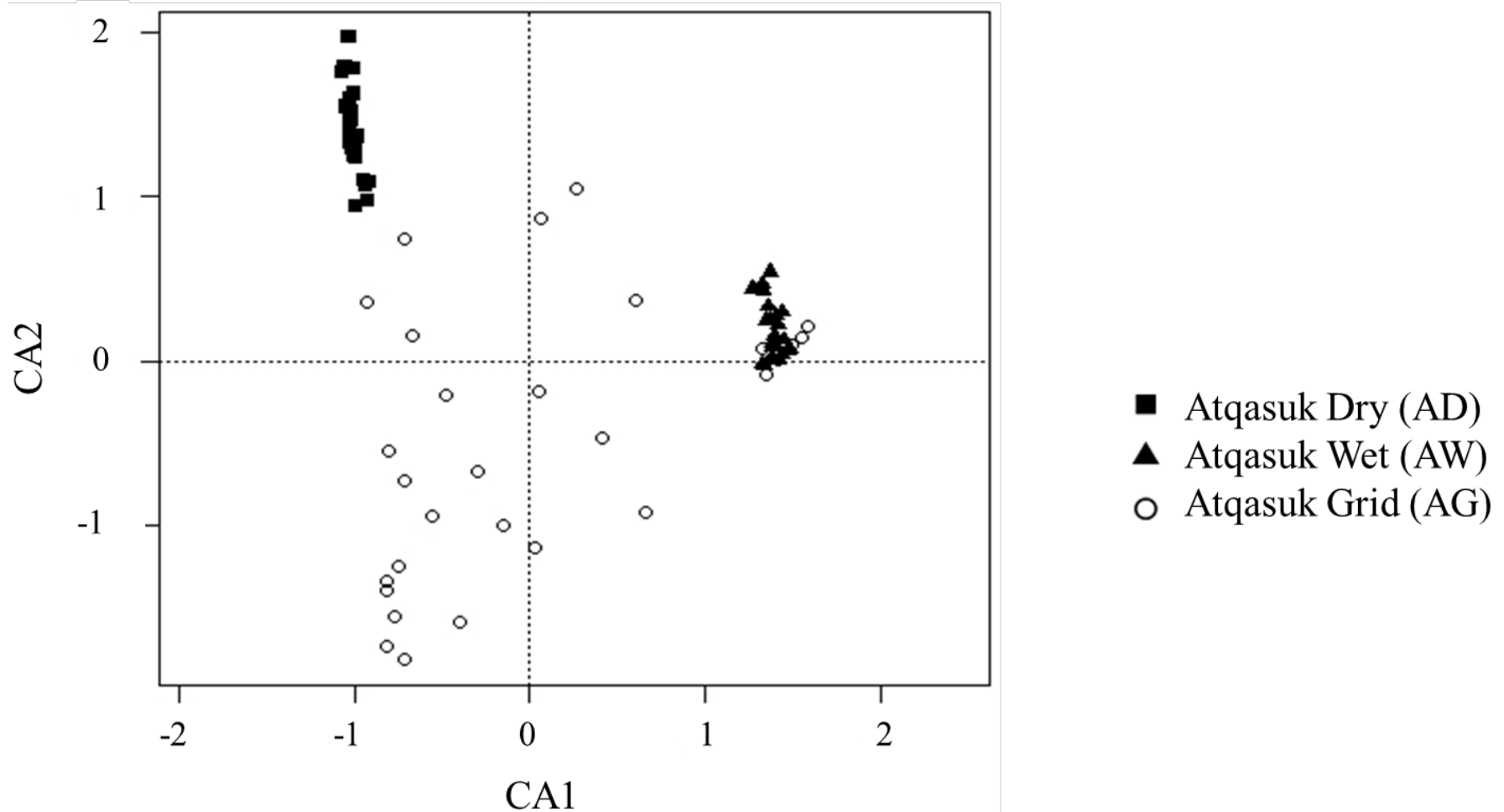
**Atqasuk Dry (AD)**



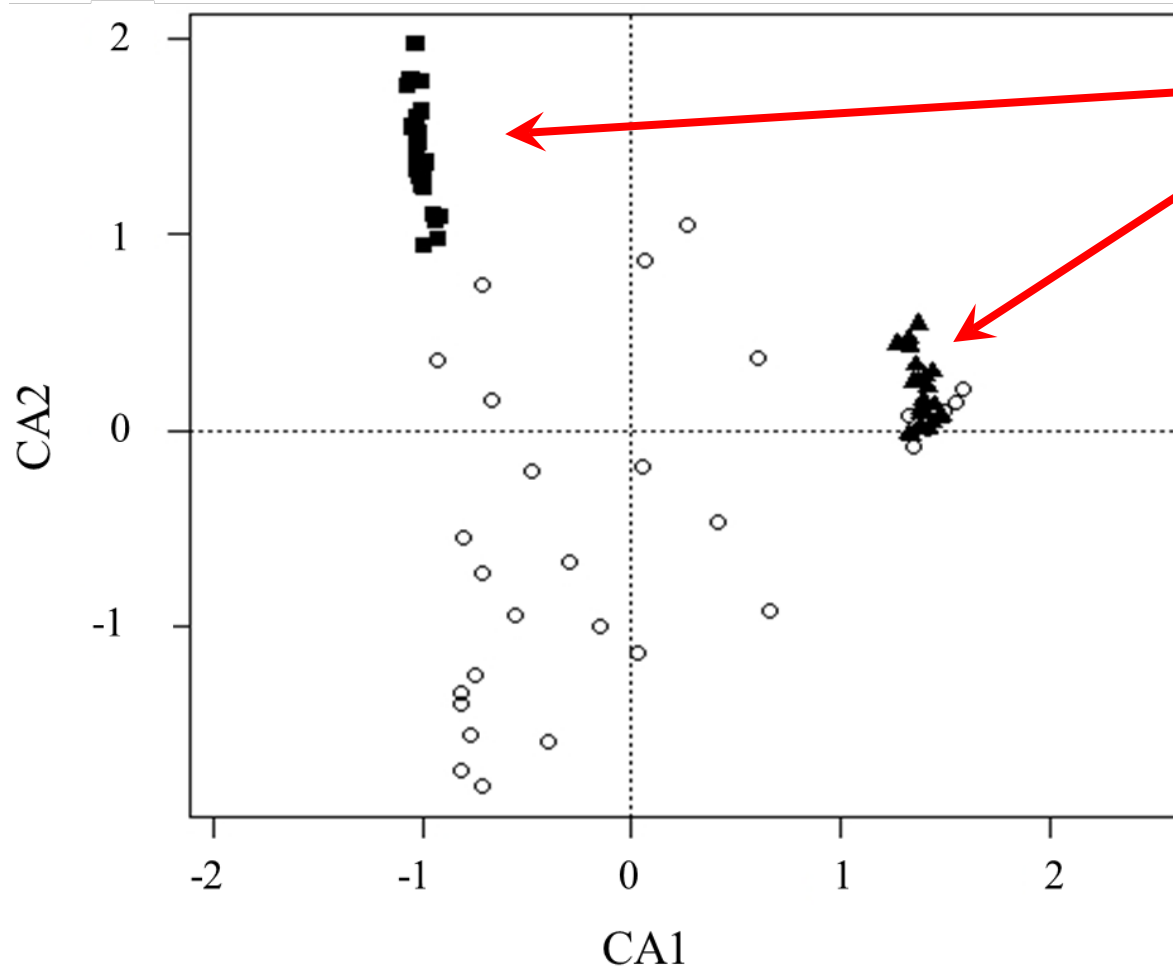
**Atqasuk Wet (AW)**



- Cover distribution of species at these sites



- Cover distribution of species at these sites

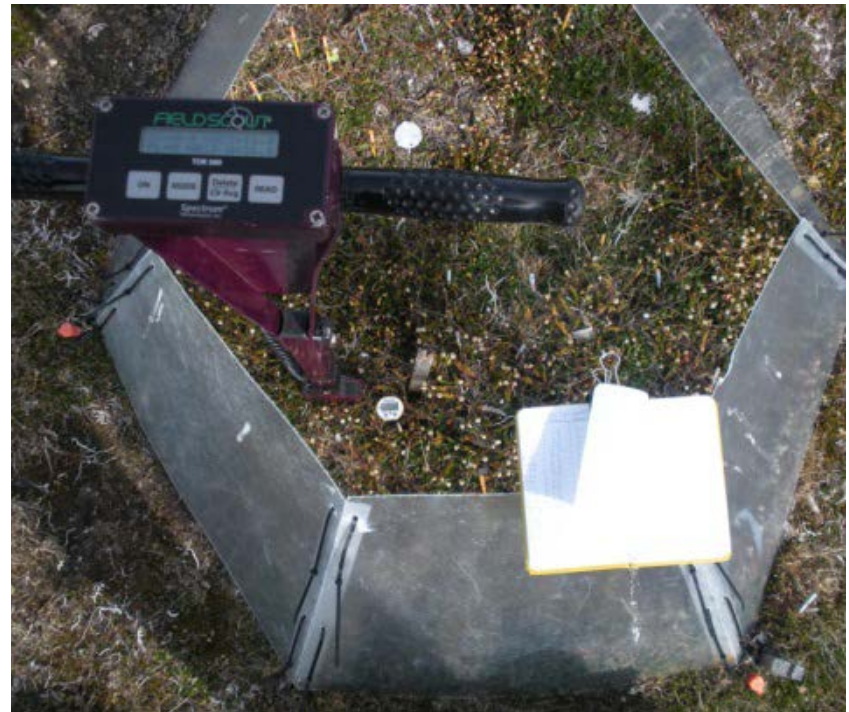


Clear separation  
in species  
present between  
the **AD** and **AW**  
sites

- Atqasuk Dry (AD)
- ▲ Atqasuk Wet (AW)
- Atqasuk Grid (AG)

# Data Collection

- Abiotic variables measured:
  - Soil moisture (% ; VWC and GWC)
  - Soil temperature ( $^{\circ}\text{C}$ )



# Data Collection

- Abiotic variables measured:
  - Soil moisture (% ; VWC and GWC)
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  - Bulk density ( $\text{g}/\text{cm}^3$ )
  - Organic matter (%)



# Data Collection

- Abiotic variables measured:
  - Soil moisture (% ; VWC and GWC)
  - Soil temperature (°C)
  - Bulk density (g/cm<sup>3</sup>)
  - Organic matter (%)
  - Thaw depth (cm)

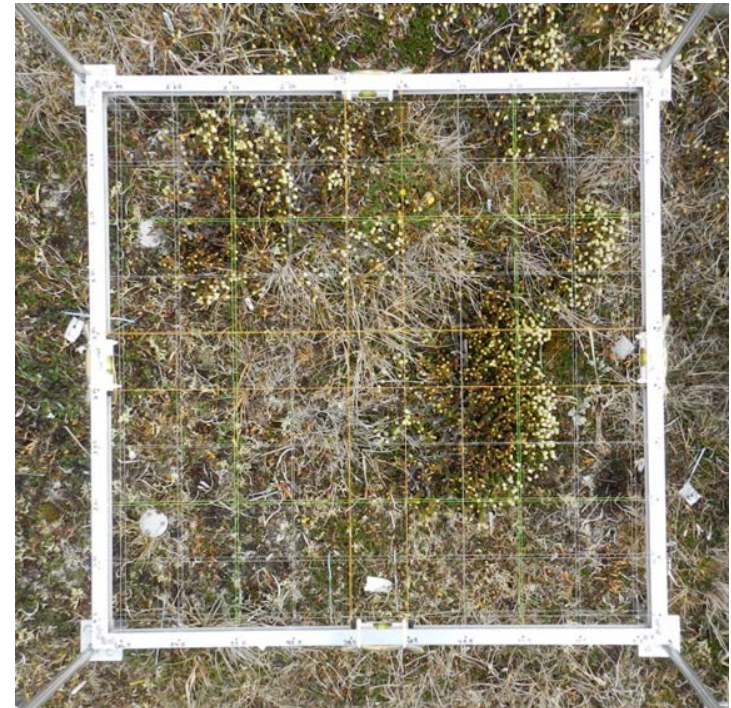




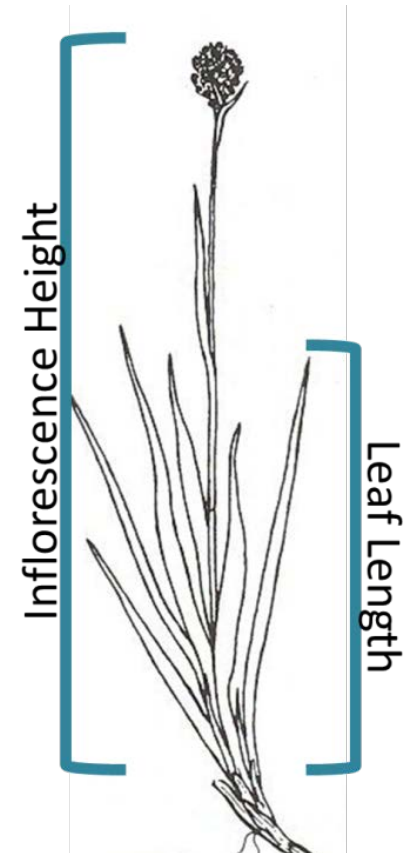
- Vegetation variables measured:
  - Cover (%)
  - Canopy height (cm)
  - Leaf length (cm)
  - Inflorescence length (cm)
  - Biomass (proxy)
  - Density (individuals/10cm<sup>2</sup>)



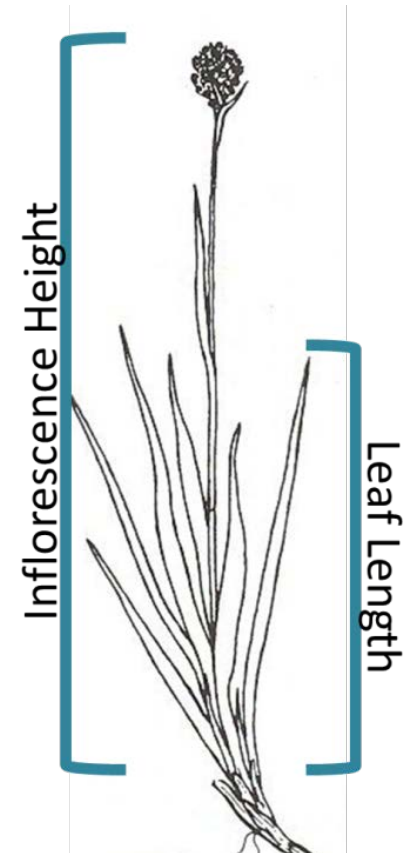
- **Cover** measured using a point frame method
  - 75cm by 75cm grid, 100 intersecting points
  - Total # live contacts summed to calculate percent cover
- **Canopy height** = difference between height of each contact and ground height
  - Measured at peak of growing season



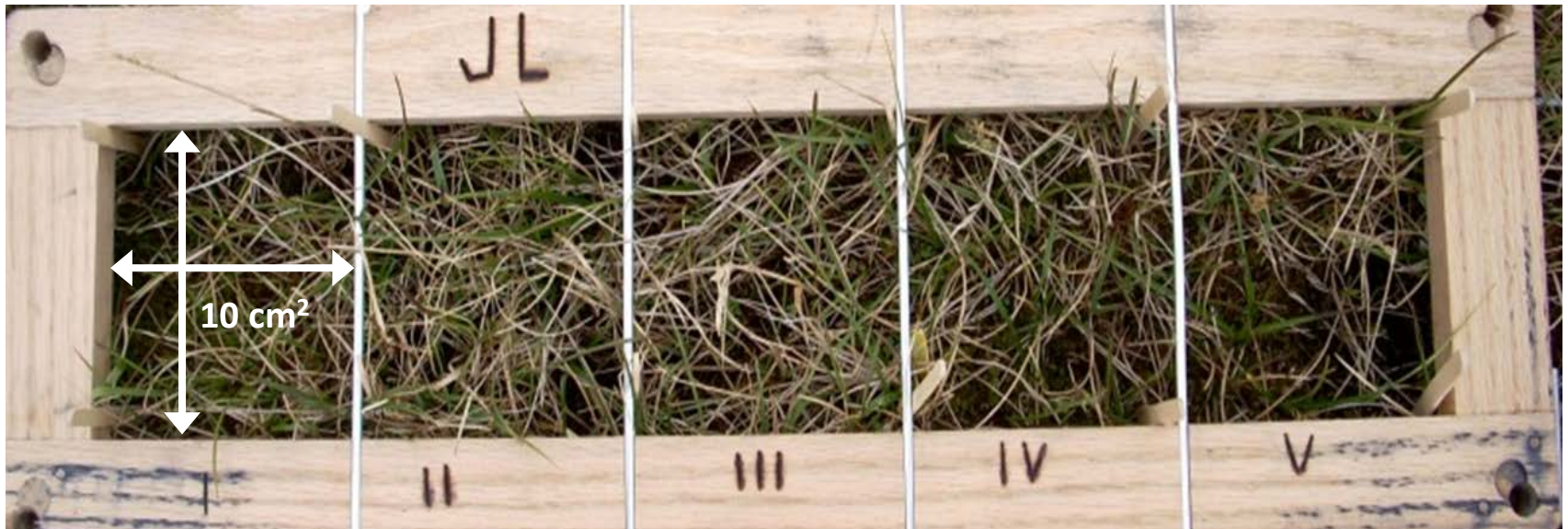
- **Leaf length** = length of longest basal leaf (measured from base of petiole to tip of leaf)
- **Inflorescence length** = length of longest inflorescence from base of stem to tip of inflorescence
  - Measured at the end of the field season = total season growth



- **Biomass (proxy)** = calculated by multiplying the *number of green leaves x leaf length*
  - Graminoids only



- **Density** = number of individual plants (ramets) using a 10cm by 50 cm wooden frame
  - Frame divided into 5 sections and situated above each plot



- **Density** = number of individual plants (ramets) using a 10cm by 50 cm wooden frame
  - Frame divided into 5 sections and situated above each plot
  - Total live counts of each species averaged for all sections = density estimate for plot



- Growth forms and dominant species from each site were included in analysis

<b>Atqasuk Dry</b>	<b>Atqasuk Wet</b>	<b>Atqasuk Grid</b>
Graminoids	Graminoids	Graminoids
<i>L. confusa</i>	<i>C. aquatilis</i>	<i>Carex spp.</i>
<i>H. alpina</i>	<i>E. angustifolium</i>	<i>Eriophorum spp.</i>
Evergreen Shrubs	<i>E. russeolum</i>	Evergreen Shrubs
<i>D. lapponica</i>	Deciduous Shrubs	Deciduous Shrubs
<i>V. vitis-idaea</i>	<i>Salix spp.</i>	--
Forbs	--	Forbs



# Data Analysis

- Variety of statistical methods used...
  - T-tests
  - Simple linear regressions (SLR)
  - One-way analysis of variance (ANOVA)
  - Multiple linear regressions (MLR)
  - Correspondence Analysis (CA)
  - Canonical Correspondence Analysis (CCA)
  - Analysis of covariance (ANCOVA)

...Also transformations and non-parametric alternatives when necessary



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- Abiotic measures collected in 2013 only
- All vegetation measures collected in 2012
- All vegetation measures collected in 2013 except cover at the AD and AW sites

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Therefore:

- **Analysis comparing vegetation with abiotic variables used 2013 only**
- **Analysis comparing vegetation variables with cover used 2012 only**

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Therefore:

- Analysis comparing vegetation with abiotic variables used 2013 only
- Analysis comparing vegetation variables with cover used 2012 only

**Multiple linear regressions performed across the AG  
(for both years) showed that year was not significant**

# Project Objectives

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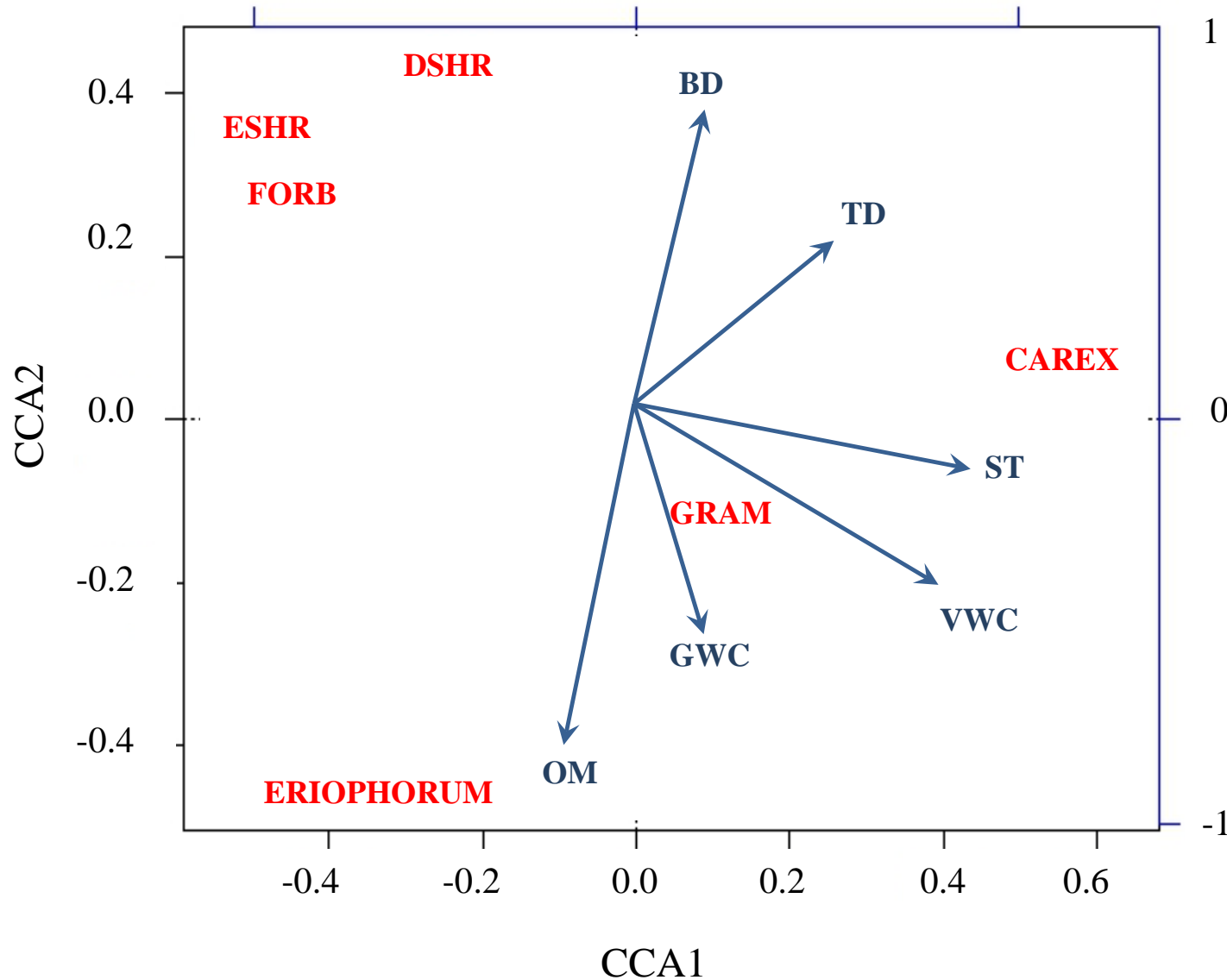
# Results

1. Abiotic variables influence vegetation cover
2. Cover of dominant growth forms correlated with different vegetation variables
3. Experimental warming significantly impacted the relationships between cover & vegetation variables
4. Results for growth forms not always consistent with those of their constituent species

# Results

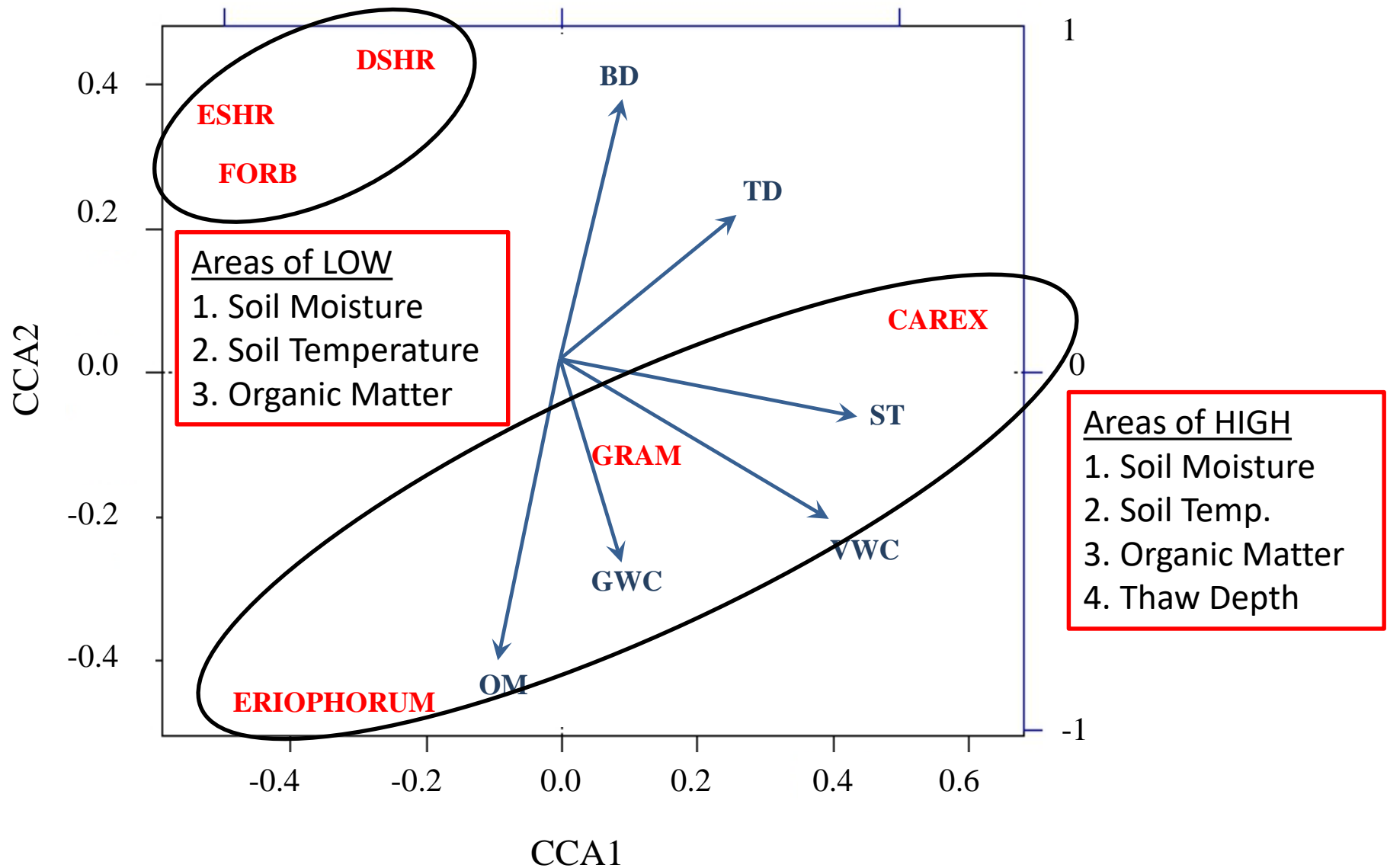
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# 1. Abiotic variables influence vegetation cover

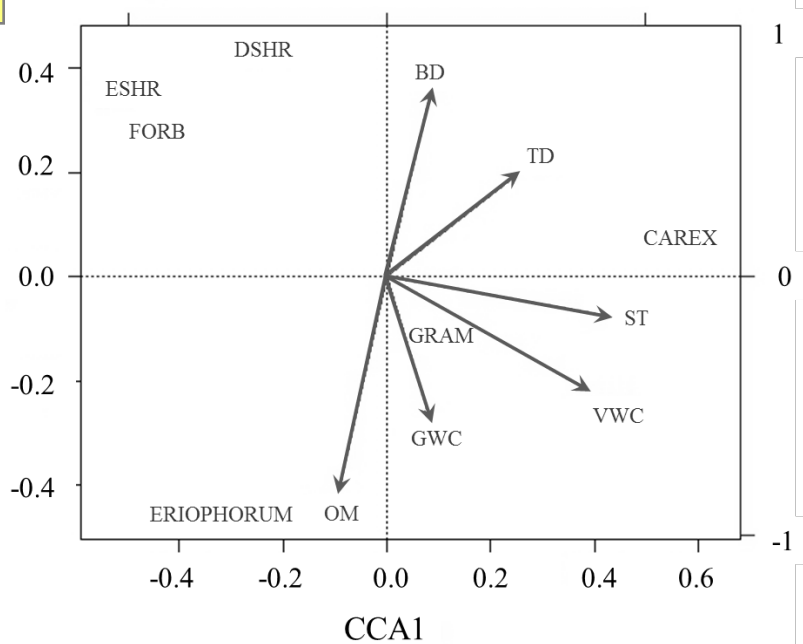


**Final model significant ( $p = 0.001$ ); explained 39.2 % of the variation across the Atqasuk Grid (AG)**

# 1. Abiotic variables influence vegetation cover







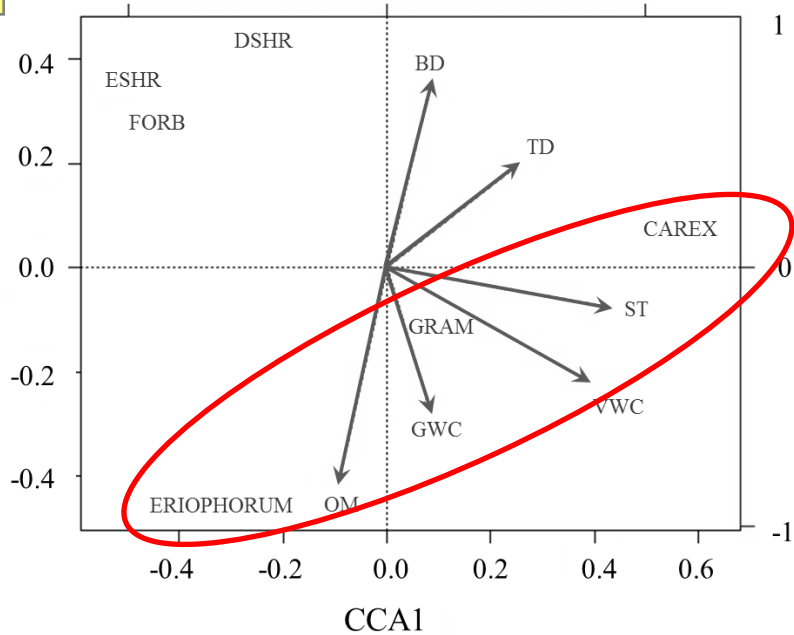
- Simple linear regressions quantitatively verified the CCA results

**BOLD = SIGNIFICANT**

Growth Form/Taxa	n	Soil Moisture (VWC%)		Soil Temperature (°C)		Soil Organic Matter (%)		Bulk Density (g/cm <sup>3</sup> )		Thaw Depth (cm)	
		R <sup>2</sup> /rho	p value	R <sup>2</sup> /rho	p value	R <sup>2</sup> /rho	p value	R <sup>2</sup> /rho	p value	R <sup>2</sup> /rho	p value
Graminoids <sup>a</sup>	30	0.00	0.80	0.00	0.82	0.06	0.19	0.09	0.10	0.00	0.75
<i>Carex spp.</i> <sup>a</sup>	30	<b>0.16</b>	<b>0.03</b>	<b>0.33</b>	<b>&lt;0.001</b>	0.03	0.37	0.01	0.59	<b>0.33</b>	<b>&lt;0.001</b>
<i>Eriophorum spp.</i>	30	0.00	0.85	0.05	0.25	<b>0.39</b>	<b>&lt;0.001</b>	<b>0.31</b>	<b>&lt;0.001</b>	0.10	0.09
Deciduous Shrubs <sup>b</sup>	30	<b>-0.46</b>	<b>0.01</b>	-0.29	0.12	-0.21	0.25	0.15	0.43	0.19	0.32
Evergreen Shrubs <sup>b</sup>	30	<b>-0.68</b>	<b>&lt;0.001</b>	<b>-0.66</b>	<b>&lt;0.001</b>	-0.13	0.50	0.27	0.14	-0.32	0.08
Forbs <sup>b</sup>	30	-0.28	0.14	<b>-0.36</b>	<b>0.05</b>	-0.31	0.09	0.16	0.38	-0.18	0.33

**Simple Linear Regression (SLR) results**

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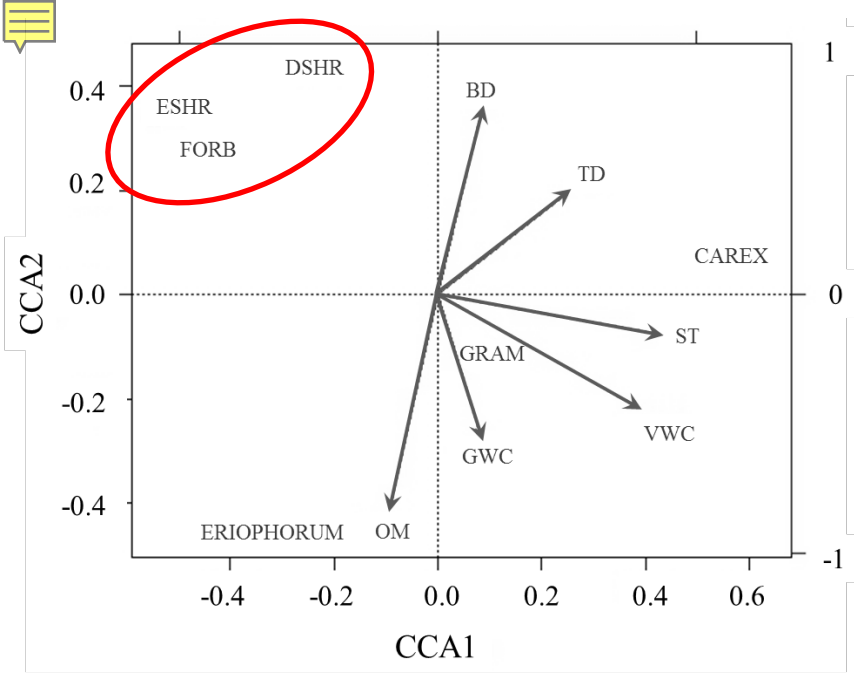


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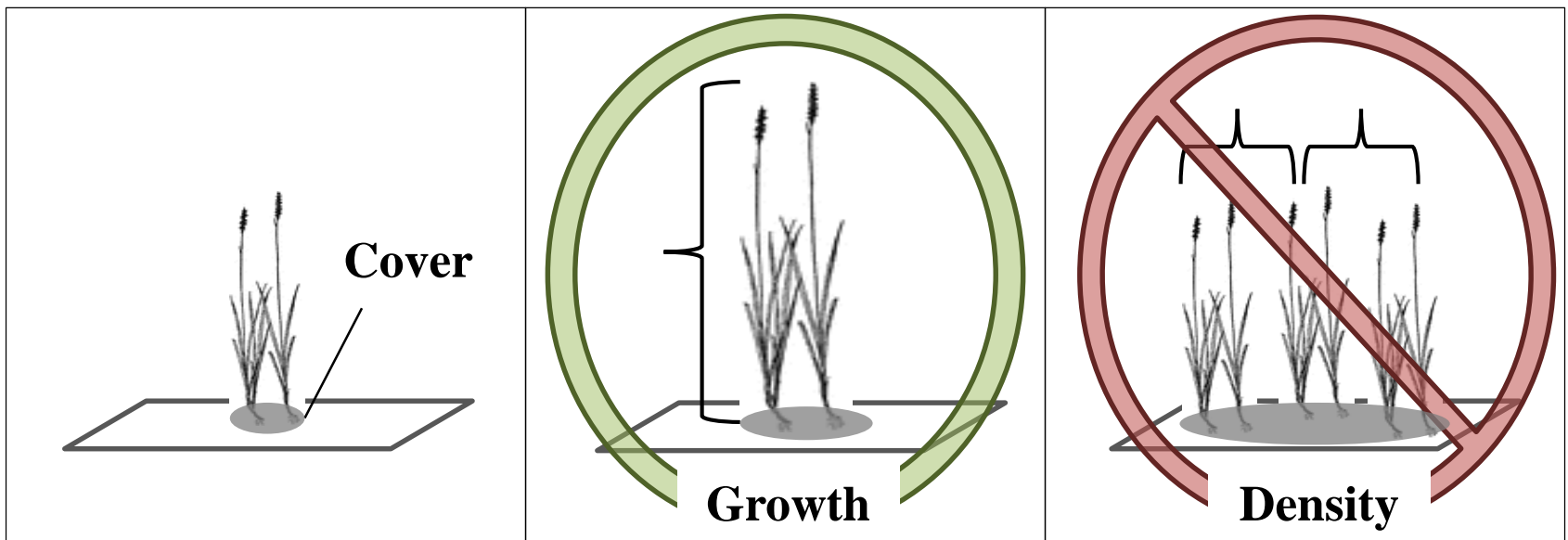
- Abiotic variables impact cover distribution of plants

# Results

1. Abiotic variables influence vegetation cover
2. Cover correlated with different vegetation variables depending on growth form
3. Experimental warming significantly impacted the relationships between cover & vegetation variables
4. Results for growth forms not always consistent with those of their constituent species

## 2. Cover correlated with different vegetation variables depending on growth form

- **Graminoid cover** most strongly correlated with growth traits



Graminoids (grasses, rushes, sedges)

– Graminoid cover most strongly correlated with growth traits

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Wet (AW)</b>															
Graminoids	48	<b>0.13</b>	<b>0.01</b>	47	0.02	0.31	48	<b>0.37</b>	<b>&lt;0.001</b>	48	0.00	0.74	48	0.06	0.09
<i>Carex aquatilis</i>	48	<b>0.23</b>	<b>&lt;0.001</b>	35	0.06	0.15	48	<b>0.42</b>	<b>&lt;0.001</b>	48	0.00	0.93	48	<b>0.16</b>	<b>0.01</b>
<i>Eriophorum angustifolium</i>	40	0.02	0.36	32	0.06	0.18	44	0.01	0.47	41	0.08	0.07	40	0.03	0.27
<i>Eriophorum russeolum</i> <sup>†</sup>	36	0.07	0.12	NA	NA	NA	42	0.04	0.21	40	0.08	0.08	36	0.02	0.45
<b>Atqasuk Dry (AD)</b>															
Graminoids	46	0.03	0.21	45	0.01	0.51	46	<b>0.24</b>	<b>&lt;0.001</b>	44	0.07	0.09	46	0.02	0.33
<i>Hierchloe alpina</i>	26	<b>0.18</b>	<b>0.03</b>	29	0.09	0.12	30	0.07	0.14	19	0.00	1.00	26	0.03	0.44
<i>Luzula confusa</i>	39	<b>0.12</b>	<b>0.03</b>	35	0.11	0.06	37	0.07	0.10	32	0.02	0.41	39	0.00	0.81

†Inflorescence length not included as a variable for *E. russeolum* due to small sample size

**Simple Linear Regression (SLR) results**

**BOLD = SIGNIFICANT**

- Plant variables correlated with cover across sites not as inconsistent as it might seem

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
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<i>Eriophorum angustifolium</i>	40	0.02	0.36	32	0.06	0.18	44	0.01	0.47	41	0.08	0.07	40	0.03	0.27
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<i>Luzula confusa</i>	39	<b>0.12</b>	<b>0.03</b>	35	0.11	0.06	37	0.07	0.10	32	0.02	0.41	39	0.00	0.81
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Graminoids	30	0.00	0.84	27	0.09	0.14	30	0.07	0.17	29	<b>0.24</b>	<b>0.01</b>	NA	NA	NA
<i>Carex spp.</i>	27	0.11	0.09	20	0.14	0.11	26	<b>0.32</b>	<b>&lt;0.01</b>	25	<b>0.22</b>	<b>0.02</b>	NA	NA	NA
<i>Eriophorum spp.</i>	21	0.01	0.65	15	<b>0.49</b>	<b>&lt;0.01</b>	24	0.03	0.46	21	0.11	0.15	NA	NA	NA

†Inflorescence length not included as a variable for *E. russeolum* due to small sample size

**Simple Linear Regression (SLR) results**

**BOLD = SIGNIFICANT**



# In the warming experiment:

- **Density** of *C. aquatilis* decreased
- **Leaf length** of *C. aquatilis* increased

→ **Density and Growth are inversely related**

Taxa	n (total)	Treatment		Test		
		Control ( C )	Warmed ( W )	Statistic	p value	Trend
<b>Atqasuk Wet (AW)</b>						
Density (individuals/10cm <sup>2</sup> )						
Graminoids	48	2.55 ±0.09	2.38 ±0.13	1.23	0.27	C > W
<i>Carex aquatilis</i> <sup>a</sup>	48	<b>4.59 ±0.33</b>	<b>3.58 ±0.19</b>	<b>6.04</b>	<b>0.02</b>	<b>C &gt; W</b>
<i>Eriophorum angustifolium</i>	42	1.37 ±0.12	1.65 ±0.13	3.25	0.07	W > C
<i>Eriophorum russeolum</i> <sup>c</sup>	42	1.97 ±0.21	1.96 ±0.21	0.00	0.99	NC
Leaf Length (cm)						
Graminoids <sup>c</sup>	48	<b>15.38 ±0.90</b>	<b>17.4 ±0.46</b>	<b>6.64</b>	<b>0.01</b>	<b>W &gt; C</b>
<i>Carex aquatilis</i>	48	<b>17.74 ±0.88</b>	<b>20.76 ±0.74</b>	<b>6.89</b>	<b>0.01</b>	<b>W &gt; C</b>
<i>Eriophorum angustifolium</i>	42	<b>18.3 ±1.17</b>	<b>20.95 ±0.72</b>	<b>4.85</b>	<b>0.03</b>	<b>W &gt; C</b>
<i>Eriophorum russeolum</i>	37	12.52 ±0.85	13.87 ±0.77	1.36	0.25	W > C



- Plant variables correlated with cover across sites not as inconsistent as it might seem

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Wet (AW)</b>															
Graminoids	48	<b>0.13</b>	<b>0.01</b>	47	0.02	0.31	48	<b>0.37</b>	<b>&lt;0.001</b>	48	0.00	0.74	48	0.06	0.09
<i>Carex aquatilis</i>	48	<b>0.23</b>	<b>&lt;0.001</b>	35	0.06	0.15	48	<b>0.42</b>	<b>&lt;0.001</b>	48	0.00	0.93	48	<b>0.16</b>	<b>0.01</b>
<i>Eriophorum angustifolium</i>	40	0.02	0.36	32	0.06	0.18	44	0.01	0.47	41	0.08	0.07	40	0.03	0.27
<i>Eriophorum russeolum</i> <sup>†</sup>	36	0.07	0.12	NA	NA	NA	42	0.04	0.21	40	0.08	0.08	36	0.02	0.45
<b>Atqasuk Dry (AD)</b>															
Graminoids	46	0.03	0.21	45	0.01	0.51	46	<b>0.24</b>	<b>&lt;0.001</b>	44	0.07	0.09	46	0.02	0.33
<i>Hierchloe alpina</i>	26	<b>0.18</b>	<b>0.03</b>	29	0.09	0.12	30	0.07	0.14	19	0.00	1.00	26	0.03	0.44
<i>Luzula confusa</i>	39	<b>0.12</b>	<b>0.03</b>	35	0.11	0.06	37	0.07	0.10	32	0.02	0.41	39	0.00	0.81
<b>Atqasuk Grid (AG)</b>															
Graminoids	30	0.00	0.84	27	0.09	0.14	30	0.07	0.17	29	<b>0.24</b>	<b>0.01</b>	NA	NA	NA
<i>Carex spp.</i>	27	0.11	0.09	20	0.14	0.11	26	<b>0.32</b>	<b>&lt;0.01</b>	25	<b>0.22</b>	<b>0.02</b>	NA	NA	NA
<i>Eriophorum spp.</i>	21	0.01	0.65	15	<b>0.49</b>	<b>&lt;0.01</b>	24	0.03	0.46	21	0.11	0.15	NA	NA	NA

†Inflorescence length not included as a variable for *E. russeolum* due to small sample size

**Simple Linear Regression (SLR) results**

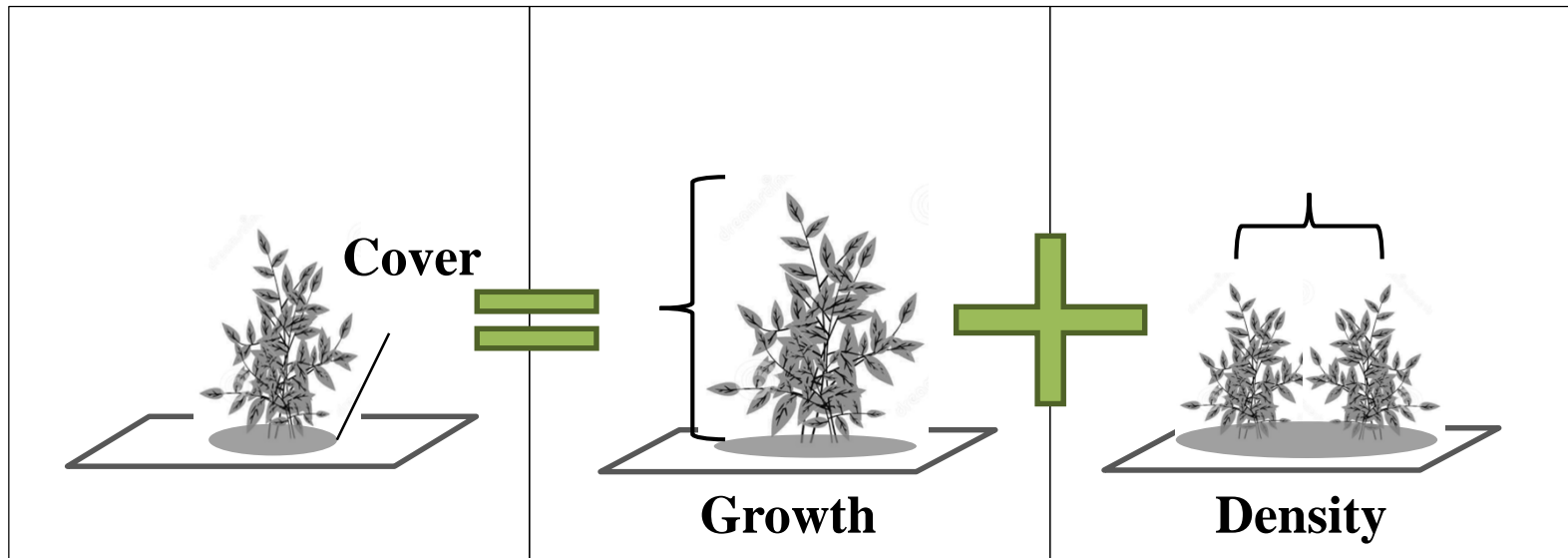
**BOLD = SIGNIFICANT**

- Species may behave differently within a particular community type than when the ‘sum’ of the relationships between cover and plant variables is considered across a broader landscape



## 2. Cover correlated with different vegetation variables depending on growth form

- **Shrub cover** was correlated with different traits depending on community type



Shrubs

– Traits correlated with shrub cover varied by community type

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Wet (AW)</b>															
Deciduous Shrubs	26	0.09	0.13	32	0.04	0.29	45	0.00	0.82	40	0.06	0.11	NA	NA	NA
<i>Salix spp.</i>	26	0.12	0.09	31	0.04	0.27	45	0.00	0.75	40	0.07	0.11	NA	NA	NA
<b>Atqasuk Dry (AD)</b>															
Evergreen Shrubs	48	0.04	0.18	48	<b>0.20</b>	<b>&lt;0.01</b>	48	<b>0.19</b>	<b>0.00</b>	48	0.06	0.10	NA	NA	NA
<i>Diapensia lapponica</i>	27	0.01	0.67	31	0.08	0.13	30	<b>0.20</b>	<b>0.01</b>	24	<b>0.25</b>	<b>0.01</b>	NA	NA	NA
<i>Vaccinium vitis-idaea</i>	46	<b>0.15</b>	<b>0.01</b>	37	0.03	0.27	44	0.06	0.10	46	<b>0.37</b>	<b>&lt;0.001</b>	NA	NA	NA

Simple Linear Regression (SLR) results

**BOLD = SIGNIFICANT**

– Traits correlated with shrub cover varied by community type

- Cover not well correlated with variables at the AW site

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Wet (AW)</b>															
Deciduous Shrubs	26	0.09	0.13	32	0.04	0.29	45	0.00	0.82	40	0.06	0.11	NA	NA	NA
<i>Salix spp.</i>	26	0.12	0.09	31	0.04	0.27	45	0.00	0.75	40	0.07	0.11	NA	NA	NA
<b>Atqasuk Dry (AD)</b>															
Evergreen Shrubs	48	0.04	0.18	48	<b>0.20</b>	<b>&lt;0.01</b>	48	<b>0.19</b>	<b>0.00</b>	48	0.06	0.10	NA	NA	NA
<i>Diapensia lapponica</i>	27	0.01	0.67	31	0.08	0.13	30	<b>0.20</b>	<b>0.01</b>	24	<b>0.25</b>	<b>0.01</b>	NA	NA	NA
<i>Vaccinium vitis-idaea</i>	46	<b>0.15</b>	<b>0.01</b>	37	0.03	0.27	44	0.06	0.10	46	<b>0.37</b>	<b>&lt;0.001</b>	NA	NA	NA

**Simple Linear Regression (SLR) results**

**BOLD = SIGNIFICANT**

– Traits correlated with shrub cover varied by community type

- Cover not well correlated with variables at the AW site
- Relationships between cover and vegetation variables at the AD site highly inconsistent

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Wet (AW)</b>															
Deciduous Shrubs	26	0.09	0.13	32	0.04	0.29	45	0.00	0.82	40	0.06	0.11	NA	NA	NA
<i>Salix spp.</i>	26	0.12	0.09	31	0.04	0.27	45	0.00	0.75	40	0.07	0.11	NA	NA	NA
<b>Atqasuk Dry (AD)</b>															
Evergreen Shrubs	48	0.04	0.18	48	<b>0.20</b>	<b>&lt;0.01</b>	48	<b>0.19</b>	<b>0.00</b>	48	0.06	0.10	NA	NA	NA
<i>Diapensia lapponica</i>	27	0.01	0.67	31	0.08	0.13	30	<b>0.20</b>	<b>0.01</b>	24	<b>0.25</b>	<b>0.01</b>	NA	NA	NA
<i>Vaccinium vitis-idaea</i>	46	<b>0.15</b>	<b>0.01</b>	37	0.03	0.27	44	0.06	0.10	46	<b>0.37</b>	<b>&lt;0.001</b>	NA	NA	NA

**Simple Linear Regression (SLR) results**

**BOLD = SIGNIFICANT**

- Across the AG plant variables correlated with cover differed by growth form (evergreen or deciduous)

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Wet (AW)</b>															
Deciduous Shrubs	26	0.09	0.13	32	0.04	0.29	45	0.00	0.82	40	0.06	0.11	NA	NA	NA
<i>Salix spp.</i>	26	0.12	0.09	31	0.04	0.27	45	0.00	0.75	40	0.07	0.11	NA	NA	NA
<b>Atqasuk Dry (AD)</b>															
Evergreen Shrubs	48	0.04	0.18	48	<b>0.20</b>	<b>&lt;0.01</b>	48	<b>0.19</b>	<b>0.00</b>	48	0.06	0.10	NA	NA	NA
<i>Diapensia lapponica</i>	27	0.01	0.67	31	0.08	0.13	30	<b>0.20</b>	<b>0.01</b>	24	<b>0.25</b>	<b>0.01</b>	NA	NA	NA
<i>Vaccinium vitis-idaea</i>	46	<b>0.15</b>	<b>0.01</b>	37	0.03	0.27	44	0.06	0.10	46	<b>0.37</b>	<b>&lt;0.001</b>	NA	NA	NA
<b>Atqasuk Grid (AG)</b>															
Deciduous Shrubs	NA	NA	NA	NA	NA	NA	20	<b>0.21</b>	<b>0.04</b>	16	0.23	0.06	NA	NA	NA
Evergreen Shrubs	NA	NA	NA	NA	NA	NA	20	0.08	0.22	21	<b>0.64</b>	<b>&lt;0.001</b>	NA	NA	NA

– Across the AG plant variables correlated with cover differed by growth form (evergreen or deciduous)

- Deciduous shrubs = Canopy height

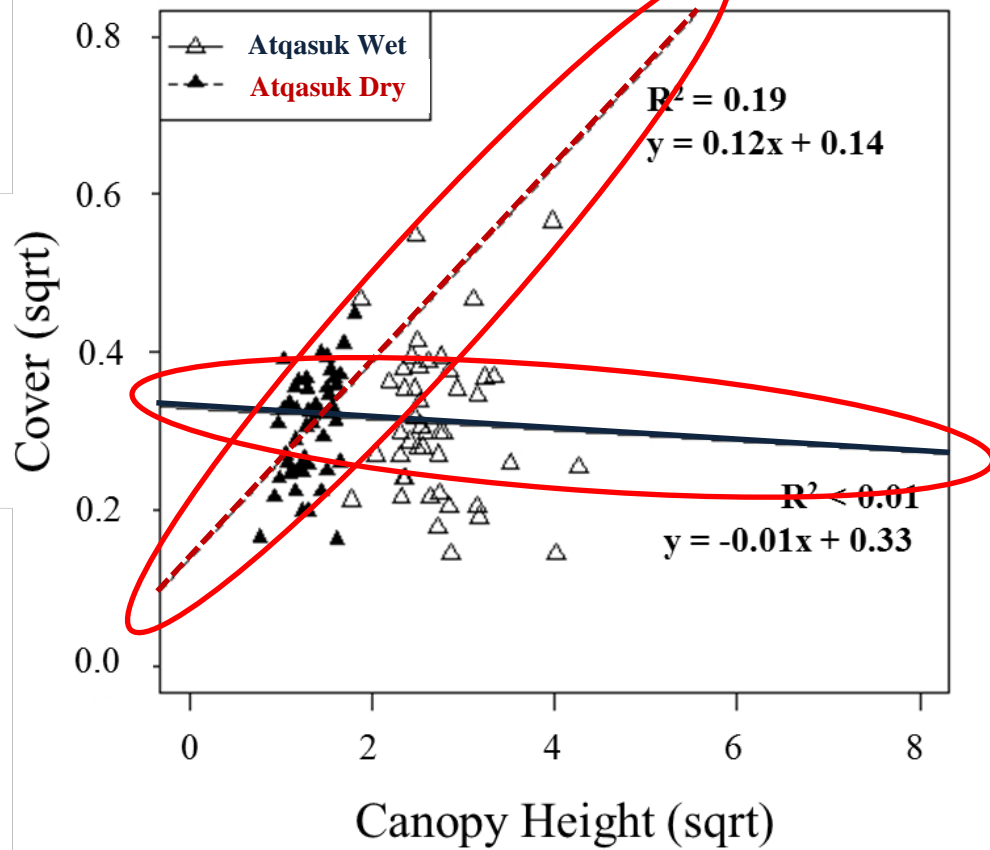
Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Wet (AW)</b>															
Deciduous Shrubs	26	0.09	0.13	32	0.04	0.29	45	0.00	0.82	40	0.06	0.11	NA	NA	NA
<i>Salix spp.</i>	26	0.12	0.09	31	0.04	0.27	45	0.00	0.75	40	0.07	0.11	NA	NA	NA
<b>Atqasuk Dry (AD)</b>															
Evergreen Shrubs	48	0.04	0.18	48	<b>0.20</b>	<b>&lt;0.01</b>	48	<b>0.19</b>	<b>0.00</b>	48	0.06	0.10	NA	NA	NA
<i>Diapensia lapponica</i>	27	0.01	0.67	31	0.08	0.13	30	<b>0.20</b>	<b>0.01</b>	24	<b>0.25</b>	<b>0.01</b>	NA	NA	NA
<i>Vaccinium vitis-idaea</i>	46	<b>0.15</b>	<b>0.01</b>	37	0.03	0.27	44	0.06	0.10	46	<b>0.37</b>	<b>&lt;0.001</b>	NA	NA	NA
<b>Atqasuk Grid (AG)</b>															
<u>Deciduous Shrubs</u>	NA	NA	NA	NA	NA	NA	20	<b>0.21</b>	<b>0.04</b>	16	0.23	0.06	NA	NA	NA
Evergreen Shrubs	NA	NA	NA	NA	NA	NA	20	0.08	0.22	21	<b>0.64</b>	<b>&lt;0.001</b>	NA	NA	NA



– Across the AG plant variables correlated with cover differed by growth form (evergreen or deciduous)

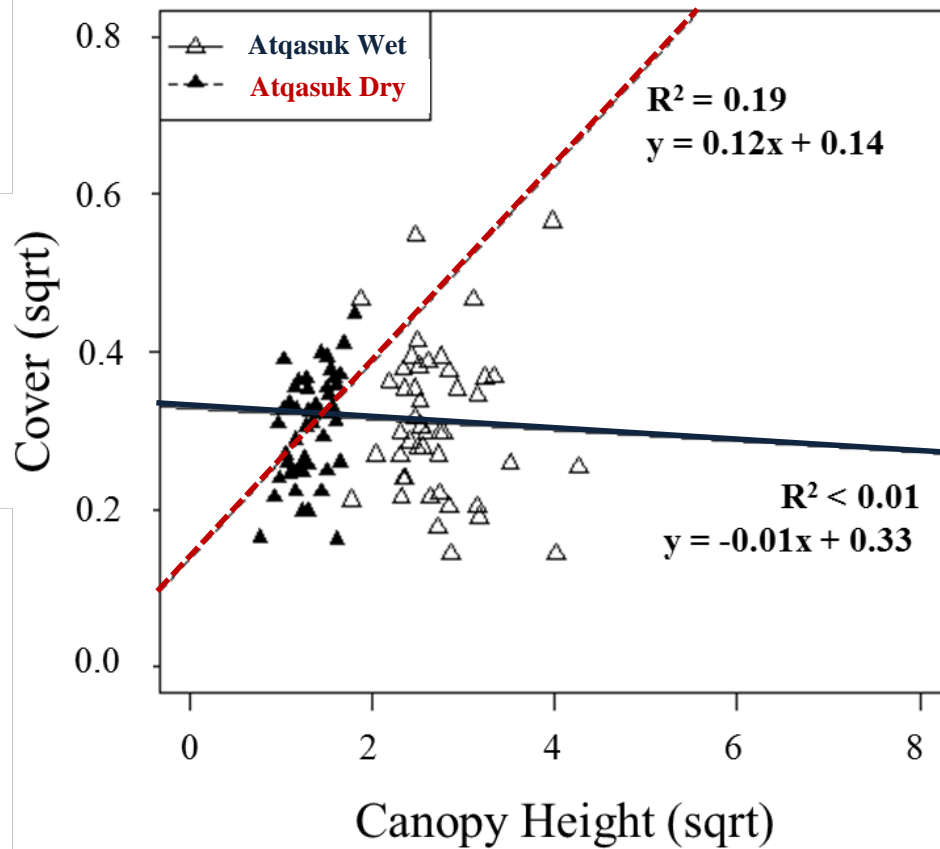
- Deciduous shrubs = Canopy height
- Evergreen shrubs = Density

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Wet (AW)</b>															
Deciduous Shrubs	26	0.09	0.13	32	0.04	0.29	45	0.00	0.82	40	0.06	0.11	NA	NA	NA
<i>Salix spp.</i>	26	0.12	0.09	31	0.04	0.27	45	0.00	0.75	40	0.07	0.11	NA	NA	NA
<b>Atqasuk Dry (AD)</b>															
Evergreen Shrubs	48	0.04	0.18	48	<b>0.20</b>	<b>&lt;0.01</b>	48	<b>0.19</b>	<b>0.00</b>	48	0.06	0.10	NA	NA	NA
<i>Diapensia lapponica</i>	27	0.01	0.67	31	0.08	0.13	30	<b>0.20</b>	<b>0.01</b>	24	<b>0.25</b>	<b>0.01</b>	NA	NA	NA
<i>Vaccinium vitis-idaea</i>	46	<b>0.15</b>	<b>0.01</b>	37	0.03	0.27	44	0.06	0.10	46	<b>0.37</b>	<b>&lt;0.001</b>	NA	NA	NA
<b>Atqasuk Grid (AG)</b>															
<u>Deciduous Shrubs</u>	NA	NA	NA	NA	NA	NA	20	<b>0.21</b>	<b>0.04</b>	16	0.23	0.06	NA	NA	NA
<u>Evergreen Shrubs</u>	NA	NA	NA	NA	NA	NA	20	0.08	0.22	21	<b>0.64</b>	<b>&lt;0.001</b>	NA	NA	NA



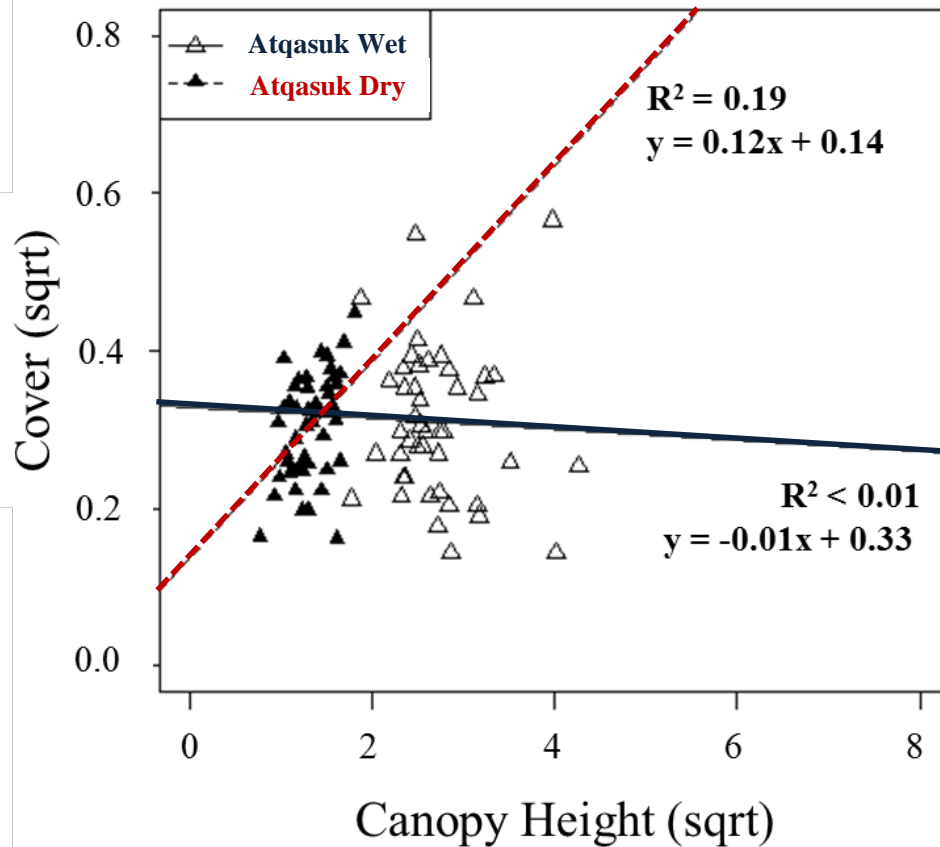
– Shrub canopy height was more highly correlated with shrub cover at the **AD** site than at the **AW** site

- Shrub cover at the **AW** site **not well described** by plant variables



– Shrub canopy height was more highly correlated with shrub cover at the **AD** site than at the **AW** site

- Shrub cover at the AW site **not well described** by plant variables
- **Plant variables** correlated with cover at the AD site were **canopy height & inflorescence length**



– Shrub canopy height was more highly correlated with shrub cover at the **AD** site than at the **AW** site

- Shrub cover at the AW site **not well described** by plant variables
- **Plant variables correlated with cover at the AD site were canopy height & inflorescence length**

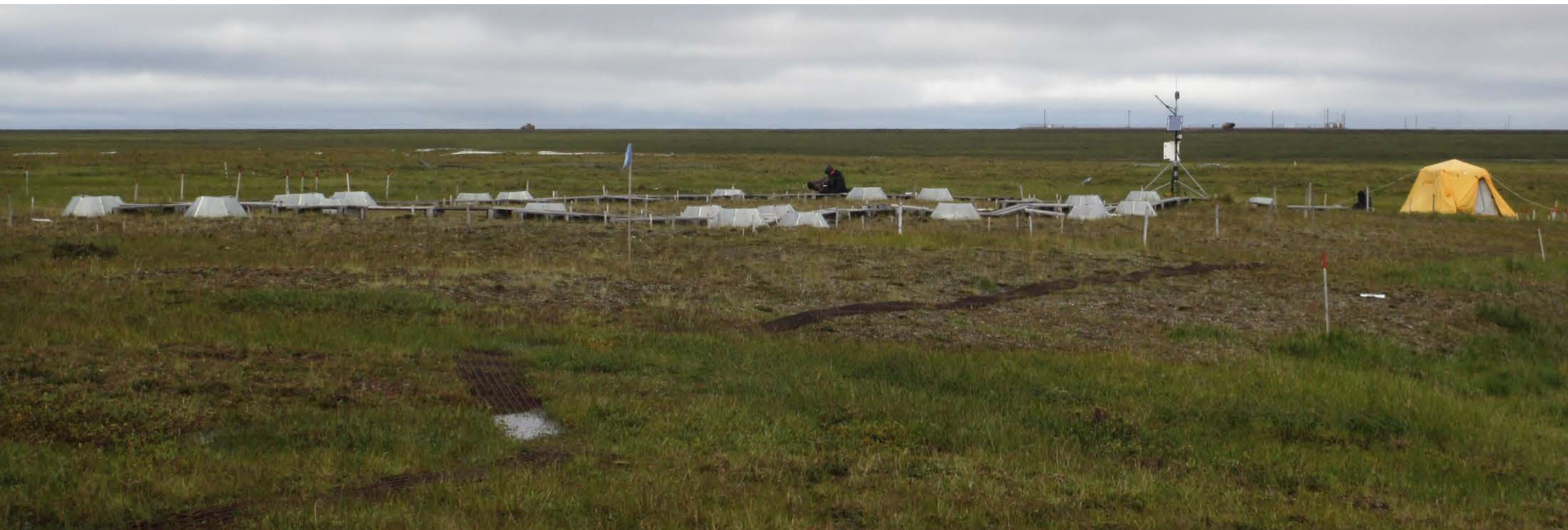
Variables that enhance canopy height particularly influential for shorter plants

# Results

1. Abiotic variables influence vegetation cover
2. Cover correlated with different vegetation variables depending on growth form
3. Experimental warming significantly impacted the relationships between cover & vegetation variables
4. Results for growth forms not always consistent with those of their constituent species

### 3. Experimental warming significantly impacted the relationships between cover & vegetation variables

- Treatment affected which plant variables correlated most strongly with cover



- Warming particularly impacted vegetation at the **AD** site

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Dry (AD)</b>															
Graminoids	46	0.03	0.21	45	0.01	0.51	46	<b>0.24</b>	<b>&lt;0.001</b>	44	0.07	0.09	46	0.02	0.33
Controls	23	<b>0.28</b>	<b>0.01</b>	23	0.11	0.12	23	0.15	0.07	21	0.04	0.38	23	0.09	0.16
Warmed	23	0.00	0.96	22	0.01	0.63	23	<b>0.27</b>	<b>0.01</b>	23	<b>0.21</b>	<b>0.03</b>	23	0.00	0.86
<i>Hierchloe alpina</i>	26	<b>0.18</b>	<b>0.03</b>	29	0.09	0.12	30	0.07	0.14	19	0.00	1.00	26	0.03	0.44
Controls	14	0.03	0.55	15	<b>0.38</b>	<b>0.02</b>	15	<b>0.29</b>	<b>0.04</b>	10	0.25	0.14	14	0.03	0.56
Warmed	12	<b>0.40</b>	<b>0.03</b>	14	0.00	0.85	15	0.00	0.93	9	0.31	0.12	12	0.02	0.66
<i>Luzula confusa</i>	39	<b>0.12</b>	<b>0.03</b>	35	0.11	0.06	37	0.07	0.10	32	0.02	0.41	39	0.00	0.81
Controls	21	0.11	0.14	18	0.05	0.36	20	0.07	0.25	17	0.00	0.95	21	0.13	0.11
Warmed	18	0.17	0.09	17	0.14	0.14	17	0.08	0.29	15	0.11	0.22	18	0.08	0.27
Evergreen Shrubs	48	0.04	0.18	48	<b>0.20</b>	<b>&lt;0.01</b>	48	<b>0.19</b>	<b>0.00</b>	48	0.06	0.10	NA	NA	NA
Controls	24	0.12	0.09	24	0.01	0.70	24	<b>0.25</b>	<b>0.01</b>	24	0.08	0.19	NA	NA	NA
Warmed	24	0.02	0.55	24	<b>0.44</b>	<b>&lt;0.001</b>	24	0.11	0.11	24	0.03	0.45	NA	NA	NA
<i>Diapensia lapponica</i>	27	0.01	0.67	31	0.08	0.13	30	<b>0.20</b>	<b>0.01</b>	24	<b>0.25</b>	<b>0.01</b>	NA	NA	NA
Controls	12	0.18	0.17	14	0.01	0.79	14	0.26	0.06	9	<b>0.46</b>	<b>0.05</b>	NA	NA	NA
Warmed	15	0.07	0.34	17	0.13	0.15	16	0.13	0.18	15	0.11	0.22	NA	NA	NA
<i>Vaccinium vitis-idaea</i>	46	<b>0.15</b>	<b>0.01</b>	37	0.03	0.27	44	0.06	0.10	46	<b>0.37</b>	<b>&lt;0.001</b>	NA	NA	NA
Controls	22	0.07	0.25	21	0.10	0.17	21	<b>0.27</b>	<b>0.02</b>	22	<b>0.33</b>	<b>&lt;0.01</b>	NA	NA	NA
Warmed	24	<b>0.25</b>	<b>0.01</b>	16	0.01	0.74	23	0.03	0.43	24	<b>0.47</b>	<b>&lt;0.001</b>	NA	NA	NA

Simple Linear Regression (SLR) results

BOLD = SIGNIFICANT

- Warming particularly impacted vegetation at the **AD** site

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Dry (AD)</b>															
Graminoids	46	0.03	0.21	45	0.01	0.51	46	<b>0.24</b>	<b>&lt;0.001</b>	44	0.07	0.09	46	0.02	0.33
Controls	23	<b>0.28</b>	<b>0.01</b>	23	0.11	0.12	23	0.15	0.07	21	0.04	0.38	23	0.09	0.16
Warmed	23	0.00	0.96	22	0.01	0.63	23	<b>0.27</b>	<b>0.01</b>	23	<b>0.21</b>	<b>0.03</b>	23	0.00	0.86
<i>Hierachloe alpina</i>	26	<b>0.18</b>	<b>0.03</b>	29	0.09	0.12	30	0.07	0.14	19	0.00	1.00	26	0.03	0.44
Controls	14	0.03	0.55	15	<b>0.38</b>	<b>0.02</b>	15	<b>0.29</b>	<b>0.04</b>	10	0.25	0.14	14	0.03	0.56
Warmed	12	<b>0.40</b>	<b>0.03</b>	14	0.00	0.85	15	0.00	0.93	9	0.31	0.12	12	0.02	0.66
<i>Luzula confusa</i>	39	<b>0.12</b>	<b>0.03</b>	35	0.11	0.06	37	0.07	0.10	32	0.02	0.41	39	0.00	0.81
Controls	21	0.11	0.14	18	0.05	0.36	20	0.07	0.25	17	0.00	0.95	21	0.13	0.11
Warmed	18	0.17	0.09	17	0.14	0.14	17	0.08	0.29	15	0.11	0.22	18	0.08	0.27
Evergreen Shrubs	48	0.04	0.18	48	<b>0.20</b>	<b>&lt;0.01</b>	48	<b>0.19</b>	<b>0.00</b>	48	0.06	0.10	NA	NA	NA
Controls	24	0.12	0.09	24	0.01	0.70	24	<b>0.25</b>	<b>0.01</b>	24	0.08	0.19	NA	NA	NA
Warmed	24	0.02	0.55	24	<b>0.44</b>	<b>&lt;0.001</b>	24	0.11	0.11	24	0.03	0.45	NA	NA	NA
<i>Diapensia lapponica</i>	27	0.01	0.67	31	0.08	0.13	30	<b>0.20</b>	<b>0.01</b>	24	<b>0.25</b>	<b>0.01</b>	NA	NA	NA
Controls	12	0.18	0.17	14	0.01	0.79	14	0.26	0.06	9	<b>0.46</b>	<b>0.05</b>	NA	NA	NA
Warmed	15	0.07	0.34	17	0.13	0.15	16	0.13	0.18	15	0.11	0.22	NA	NA	NA
<i>Vaccinium vitis-idaea</i>	46	<b>0.15</b>	<b>0.01</b>	37	0.03	0.27	44	0.06	0.10	46	<b>0.37</b>	<b>&lt;0.001</b>	NA	NA	NA
Controls	22	0.07	0.25	21	0.10	0.17	21	<b>0.27</b>	<b>0.02</b>	22	<b>0.33</b>	<b>&lt;0.01</b>	NA	NA	NA
Warmed	24	<b>0.25</b>	<b>0.01</b>	16	0.01	0.74	23	0.03	0.43	24	<b>0.47</b>	<b>&lt;0.001</b>	NA	NA	NA

Simple Linear Regression (SLR) results

**BOLD = SIGNIFICANT**



- Warming particularly impacted vegetation at the **AD** site

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Dry (AD)</b>															
Graminoids	46	0.03	0.21	45	0.01	0.51	46	<b>0.24</b>	<b>&lt;0.001</b>	44	0.07	0.09	46	0.02	0.33
Controls	23	<b>0.28</b>	<b>0.01</b>	23	0.11	0.12	23	<b>0.15</b>	<b>0.07</b>	21	<b>0.04</b>	<b>0.38</b>	23	0.09	0.16
Warmed	23	<b>0.00</b>	<b>0.96</b>	22	0.01	0.63	23	<b>0.27</b>	<b>0.01</b>	23	<b>0.21</b>	<b>0.03</b>	23	0.00	0.86
<i>Hierchloe alpina</i>	26	<b>0.18</b>	<b>0.03</b>	29	0.09	0.12	30	<b>0.07</b>	<b>0.14</b>	19	<b>0.00</b>	<b>1.00</b>	26	0.03	0.44
Controls	14	0.03	0.55	15	<b>0.38</b>	<b>0.02</b>	15	<b>0.29</b>	<b>0.04</b>	10	0.25	0.14	14	0.03	0.56
Warmed	12	<b>0.40</b>	<b>0.03</b>	14	<b>0.00</b>	<b>0.85</b>	15	<b>0.00</b>	<b>0.93</b>	9	0.31	0.12	12	0.02	0.66
<i>Luzula confusa</i>	39	<b>0.12</b>	<b>0.03</b>	35	0.11	0.06	37	<b>0.07</b>	<b>0.10</b>	32	0.02	0.41	39	0.00	0.81
Controls	21	0.11	0.14	18	0.05	0.36	20	<b>0.07</b>	<b>0.25</b>	17	<b>0.00</b>	<b>0.95</b>	21	0.13	0.11
Warmed	18	0.17	0.09	17	0.14	0.14	17	<b>0.08</b>	<b>0.29</b>	15	0.11	0.22	18	0.08	0.27
Evergreen Shrubs	48	0.04	0.18	48	<b>0.20</b>	<b>&lt;0.01</b>	48	<b>0.19</b>	<b>0.00</b>	48	0.06	0.10	NA	NA	NA
Controls	24	0.12	0.09	24	<b>0.01</b>	<b>0.70</b>	24	<b>0.25</b>	<b>0.01</b>	24	0.08	0.19	NA	NA	NA
Warmed	24	0.02	0.55	24	<b>0.44</b>	<b>&lt;0.001</b>	24	<b>0.11</b>	<b>0.11</b>	24	0.03	0.45	NA	NA	NA
<i>Diapensia lapponica</i>	27	0.01	0.67	31	0.08	0.13	30	<b>0.20</b>	<b>0.01</b>	24	<b>0.25</b>	<b>0.01</b>	NA	NA	NA
Controls	12	0.18	0.17	14	0.01	0.79	14	0.26	0.06	9	<b>0.46</b>	<b>0.05</b>	NA	NA	NA
Warmed	15	0.07	0.34	17	0.13	0.15	16	0.13	0.18	15	<b>0.11</b>	<b>0.22</b>	NA	NA	NA
<i>Vaccinium vitis-idaea</i>	46	<b>0.15</b>	<b>0.01</b>	37	0.03	0.27	44	0.06	0.10	46	<b>0.37</b>	<b>&lt;0.001</b>	NA	NA	NA
Controls	22	<b>0.07</b>	<b>0.25</b>	21	0.10	0.17	21	<b>0.27</b>	<b>0.02</b>	22	<b>0.33</b>	<b>&lt;0.01</b>	NA	NA	NA
Warmed	24	<b>0.25</b>	<b>0.01</b>	16	0.01	0.74	23	<b>0.03</b>	<b>0.43</b>	24	<b>0.47</b>	<b>&lt;0.001</b>	NA	NA	NA

Simple Linear Regression (SLR) results

BOLD = SIGNIFICANT

- More consistent response at the **AW** site

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Wet (AW)</b>															
Graminoids	48	<b>0.13</b>	<b>0.01</b>	47	0.02	0.31	48	<b>0.37</b>	<b>&lt;0.001</b>	48	0.00	0.74	48	0.06	0.09
Controls	24	<b>0.16</b>	<b>0.05</b>	24	0.00	0.78	24	<b>0.34</b>	<b>&lt;0.01</b>	24	0.02	0.56	24	0.04	0.34
Warmed	24	0.10	0.14	23	0.03	0.44	24	<b>0.31</b>	<b>0.01</b>	24	0.00	0.94	24	0.06	0.24
<i>Carex aquatilis</i>	48	<b>0.23</b>	<b>&lt;0.001</b>	35	0.06	0.15	48	<b>0.42</b>	<b>&lt;0.001</b>	48	0.00	0.93	48	<b>0.16</b>	<b>0.01</b>
Controls	24	0.09	0.15	19	0.00	0.88	24	<b>0.47</b>	<b>&lt;0.001</b>	24	0.11	0.12	24	0.05	0.30
Warmed	24	<b>0.23</b>	<b>0.02</b>	16	0.05	0.43	24	<b>0.21</b>	<b>0.02</b>	24	0.01	0.73	24	<b>0.25</b>	<b>0.01</b>
<i>Eriophorum angustifolium</i>	40	0.02	0.36	32	0.06	0.18	44	0.01	0.47	41	0.08	0.07	40	0.03	0.27
Controls	20	0.01	0.63	16	0.00	0.81	22	0.00	0.76	21	0.15	0.08	20	0.02	0.55
Warmed	20	0.03	0.48	16	0.13	0.16	22	0.01	0.60	20	0.03	0.45	20	0.04	0.41
<i>Eriophorum russeolum</i> <sup>†</sup>	36	0.07	0.12	NA	NA	NA	42	0.04	0.21	40	0.08	0.08	36	0.02	0.45
Controls	19	0.15	0.10	NA	NA	NA	21	0.09	0.17	21	0.06	0.29	19	0.00	0.91
Warmed	17	0.03	0.49	NA	NA	NA	21	0.03	0.49	19	0.10	0.20	17	0.09	0.25
Deciduous Shrubs	26	0.09	0.13	32	0.04	0.29	45	0.00	0.82	40	0.06	0.11	NA	NA	NA
Controls	17	0.10	0.21	17	0.01	0.67	21	0.11	0.14	19	0.05	0.38	NA	NA	NA
Warmed	9	0.20	0.23	15	0.04	0.50	24	0.00	0.74	21	0.14	0.10	NA	NA	NA
<i>Salix spp.</i>	26	0.12	0.09	31	0.04	0.27	45	0.00	0.75	40	0.07	0.11	NA	NA	NA
Controls	17	0.15	0.13	16	0.01	0.67	21	0.12	0.12	19	0.05	0.36	NA	NA	NA
Warmed	9	0.20	0.23	15	0.04	0.50	24	0.00	0.74	21	0.14	0.10	NA	NA	NA

**Simple Linear Regression (SLR) results**

**BOLD = SIGNIFICANT**

- More consistent response at the **AW** site

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Wet (AW)</b>															
Graminoids	48	<b>0.13</b>	<b>0.01</b>	47	0.02	0.31	48	<b>0.37</b>	<b>&lt;0.001</b>	48	0.00	0.74	48	0.06	0.09
Controls	24	<b>0.16</b>	<b>0.05</b>	24	0.00	0.78	24	<b>0.34</b>	<b>&lt;0.01</b>	24	0.02	0.56	24	0.04	0.34
Warmed	24	0.10	0.14	23	0.03	0.44	24	<b>0.31</b>	<b>0.01</b>	24	0.00	0.94	24	0.06	0.24
<i>Carex aquatilis</i>	48	<b>0.23</b>	<b>&lt;0.001</b>	35	0.06	0.15	48	<b>0.42</b>	<b>&lt;0.001</b>	48	0.00	0.93	48	<b>0.16</b>	<b>0.01</b>
Controls	24	0.09	0.15	19	0.00	0.88	24	<b>0.47</b>	<b>&lt;0.001</b>	24	0.11	0.12	24	0.05	0.30
Warmed	24	<b>0.23</b>	<b>0.02</b>	16	0.05	0.43	24	<b>0.21</b>	<b>0.02</b>	24	0.01	0.73	24	<b>0.25</b>	<b>0.01</b>
<i>Eriophorum angustifolium</i>	40	0.02	0.36	32	0.06	0.18	44	0.01	0.47	41	0.08	0.07	40	0.03	0.27
Controls	20	0.01	0.63	16	0.00	0.81	22	0.00	0.76	21	0.15	0.08	20	0.02	0.55
Warmed	20	0.03	0.48	16	0.13	0.16	22	0.01	0.60	20	0.03	0.45	20	0.04	0.41
<i>Eriophorum russeolum</i> <sup>†</sup>	36	0.07	0.12	NA	NA	NA	42	0.04	0.21	40	0.08	0.08	36	0.02	0.45
Controls	19	0.15	0.10	NA	NA	NA	21	0.09	0.17	21	0.06	0.29	19	0.00	0.91
Warmed	17	0.03	0.49	NA	NA	NA	21	0.03	0.49	19	0.10	0.20	17	0.09	0.25
Deciduous Shrubs	26	0.09	0.13	32	0.04	0.29	45	0.00	0.82	40	0.06	0.11	NA	NA	NA
Controls	17	0.10	0.21	17	0.01	0.67	21	0.11	0.14	19	0.05	0.38	NA	NA	NA
Warmed	9	0.20	0.23	15	0.04	0.50	24	0.00	0.74	21	0.14	0.10	NA	NA	NA
<i>Salix spp.</i>	26	0.12	0.09	31	0.04	0.27	45	0.00	0.75	40	0.07	0.11	NA	NA	NA
Controls	17	0.15	0.13	16	0.01	0.67	21	0.12	0.12	19	0.05	0.36	NA	NA	NA
Warmed	9	0.20	0.23	15	0.04	0.50	24	0.00	0.74	21	0.14	0.10	NA	NA	NA

**Simple Linear Regression (SLR) results**

**BOLD = SIGNIFICANT**

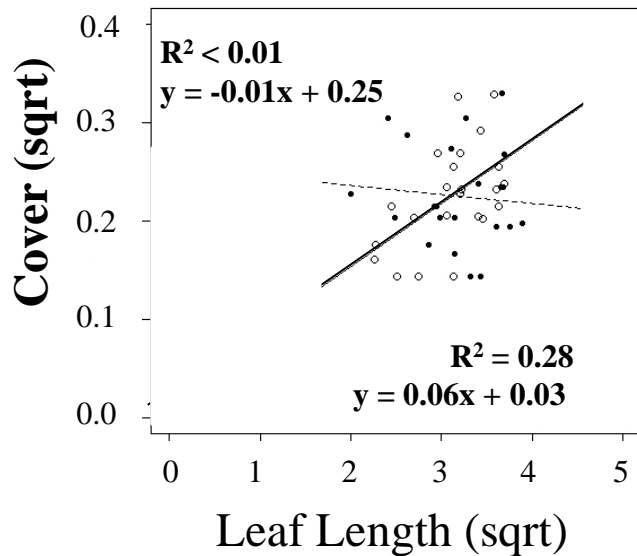
- More consistent response at the **AW** site

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Wet (AW)</b>															
Graminoids	48	<b>0.13</b>	<b>0.01</b>	47	0.02	0.31	48	<b>0.37</b>	<b>&lt;0.001</b>	48	0.00	0.74	48	0.06	0.09
Controls	24	<b>0.16</b>	<b>0.05</b>	24	0.00	0.78	24	<b>0.34</b>	<b>&lt;0.01</b>	24	0.02	0.56	24	0.04	0.34
Warmed	24	0.10	0.14	23	0.03	0.44	24	<b>0.31</b>	<b>0.01</b>	24	0.00	0.94	24	0.06	0.24
<i>Carex aquatilis</i>	48	<b>0.23</b>	<b>&lt;0.001</b>	35	0.06	0.15	48	<b>0.42</b>	<b>&lt;0.001</b>	48	0.00	0.93	48	<b>0.16</b>	<b>0.01</b>
Controls	24	0.09	0.15	19	0.00	0.88	24	<b>0.47</b>	<b>&lt;0.001</b>	24	0.11	0.12	24	0.05	0.30
Warmed	24	<b>0.23</b>	<b>0.02</b>	16	0.05	0.43	24	<b>0.21</b>	<b>0.02</b>	24	0.01	0.73	24	<b>0.25</b>	<b>0.01</b>
<i>Eriophorum angustifolium</i>	40	0.02	0.36	32	0.06	0.18	44	0.01	0.47	41	0.08	0.07	40	0.03	0.27
Controls	20	0.01	0.63	16	0.00	0.81	22	0.00	0.76	21	0.15	0.08	20	0.02	0.55
Warmed	20	0.03	0.48	16	0.13	0.16	22	0.01	0.60	20	0.03	0.45	20	0.04	0.41
<i>Eriophorum russeolum</i> <sup>†</sup>	36	0.07	0.12	NA	NA	NA	42	0.04	0.21	40	0.08	0.08	36	0.02	0.45
Controls	19	0.15	0.10	NA	NA	NA	21	0.09	0.17	21	0.06	0.29	19	0.00	0.91
Warmed	17	0.03	0.49	NA	NA	NA	21	0.03	0.49	19	0.10	0.20	17	0.09	0.25
Deciduous Shrubs	26	0.09	0.13	32	0.04	0.29	45	0.00	0.82	40	0.06	0.11	NA	NA	NA
Controls	17	0.10	0.21	17	0.01	0.67	21	0.11	0.14	19	0.05	0.38	NA	NA	NA
Warmed	9	0.20	0.23	15	0.04	0.50	24	0.00	0.74	21	0.14	0.10	NA	NA	NA
<i>Salix spp.</i>	26	0.12	0.09	31	0.04	0.27	45	0.00	0.75	40	0.07	0.11	NA	NA	NA
Controls	17	0.15	0.13	16	0.01	0.67	21	0.12	0.12	19	0.05	0.36	NA	NA	NA
Warmed	9	0.20	0.23	15	0.04	0.50	24	0.00	0.74	21	0.14	0.10	NA	NA	NA

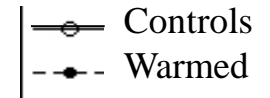
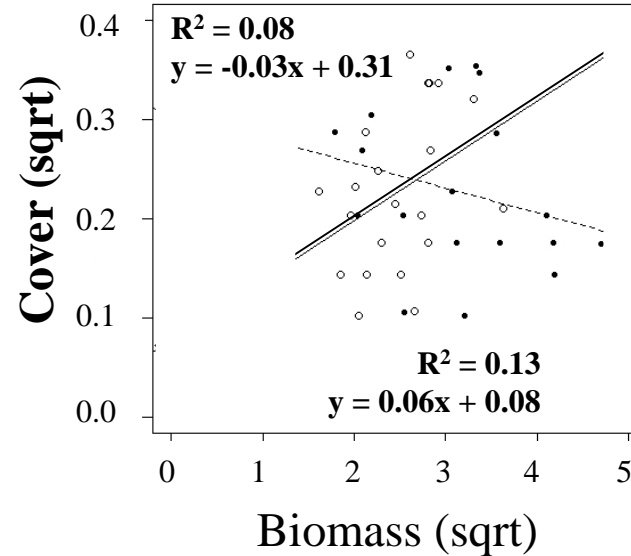
Simple Linear Regression (SLR) results

**BOLD = SIGNIFICANT**

a) Graminoids

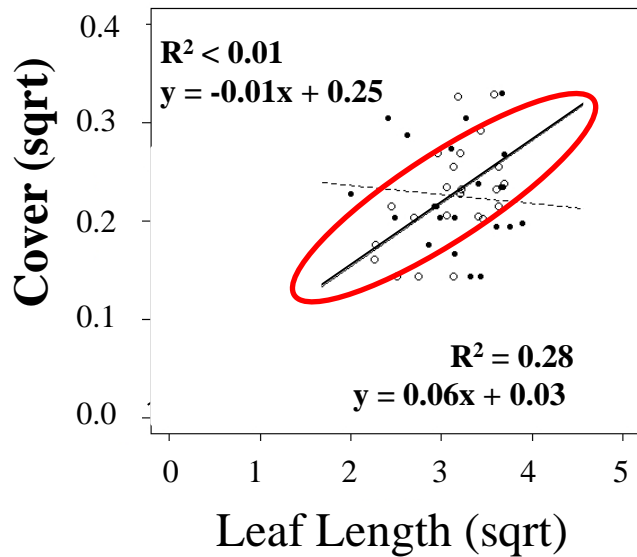


b) *Luzula confusa*

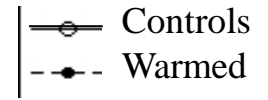
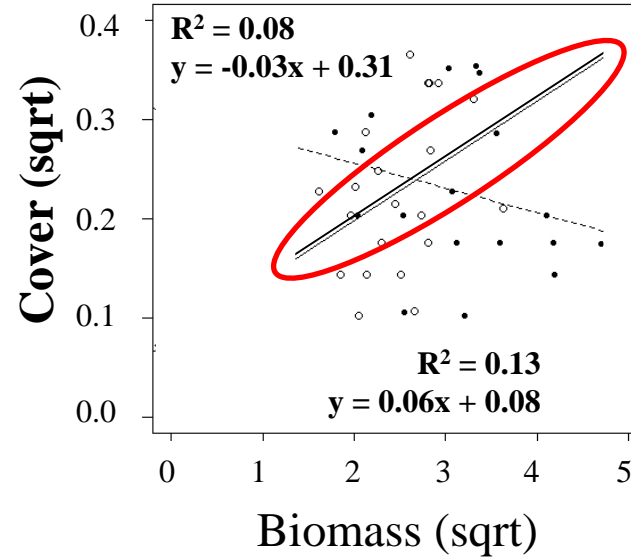


- Effect of warming at the **AD** site demonstrated by significantly different slopes
  - Graminoids – more responsive to temperature change

a) Graminoids



b) *Luzula confusa*



- **Growth traits** (Leaf Length & Biomass proxy) were more strongly correlated with cover in the **control plots** than in the warmed plots
  - Individuals within a species are adapted to different microclimates

**Control Plots  
(Normal Conditions)**



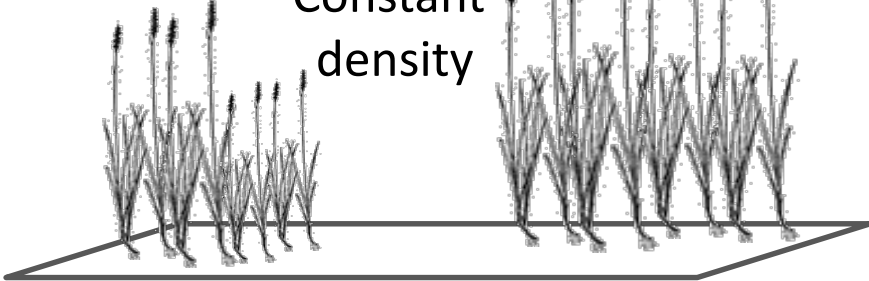
Smaller plants

Larger plants

**LOW  
Cover**

**HIGH  
Cover**

Constant  
density



**Treatment Plots  
(Experimental Warming)**



Many smaller  
plants

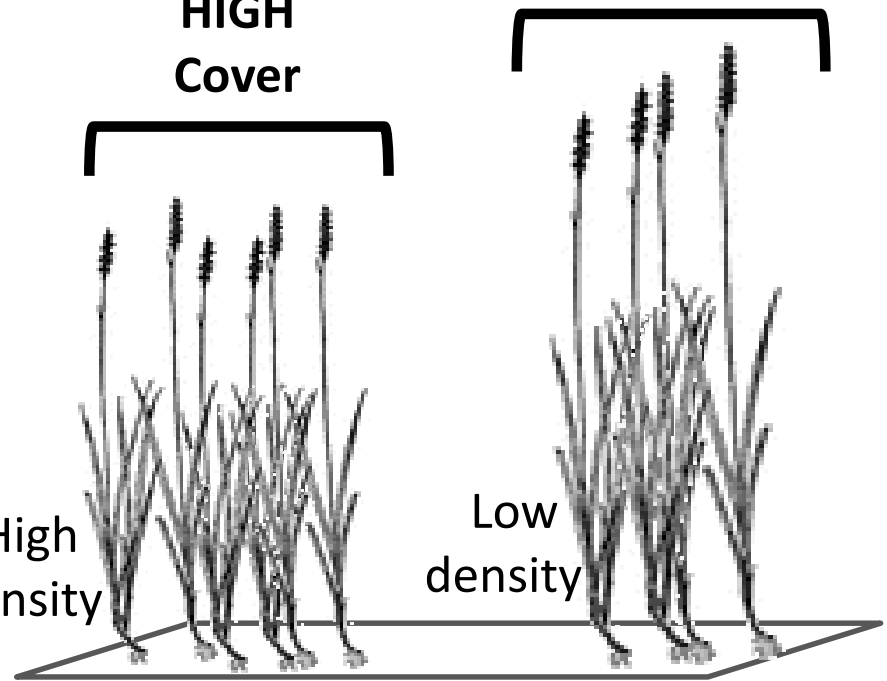
Few Large  
plants

**LOW  
Cover**

**HIGH  
Cover**

High  
density

Low  
density



# Results

1. Abiotic variables influence vegetation cover
2. Cover correlated with different vegetation variables depending on growth form
3. Experimental warming significantly impacted the relationships between cover & vegetation variables
4. Results for growth forms not always consistent with those of their constituent species



## 4. Results for growth forms not always consistent with those of their constituent species

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Grid (AG)</b>															
Graminoids	30	0.00	0.84	27	0.09	0.14	30	0.07	0.17	29	<b>0.24</b>	<b>0.01</b>	NA	NA	NA
<i>Carex spp.</i>	27	0.11	0.09	20	0.14	0.11	26	<b>0.32</b>	<b>&lt;0.01</b>	25	<b>0.22</b>	<b>0.02</b>	NA	NA	NA
<i>Eriophorum spp.</i>	21	0.01	0.65	15	<b>0.49</b>	<b>&lt;0.01</b>	24	0.03	0.46	21	0.11	0.15	NA	NA	NA
Deciduous Shrubs	NA	NA	NA	NA	NA	NA	20	<b>0.21</b>	<b>0.04</b>	16	0.23	0.06	NA	NA	NA
Evergreen Shrubs	NA	NA	NA	NA	NA	NA	20	0.08	0.22	21	<b>0.64</b>	<b>&lt;0.001</b>	NA	NA	NA
Forbs	NA	NA	NA	NA	NA	NA	14	0.02	0.59	14	0.01	0.73	NA	NA	NA

**Simple Linear Regression (SLR) results**

**BOLD = SIGNIFICANT**

- Graminoid results mirrored by *C. aquatilis*
  - Similar but insignificant trends for other species

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Wet (AW)</b>															
Graminoids	48	<b>0.13</b>	<b>0.01</b>	47	0.02	0.31	48	<b>0.37</b>	<b>&lt;0.001</b>	48	0.00	0.74	48	0.06	0.09
Controls	24	<b>0.16</b>	<b>0.05</b>	24	0.00	0.78	24	<b>0.34</b>	<b>&lt;0.01</b>	24	0.02	0.56	24	0.04	0.34
Warmed	24	0.10	0.14	23	0.03	0.44	24	<b>0.31</b>	<b>0.01</b>	24	0.00	0.94	24	0.06	0.24
<i>Carex aquatilis</i>	48	<b>0.23</b>	<b>&lt;0.001</b>	35	0.06	0.15	48	<b>0.42</b>	<b>&lt;0.001</b>	48	0.00	0.93	48	<b>0.16</b>	<b>0.01</b>
Controls	24	0.09	0.15	19	0.00	0.88	24	<b>0.47</b>	<b>&lt;0.001</b>	24	0.11	0.12	24	0.05	0.30
Warmed	24	<b>0.23</b>	<b>0.02</b>	16	0.05	0.43	24	<b>0.21</b>	<b>0.02</b>	24	0.01	0.73	24	<b>0.25</b>	<b>0.01</b>
<i>Eriophorum angustifolium</i>	40	0.02	0.36	32	0.06	0.18	44	0.01	0.47	41	0.08	0.07	40	0.03	0.27
Controls	20	0.01	0.63	16	0.00	0.81	22	0.00	0.76	21	0.15	0.08	20	0.02	0.55
Warmed	20	0.03	0.48	16	0.13	0.16	22	0.01	0.60	20	0.03	0.45	20	0.04	0.41
<i>Eriophorum russeolum</i> <sup>†</sup>	36	0.07	0.12	NA	NA	NA	42	0.04	0.21	40	0.08	0.08	36	0.02	0.45
Controls	19	0.15	0.10	NA	NA	NA	21	0.09	0.17	21	0.06	0.29	19	0.00	0.91
Warmed	17	0.03	0.49	NA	NA	NA	21	0.03	0.49	19	0.10	0.20	17	0.09	0.25

**Simple Linear Regression (SLR) results**

**BOLD = SIGNIFICANT**

- Graminoid results mirrored by *C. aquatilis*
  - Similar but insignificant trends for other species

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Wet (AW)</b>															
Graminoids	48	<b>0.13</b>	<b>0.01</b>	47	0.02	0.31	48	<b>0.37</b>	<b>&lt;0.001</b>	48	0.00	0.74	48	0.06	0.09
Controls	24	<b>0.16</b>	<b>0.05</b>	24	0.00	0.78	24	<b>0.34</b>	<b>&lt;0.01</b>	24	0.02	0.56	24	0.04	0.34
Warmed	24	0.10	0.14	23	0.03	0.44	24	<b>0.31</b>	<b>0.01</b>	24	0.00	0.94	24	0.06	0.24
<i>Carex aquatilis</i>	48	<b>0.23</b>	<b>&lt;0.001</b>	35	0.06	0.15	48	<b>0.42</b>	<b>&lt;0.001</b>	48	0.00	0.93	48	<b>0.16</b>	<b>0.01</b>
Controls	24	0.09	0.15	19	0.00	0.88	24	<b>0.47</b>	<b>&lt;0.001</b>	24	0.11	0.12	24	0.05	0.30
Warmed	24	<b>0.23</b>	<b>0.02</b>	16	0.05	0.43	24	<b>0.21</b>	<b>0.02</b>	24	0.01	0.73	24	<b>0.25</b>	<b>0.01</b>
<i>Eriophorum angustifolium</i>	40	0.02	0.36	32	0.06	0.18	44	0.01	0.47	41	0.08	0.07	40	0.03	0.27
Controls	20	0.01	0.63	16	0.00	0.81	22	0.00	0.76	21	0.15	0.08	20	0.02	0.55
Warmed	20	0.03	0.48	16	0.13	0.16	22	0.01	0.60	20	0.03	0.45	20	0.04	0.41
<i>Eriophorum russeolum</i> <sup>†</sup>	36	0.07	0.12	NA	NA	NA	42	0.04	0.21	40	0.08	0.08	36	0.02	0.45
Controls	19	0.15	0.10	NA	NA	NA	21	0.09	0.17	21	0.06	0.29	19	0.00	0.91
Warmed	17	0.03	0.49	NA	NA	NA	21	0.03	0.49	19	0.10	0.20	17	0.09	0.25

**Simple Linear Regression (SLR) results**

**BOLD = SIGNIFICANT**

- Lots of variation between growth forms and species!!

– Analysis at species level crucial

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Dry (AD)</b>															
Graminoids	46	0.03	0.21	45	0.01	0.51	46	<b>0.24</b>	<b>&lt;0.001</b>	44	0.07	0.09	46	0.02	0.33
Controls	23	<b>0.28</b>	<b>0.01</b>	23	0.11	0.12	23	0.15	0.07	21	0.04	0.38	23	0.09	0.16
Warmed	23	0.00	0.96	22	0.01	0.63	23	<b>0.27</b>	<b>0.01</b>	23	<b>0.21</b>	<b>0.03</b>	23	0.00	0.86
<i>Hierachloe alpina</i>	26	<b>0.18</b>	<b>0.03</b>	29	0.09	0.12	30	0.07	0.14	19	0.00	1.00	26	0.03	0.44
Controls	14	0.03	0.55	15	<b>0.38</b>	<b>0.02</b>	15	<b>0.29</b>	<b>0.04</b>	10	0.25	0.14	14	0.03	0.56
Warmed	12	<b>0.40</b>	<b>0.03</b>	14	0.00	0.85	15	0.00	0.93	9	0.31	0.12	12	0.02	0.66
<i>Luzula confusa</i>	39	<b>0.12</b>	<b>0.03</b>	35	0.11	0.06	37	0.07	0.10	32	0.02	0.41	39	0.00	0.81
Controls	21	0.11	0.14	18	0.05	0.36	20	0.07	0.25	17	0.00	0.95	21	0.13	0.11
Warmed	18	0.17	0.09	17	0.14	0.14	17	0.08	0.29	15	0.11	0.22	18	0.08	0.27
Evergreen Shrubs	48	0.04	0.18	48	<b>0.20</b>	<b>&lt;0.01</b>	48	<b>0.19</b>	<b>0.00</b>	48	0.06	0.10	NA	NA	NA
Controls	24	0.12	0.09	24	0.01	0.70	24	<b>0.25</b>	<b>0.01</b>	24	0.08	0.19	NA	NA	NA
Warmed	24	0.02	0.55	24	<b>0.44</b>	<b>&lt;0.001</b>	24	0.11	0.11	24	0.03	0.45	NA	NA	NA
<i>Diapensia lapponica</i>	27	0.01	0.67	31	0.08	0.13	30	<b>0.20</b>	<b>0.01</b>	24	<b>0.25</b>	<b>0.01</b>	NA	NA	NA
Controls	12	0.18	0.17	14	0.01	0.79	14	0.26	0.06	9	<b>0.46</b>	<b>0.05</b>	NA	NA	NA
Warmed	15	0.07	0.34	17	0.13	0.15	16	0.13	0.18	15	0.11	0.22	NA	NA	NA
<i>Vaccinium vitis-idaea</i>	46	<b>0.15</b>	<b>0.01</b>	37	0.03	0.27	44	0.06	0.10	46	<b>0.37</b>	<b>&lt;0.001</b>	NA	NA	NA
Controls	22	0.07	0.25	21	0.10	0.17	21	<b>0.27</b>	<b>0.02</b>	22	<b>0.33</b>	<b>&lt;0.01</b>	NA	NA	NA
Warmed	24	<b>0.25</b>	<b>0.01</b>	16	0.01	0.74	23	0.03	0.43	24	<b>0.47</b>	<b>&lt;0.001</b>	NA	NA	NA

- Lots of variation between growth forms and species!!

– Analysis at species level crucial

Growth Form/Taxa	Leaf Length			Inflorescence Length			Canopy Height			Density			Biomass		
	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value	n	R <sup>2</sup>	p value
<b>Atqasuk Dry (AD)</b>															
Graminoids	46	0.03	0.21	45	0.01	0.51	46	<b>0.24</b>	<b>&lt;0.001</b>	44	0.07	0.09	46	0.02	0.33
Controls	23	<b>0.28</b>	<b>0.01</b>	23	0.11	0.12	23	0.15	0.07	21	0.04	0.38	23	0.09	0.16
Warmed	23	0.00	0.96	22	0.01	0.63	23	<b>0.27</b>	<b>0.01</b>	23	<b>0.21</b>	<b>0.03</b>	23	0.00	0.86
<u><i>Hierachloe alpina</i></u>	26	<b>0.18</b>	<b>0.03</b>	29	0.09	0.12	30	0.07	0.14	19	0.00	1.00	26	0.03	0.44
Controls	14	0.03	0.55	15	<b>0.38</b>	<b>0.02</b>	15	<b>0.29</b>	<b>0.04</b>	10	0.25	0.14	14	0.03	0.56
Warmed	12	<b>0.40</b>	<b>0.03</b>	14	0.00	0.85	15	0.00	0.93	9	0.31	0.12	12	0.02	0.66
<u><i>Luzula confusa</i></u>	39	<b>0.12</b>	<b>0.03</b>	35	0.11	0.06	37	0.07	0.10	32	0.02	0.41	39	0.00	0.81
Controls	21	0.11	0.14	18	0.05	0.36	20	0.07	0.25	17	0.00	0.95	21	0.13	0.11
Warmed	18	0.17	0.09	17	0.14	0.14	17	0.08	0.29	15	0.11	0.22	18	0.08	0.27
Evergreen Shrubs	48	0.04	0.18	48	<b>0.20</b>	<b>&lt;0.01</b>	48	<b>0.19</b>	<b>0.00</b>	48	0.06	0.10	NA	NA	NA
Controls	24	0.12	0.09	24	0.01	0.70	24	<b>0.25</b>	<b>0.01</b>	24	0.08	0.19	NA	NA	NA
Warmed	24	0.02	0.55	24	<b>0.44</b>	<b>&lt;0.001</b>	24	0.11	0.11	24	0.03	0.45	NA	NA	NA
<u><i>Diapensia lapponica</i></u>	27	0.01	0.67	31	0.08	0.13	30	<b>0.20</b>	<b>0.01</b>	24	<b>0.25</b>	<b>0.01</b>	NA	NA	NA
Controls	12	0.18	0.17	14	0.01	0.79	14	0.26	0.06	9	<b>0.46</b>	<b>0.05</b>	NA	NA	NA
Warmed	15	0.07	0.34	17	0.13	0.15	16	0.13	0.18	15	0.11	0.22	NA	NA	NA
<u><i>Vaccinium vitis-idaea</i></u>	46	<b>0.15</b>	<b>0.01</b>	37	0.03	0.27	44	0.06	0.10	46	<b>0.37</b>	<b>&lt;0.001</b>	NA	NA	NA
Controls	22	0.07	0.25	21	0.10	0.17	21	<b>0.27</b>	<b>0.02</b>	22	<b>0.33</b>	<b>&lt;0.01</b>	NA	NA	NA
Warmed	24	<b>0.25</b>	<b>0.01</b>	16	0.01	0.74	23	0.03	0.43	24	<b>0.47</b>	<b>&lt;0.001</b>	NA	NA	NA

# Conclusions

- Plant cover is related to structural processes which may vary
  1. Across growth forms and species
  2. Across community types
  3. With experimental warming
- Abiotic conditions may impact relationships between cover and vegetation traits



# Conclusions

- Continued research at the landscape level is needed
  - Provide a better understanding of how vegetation responds to climate warming and the potential far-reaching ecosystem consequences



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  - Timothy Botting
  - Andrew Smith
  - Michaela Clingaman
  - Raul Armendariz
  - Mayra Melendez





# Questions?





# Future Directions

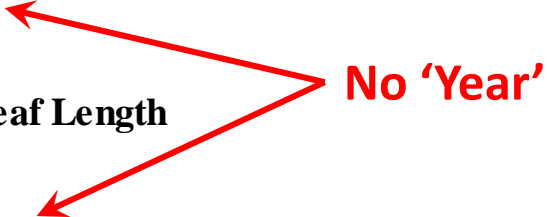
1. Distinguish plant traits that would more effectively capture structural changes occurring in shrubs
  - How might this impact shrub expansion in the Arctic?
2. Document the impact of nonvascular cover
3. Monitor canopy structural changes across the landscape
  - Identify broad-scale change with continued warming

- Multiple linear regression analysis was used to determine if ‘year’ significantly impacted relationships between cover and plant variables
  - ‘Year’ was never significant, so only measurements from 2012 were used for additional analysis across the AG

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Growth Form/Taxa	n	R <sup>2</sup> (adj.)	p value	Variables Strongly Correlated with Cover
<b>Atqasuk Grid (AG)</b>				
Graminoids	26	0.18	0.02	<b>Density</b>
<i>Carex spp.</i>	19	0.28	0.03	Density, Canopy height
<i>Eriophorum spp.</i>	14	0.60	<0.01	<b>Inflorescence length, Leaf Length</b>
Deciduous Shrubs	16	0.37	0.02	<b>Canopy height, Density</b>
Evergreen Shrubs	19	0.59	<0.001	<b>Density</b>

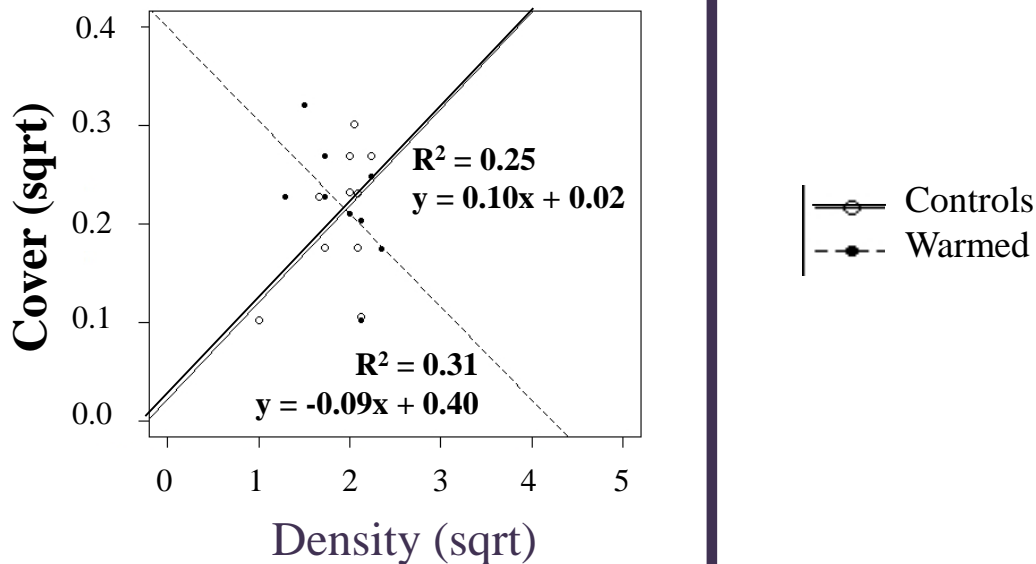
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- **Density** more important to cover of *H. alpina* in the **control plots**

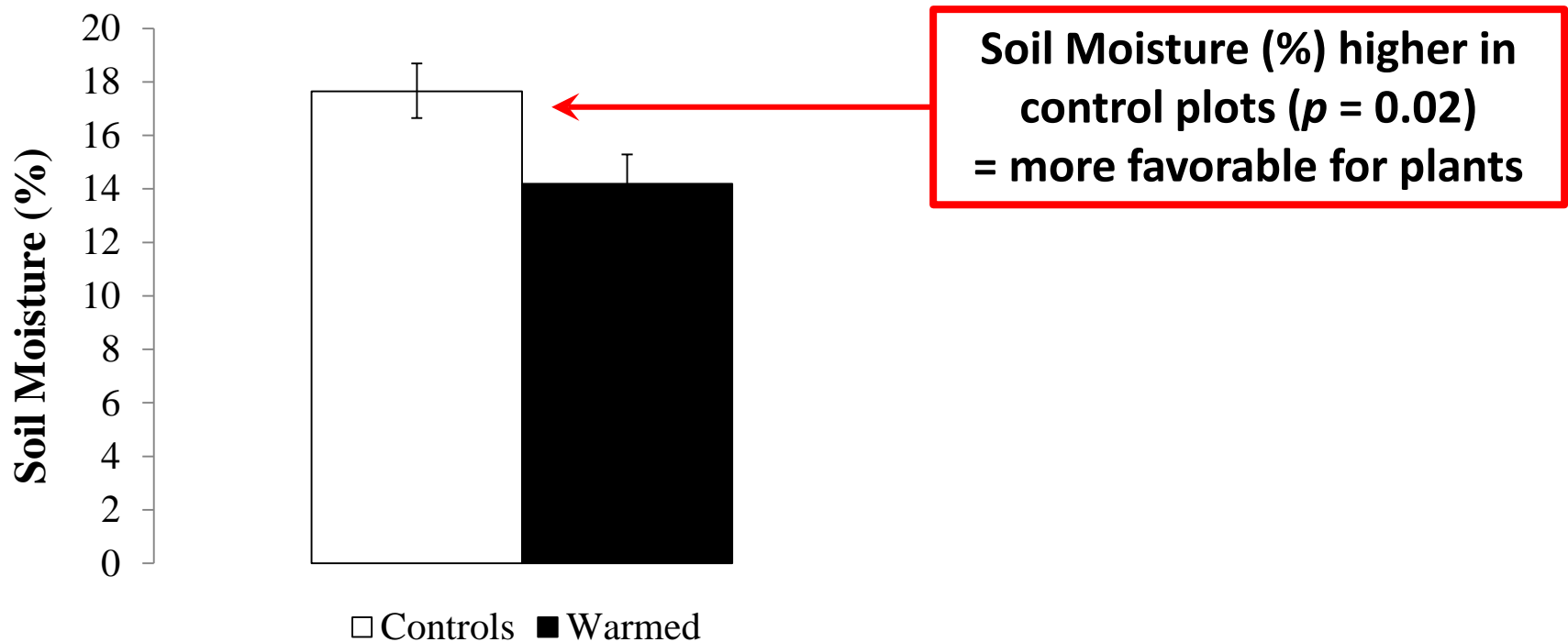
- Difficult to explain biologically
- Controls: More plants = Higher cover
- Warmed: More plants = Lower cover (?)

c) *Hierachloe alpina*



- Smaller plants in warmed plots = lower cover (?)
- **Not supported by plant measurements for this species**

- Experimental warming at the AD site may also have caused water stress conditions
  - Making conditions unfavorable for growth of some species



- Treatment significantly impacted which plant variables correlated with cover

Growth Form/Taxa	n	R <sup>2</sup> (adj.)	p value	Variables Strongly Correlated with Cover
<b>Atqasuk Wet (AW)</b>				
Graminoids	47	0.42	<0.001	<b>Canopy height, Treatment</b>
<i>Carex aquatilis</i>	35	0.46	<0.001	<b>Canopy height, Treatment, Inflorescence length, Leaf length</b>
<i>Eriophorum russeolum</i>	35	0.22	0.01	<b>Leaf length, Density, Canopy height</b>
<b>Atqasuk Dry (AD)</b>				
Evergreen Shrubs	48	0.25	<0.001	<b>Inflorescence length, Canopy height</b>
<i>Vaccinium vitis-idaea</i>	35	0.46	<0.001	<b>Density, Leaf length, Canopy height</b>
Graminoids	43	0.18	0.01	<b>Canopy height, Inflorescence length, Treatment</b>

**Multiple Linear Regression (MLR) results**

**BOLD = SIGNIFICANT**

- Treatment significantly impacted which plant variables correlated with cover

Growth Form/Taxa	n	R <sup>2</sup> (adj.)	p value	Variables Strongly Correlated with Cover
<b>Atqasuk Wet (AW)</b>				
Graminoids	47	0.42	<0.001	Canopy height, Treatment
<i>Carex aquatilis</i>	35	0.46	<0.001	Canopy height, Treatment, Inflorescence length, Leaf length
<i>Eriophorum russeolum</i>	35	0.22	0.01	Leaf length, Density, Canopy height
<b>Atqasuk Dry (AD)</b>				
Evergreen Shrubs	48	0.25	<0.001	Inflorescence length, Canopy height
<i>Vaccinium vitis-idaea</i>	35	0.46	<0.001	Density, Leaf length, Canopy height
Graminoids	43	0.18	0.01	Canopy height, Inflorescence length, Treatment

- Relationships were subsequently analyzed by separating controls and warmed plots