

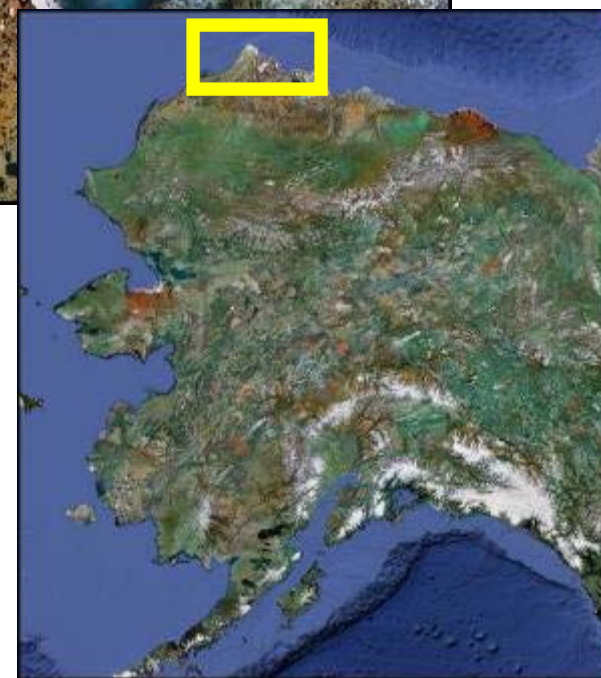
Warming the Tundra: Changes in Cover of Species Groups

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Grand Valley State University



Climate Change: Impacts on the Arctic





Site Locations



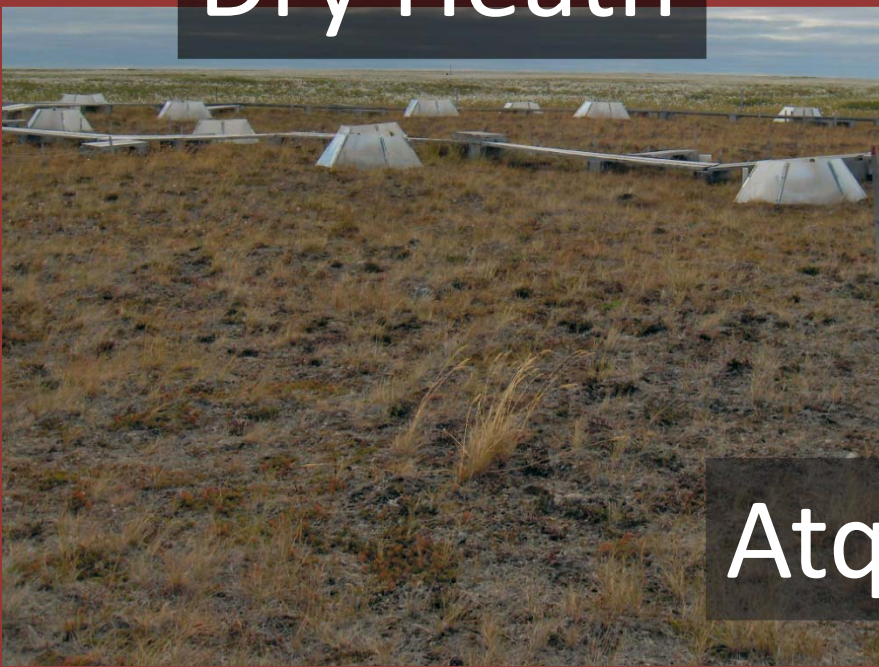


Dry Heath

Barrow



Wet Meadow



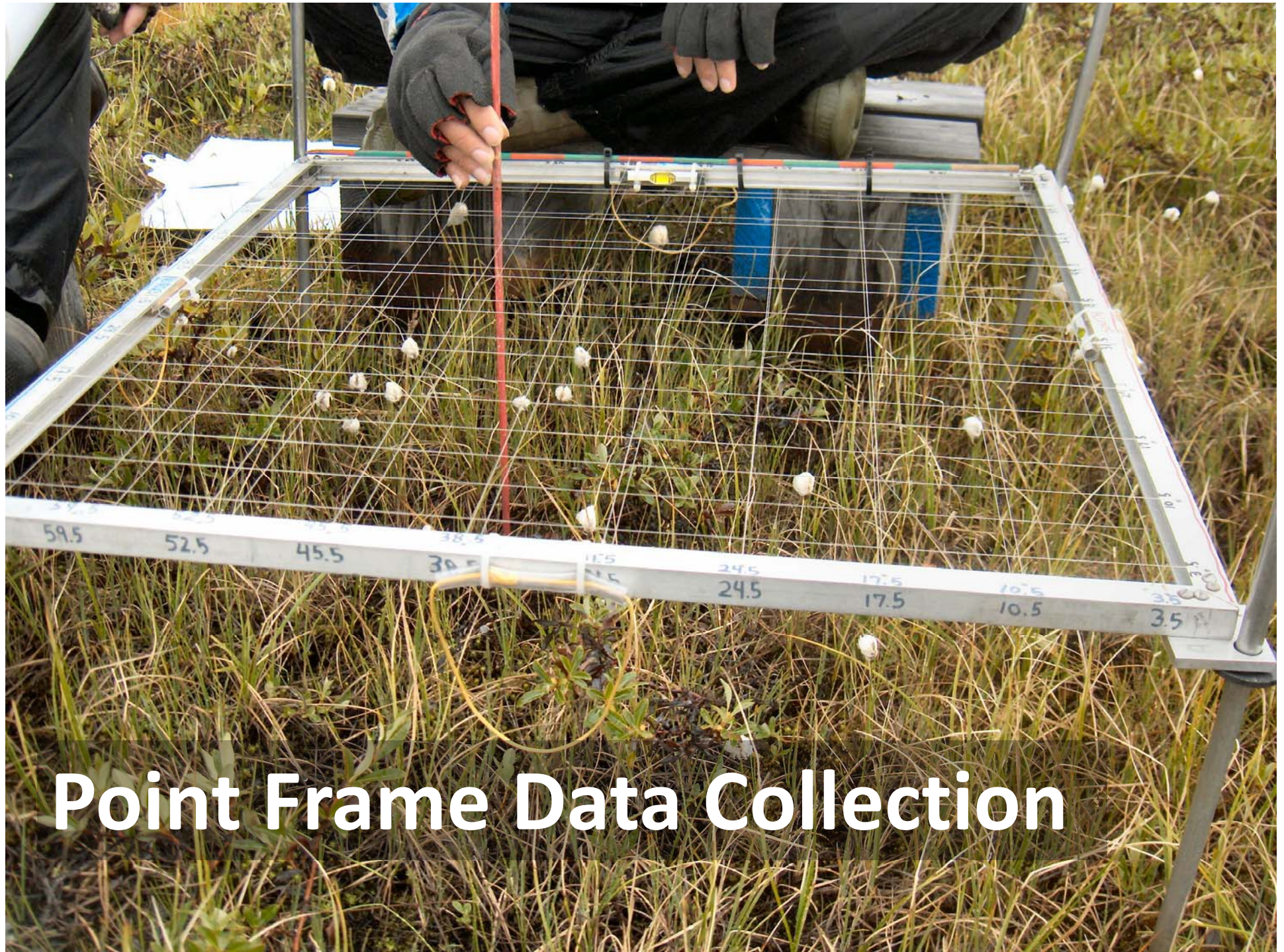
Atqasuk



Warming Treatment

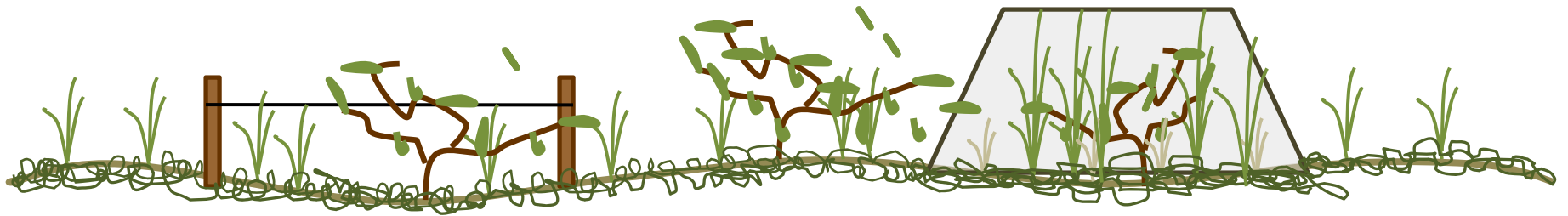
↑1° - 3°C





Point Frame Data Collection

How does cover change?



- Warming results in an increase in cover
(driven by the increase in the Barrow Dry Site)
- Increase in litter and standing dead
- Decrease in mosses and lichens
- Even if there is no net change, there are increases in some species and decreases in others
- How can we predict response?



Summary of Current Investigation

	Young Zones <i>Young 1971</i>	42/72	High Arctic / Low Arctic <i>Gould and Walker 1999</i>	40/72	Biome Distribution	54/72	Latitudinal Distribution <i>Hultén 1968</i>	72/72	Longitudinal Distribution <i>Hultén 1968</i>	72/72	Alaskan Distribution <i>Hultén 1968</i>	72/72	Greenland Distribution <i>Sørensen 1941</i>	41/72	Family	72/72	Monocot/Dicot	72/72	TDD _{sm} / Julian Day <i>Hollister 2003</i>	10/72	Rainkær's Life Forms <i>Sørensen 1941</i>	41/72	Thawing Type <i>Sørensen 1941</i>	41/72	Wintering State of Leaves <i>Sørensen 1941</i>	41/72	Wintering State of Buds <i>Sørensen 1941</i>	41/72	Floral Wintering Stage <i>Sørensen 1941</i>	41/72	Early / Late Leaf Bud Burst <i>ITEX phenology data</i>	52/72	Early / Late Flower Burst <i>ITEX phenology data</i>	39/72
All Sites Combined			*		.						*		*																					
Barrow Wet													*																		*		.	
Barrow Dry	*		*		.				*		*			*											*	*								
Atqasuk Wet							.				*		*												*			*						
Atqasuk Dry													*						.				.											

*p<.05, ·p<.10



Sørensen's Greenland Distribution

Species classified by their distribution in
Greenland

NN: Distinct southern limit, no northern limit

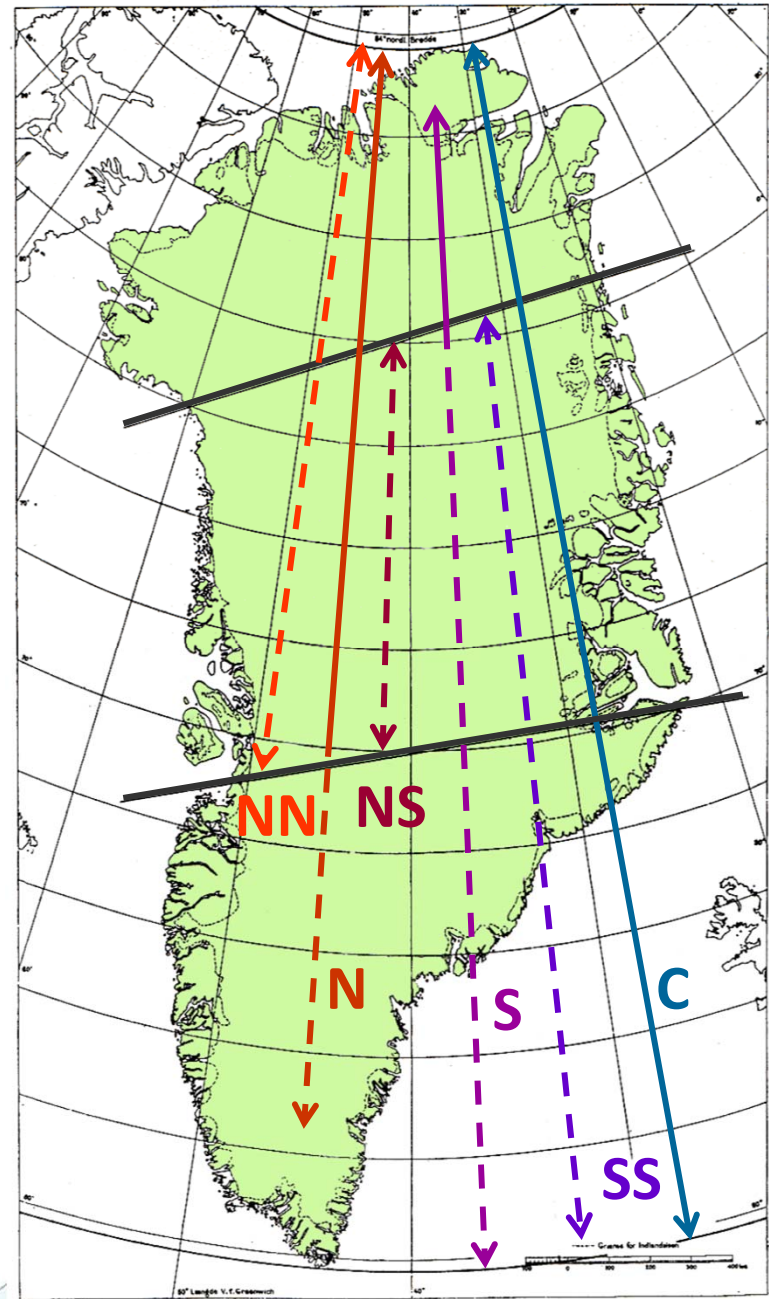
N: No distinct limits, present mostly in north

NS: Distinct northern and southern limits

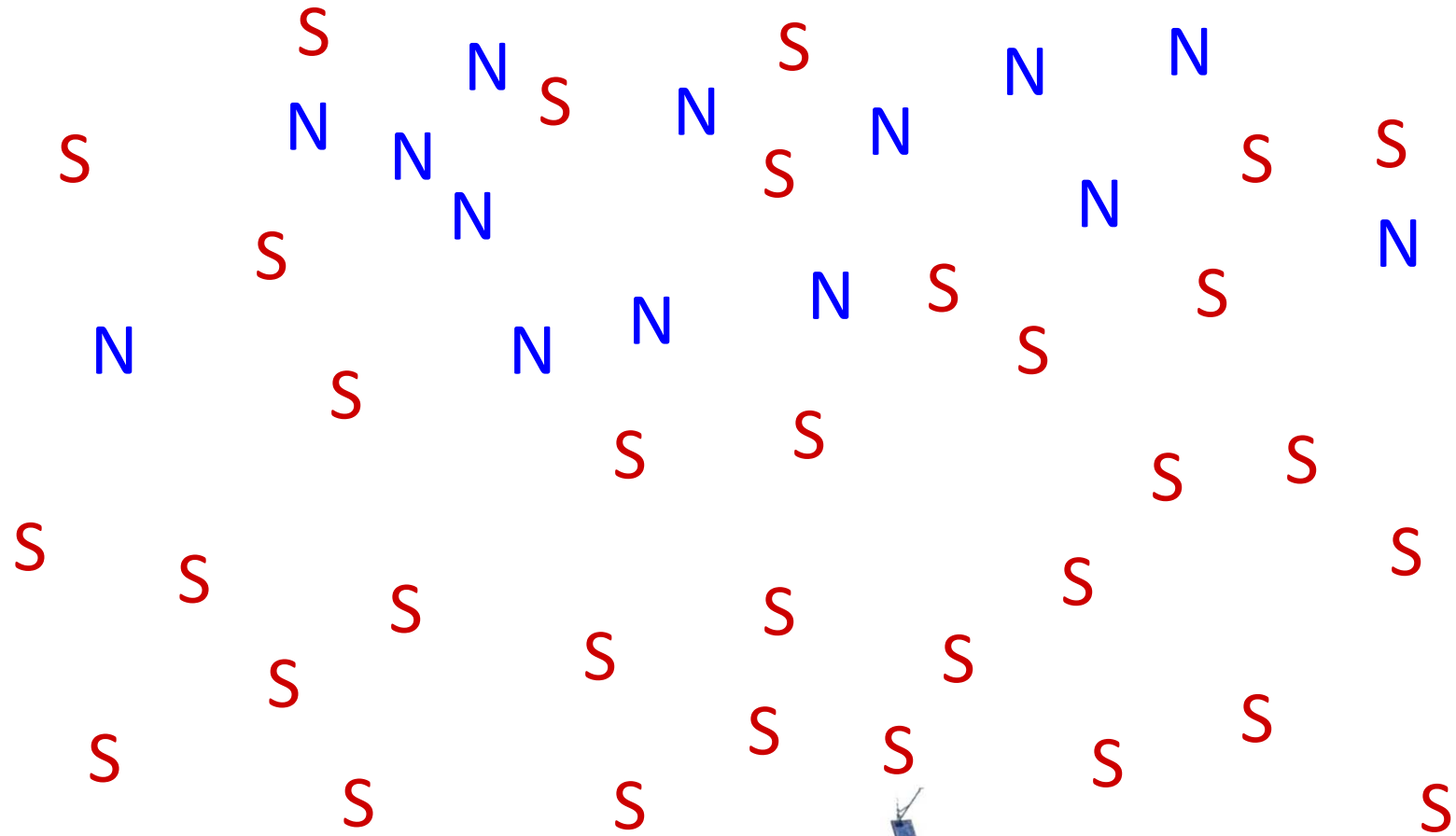
S: No distinct limits, present mostly in south

SS: Distinct northern limit, no southern limit

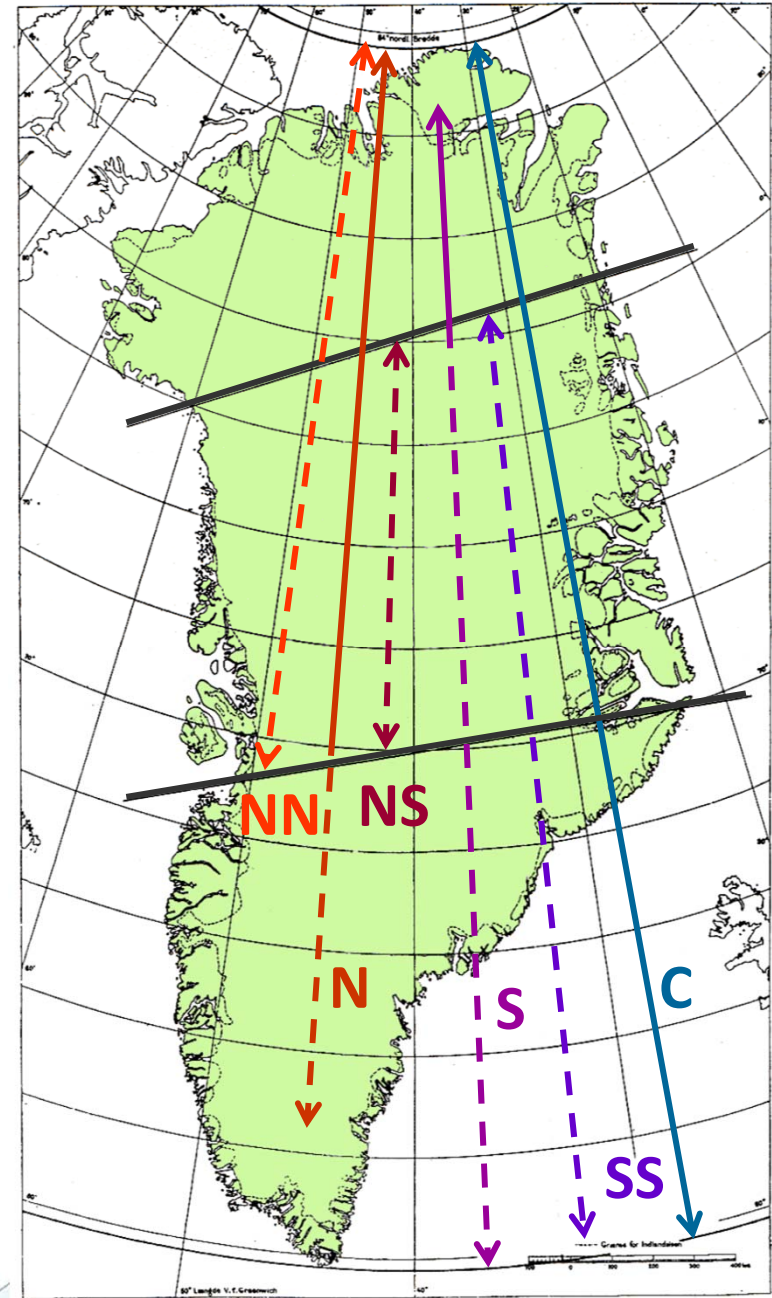
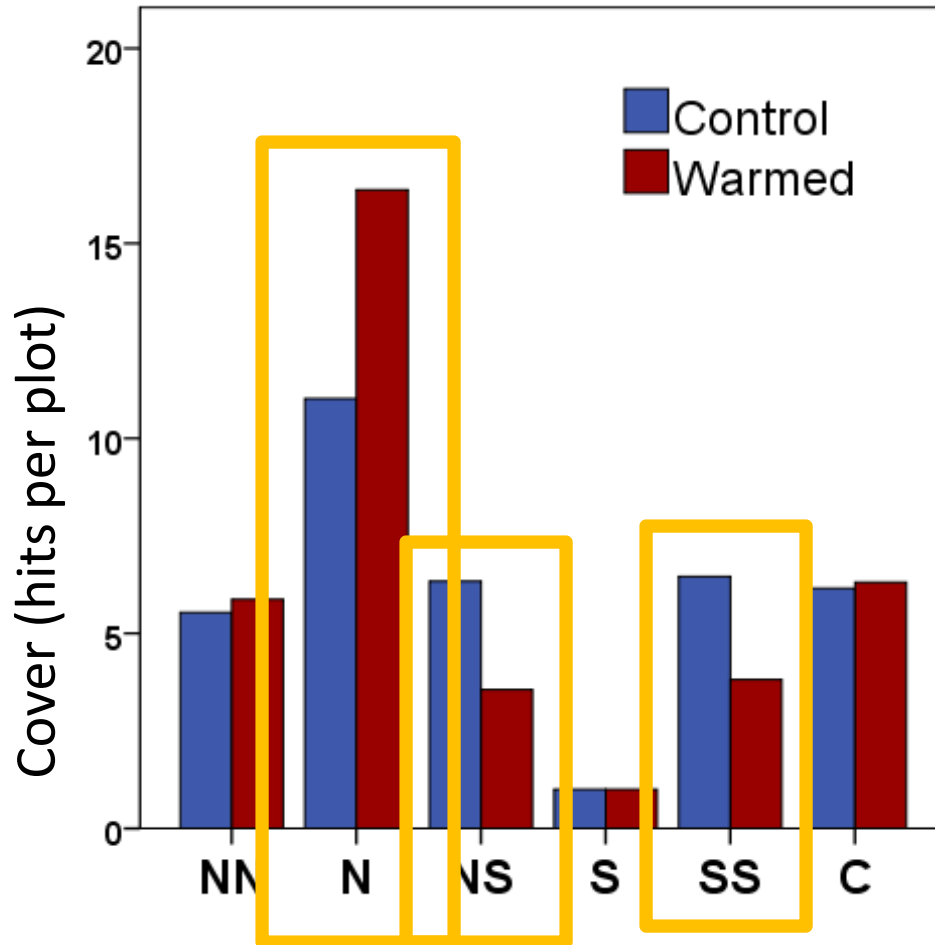
C: Circumgreenlandic species



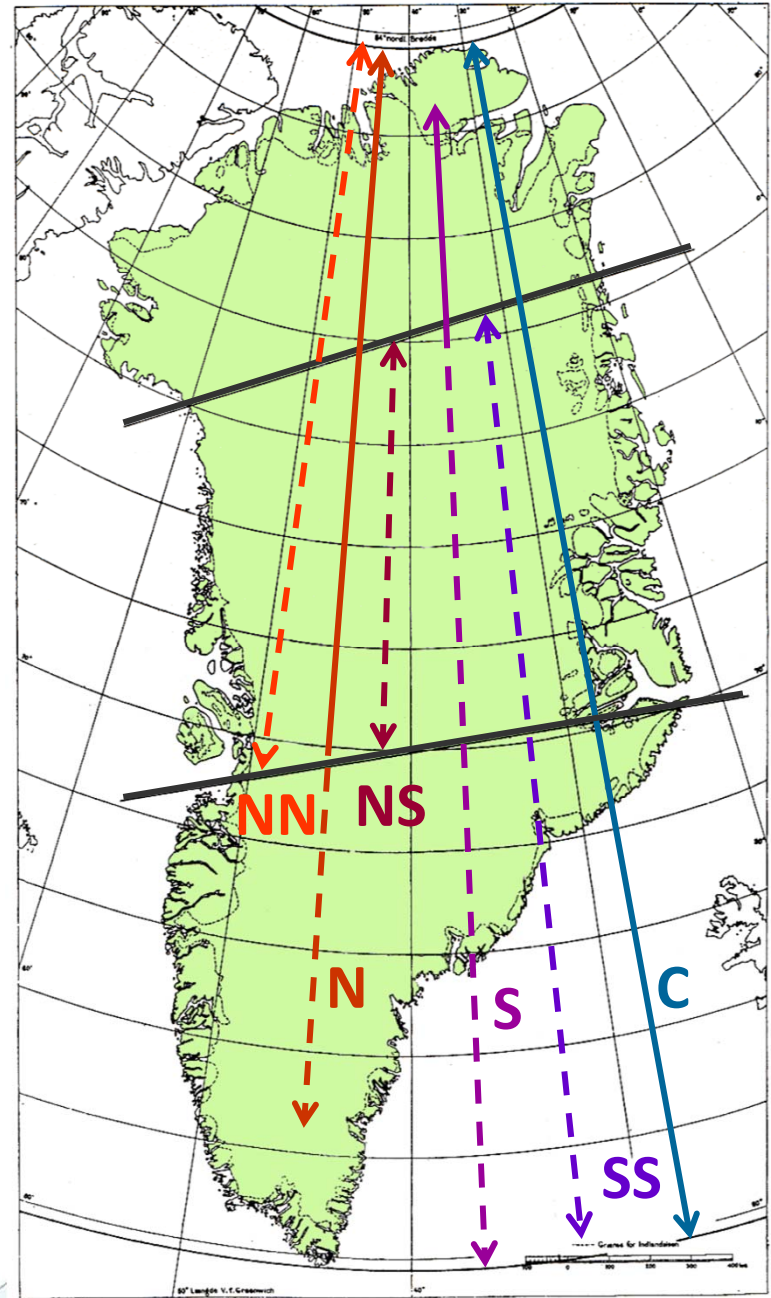
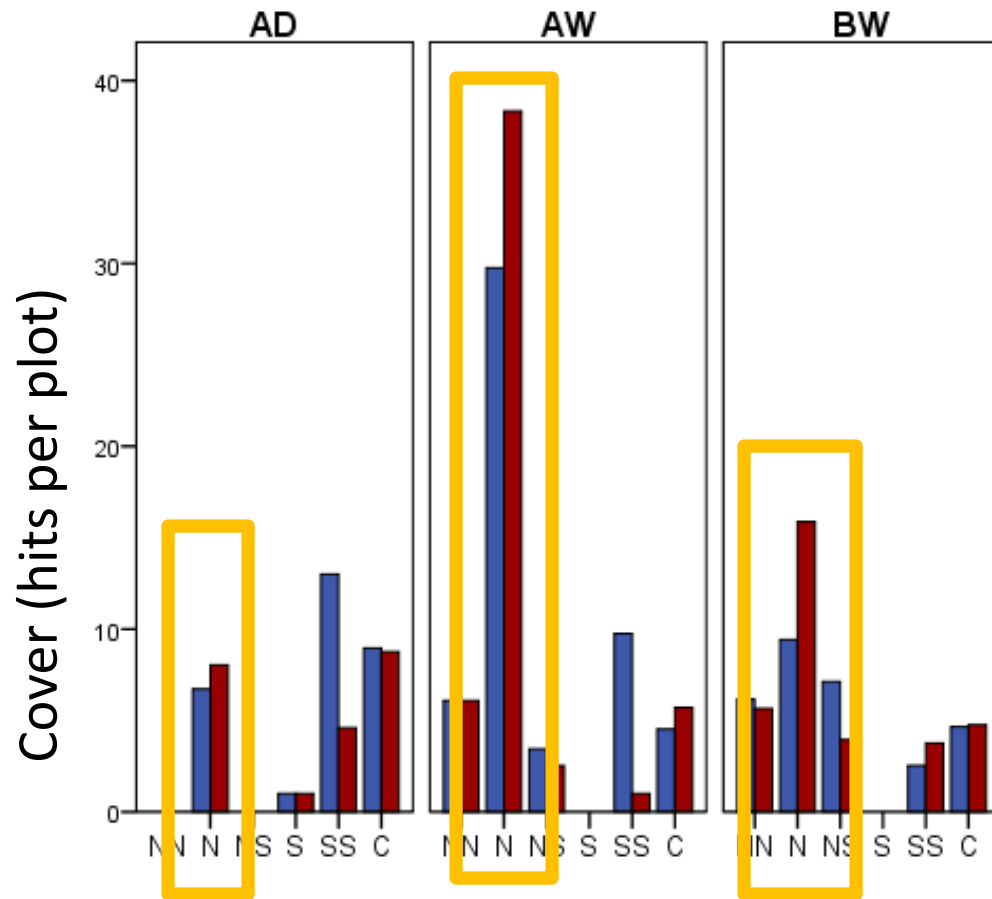
Expected Trends



Greenland: All Sites Combined



Greenland:
 Atqasuk Dry Site
 Atqasuk Wet Site
 Barrow Wet Site



	Young Zones <i>Young 1971</i>	42/72	High Arctic / Low Arctic <i>Gould and Walker 1999</i>	40/72	Biome Distribution	54/72	Latitudinal Distribution <i>Hultén 1968</i>	72/72	Longitudinal Distribution <i>Hultén 1968</i>	72/72	Alaskan Distribution <i>Hultén 1968</i>	72/72	Greenland Distribution <i>Sørensen 1941</i>	41/72	Family	72/72	Monocot/Dicot	72/72	TDD _{sm} / Julian Day <i>Hollister 2003</i>	10/72	Rainkær's Life Forms <i>Sørensen 1941</i>	41/72	Thawing Type <i>Sørensen 1941</i>	41/72	Wintering State of Leaves <i>Sørensen 1941</i>	41/72	Wintering State of Buds <i>Sørensen 1941</i>	41/72	Floral Wintering Stage <i>Sørensen 1941</i>	41/72	Early / Late Leaf Bud Burst <i>ITEX phenology data</i>	52/72	Early / Late Flower Burst <i>ITEX phenology data</i>	39/72	
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Barrow Dry	*		*		.			*		*	*				*									*	*										
Atqasuk Wet						.					*	*								.				*	*		*								
Atqasuk Dry												*							.				.												

*p<.05, ·p<.10



Barrow Dry Site

	Family	72/72	Monocot/Dicot	72/72	TDD _{sm} / Julian Day <i>Hollister 2003</i>	10/72	Rainkiær's Life Forms <i>Sørensen 1941</i>	41/72	Thawing Type <i>Sørensen 1941</i>	41/72	Wintering State of Leaves <i>Sørensen 1941</i>	41/72	Wintering State of Buds <i>Sørensen 1941</i>	41/72	Floral Wintering Stage <i>Sørensen 1941</i>	41/72	Early / Late Leaf Bud Burst <i>ITEX phenology data</i>	52/72	Early / Late Flower Burst <i>ITEX phenology data</i>	39/72
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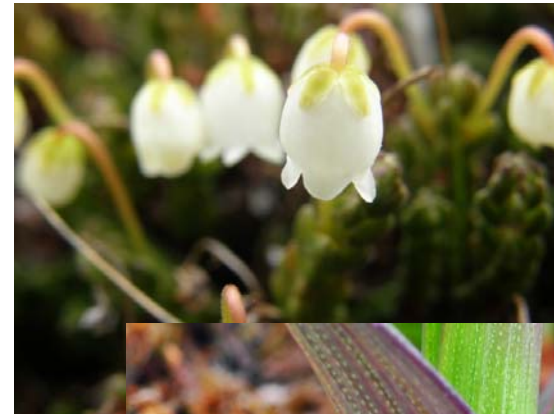


Sørensen: Wintering State Of Buds

Indicates state of shoot apices during winter

- **A: active bud protection**

Shrub species and forb species: *Betula nana*,
Cassiope tetragona, *Polygonum viviparum*



- **P: passive bud protection**

Mostly graminoid species: *Carex spp*, *Eriophorum spp*, *Luzula spp*, also *Ranunculus spp*

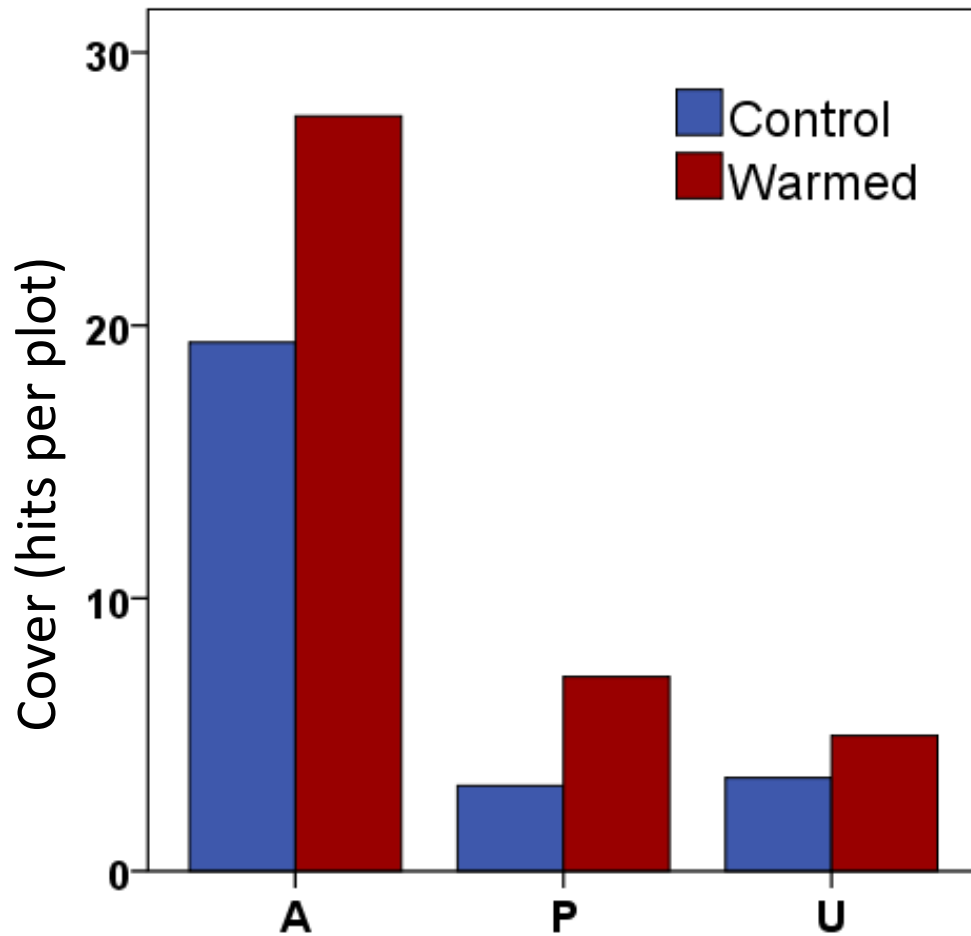


- **U: Unprotected buds**

Mostly forb species: *Cochlearia officinalis*,
Cadamine pratensis, *Draba spp*, most *Saxifraga spp*



Wintering State of Buds: Barrow Dry Site



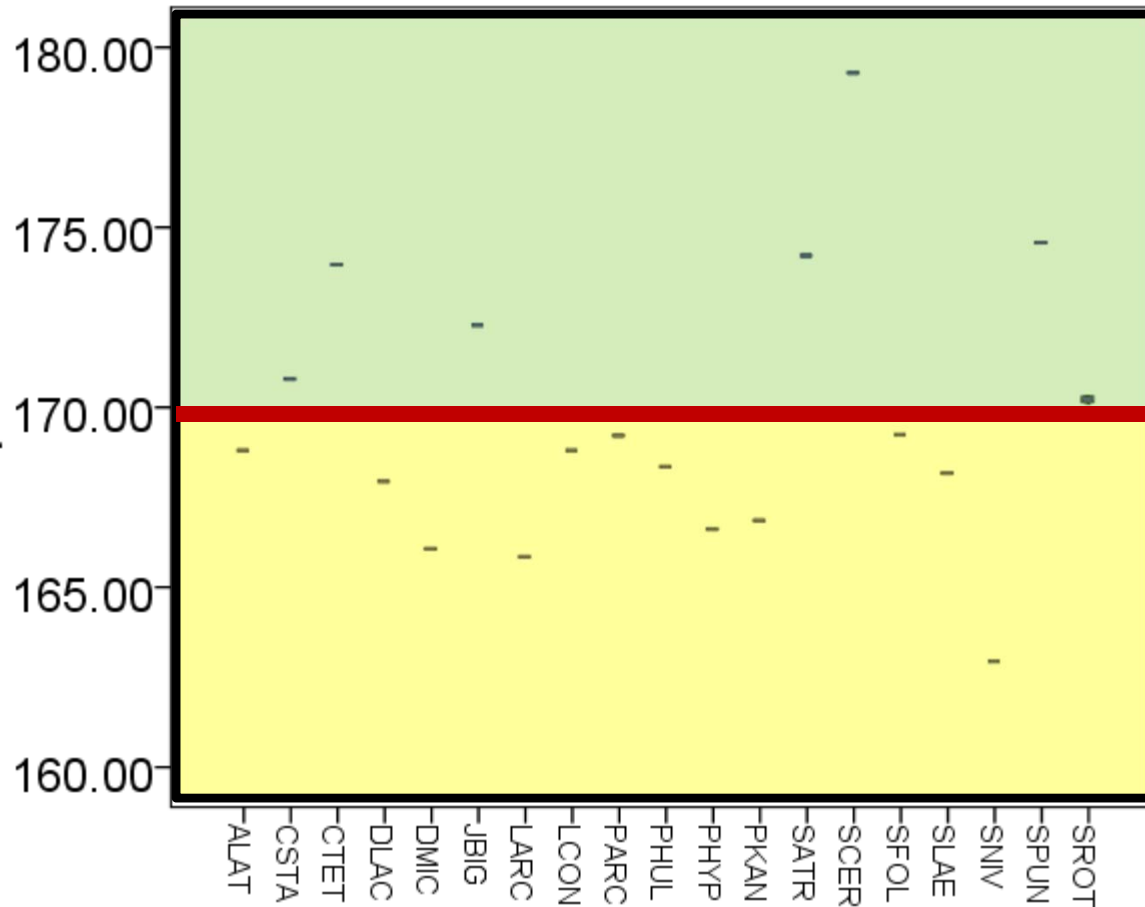
Barrow Wet Site

	Family	Monocot/Dicot	TDD _{sm} / Julian Day <i>Hollister 2003</i>	Rainkjaer's Life Forms <i>Sørensen 1941</i>	Thawing Type <i>Sørensen 1941</i>	Wintering State of Leaves <i>Sørensen 1941</i>	Wintering State of Buds <i>Sørensen 1941</i>	Floral Wintering Stage <i>Sørensen 1941</i>	Early / Late Leaf Bud Burst <i>ITEX phenology data</i>	Early / Late Flower Burst <i>ITEX phenology data</i>
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Barrow Wet									*	.
Barrow Dry	*					*	*			
Atqasuk Wet								*		
Atqasuk Dry			.		.					

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Early/Late Leaf Burst



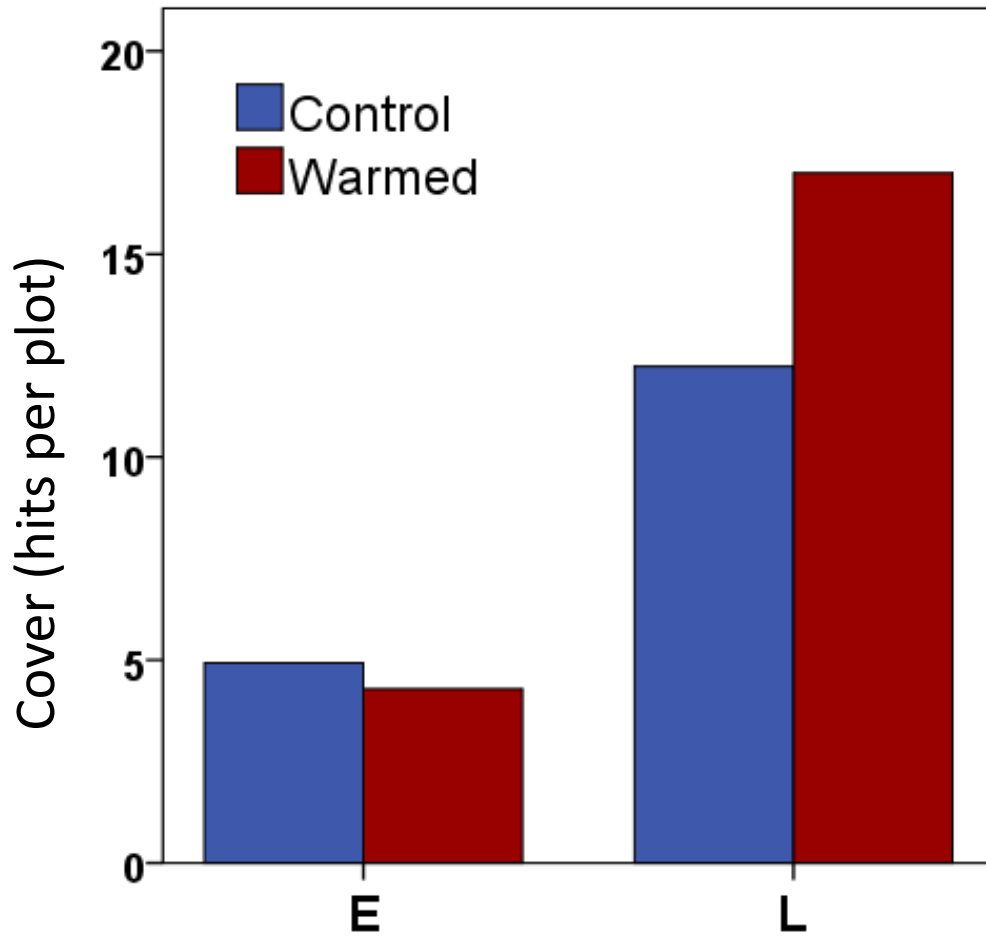
Means were taken from observations of phenological responses collected since establishment of sites (169.7)

Late: Spp mean leaf bud burst is after mean leaf bud burst for all spp at the site

Early: Spp mean leaf bud burst is before mean leaf bud burst for all spp at that site



Barrow Wet Site: Leaf Burst



Atqasuk Wet Site

	Family	Monocot/Dicot	TDD _{sm} / Julian Day <i>Hollister 2003</i>	Rainkjaer's Life Forms <i>Sørensen 1941</i>	Thawing Type <i>Sørensen 1941</i>	Wintering State of Leaves <i>Sørensen 1941</i>	Wintering State of Buds <i>Sørensen 1941</i>	Floral Wintering Stage <i>Sørensen 1941</i>	Early / Late Leaf Bud Burst <i>ITEX phenology data</i>	Early / Late Flower Burst <i>ITEX phenology data</i>
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Barrow Wet									*	.
Barrow Dry	*					*	*			
Atqasuk Wet								*		
Atqasuk Dry			.		.					

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Sørensen: Floral Wintering Stage

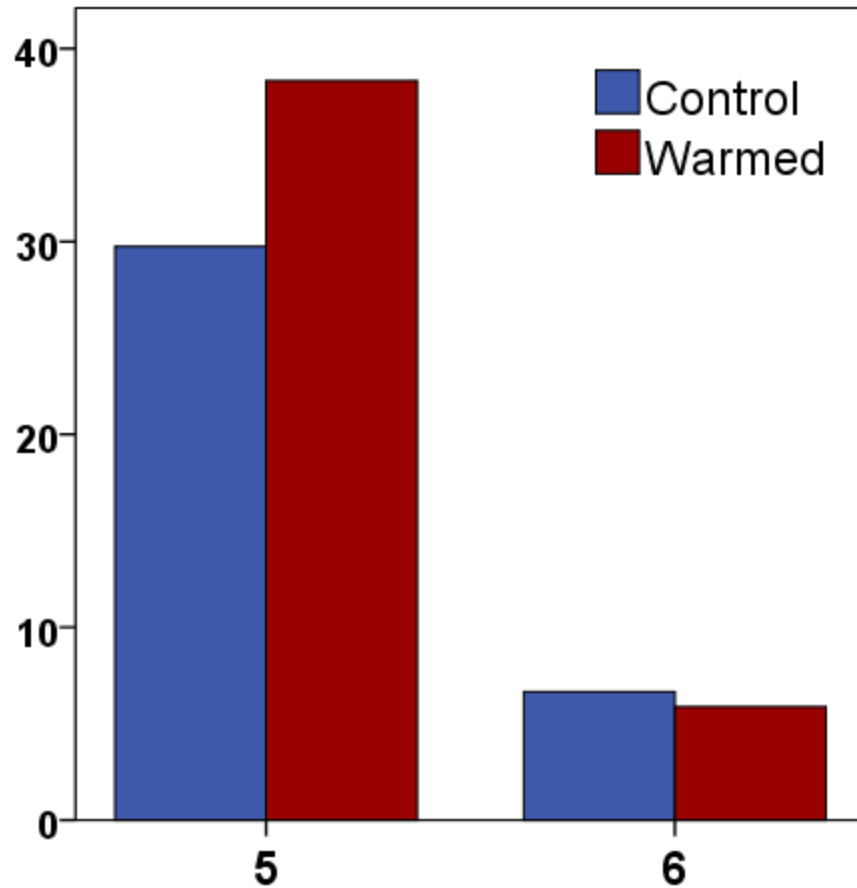
State of individual over winter, with 1 being the least developed and 7 being the most developed

More developed
Less developed

- 1: Purely vegetative. Some leaf primordia to form in summer, along with all floral primordia.
- 2: All leaf primordia formed. Floral primordia to form in summer.
- 3: Not purely vegetative. Inflorescence without differentiated floral primordia.
- 4: Floral parts in incipient differentiation.
- 5: Calyx, anthers formed. Ovary developing.
- 6: Flower buds large and roughly developed.
- 7: Flower buds fully developed. Anthers with pollen
- 8: Floral development aperiodical. Buds at stages 3-7.



Atqasuk Wet: Floral Wintering Stage



Atqasuk Dry Site

	Family	72/72	Monocot/Dicot	72/72	TDD _{sm} / Julian Day	10/72	Hollister 2003	Rainkiær's Life Forms	41/72	Sørensen 1941	Thawing Type	41/72	Sørensen 1941	Wintering State of Leaves	41/72	Sørensen 1941	Wintering State of Buds	41/72	Sørensen 1941	Floral Wintering Stage	41/72	Sørensen 1941	Early / Late Leaf Bud Burst	52/72	ITEX phenology data	Early / Late Flower Burst	39/72	ITEX phenology data
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Atqasuk Dry Site



- Geographical distribution can be an effective predictor of response to warming
- In the Barrow Dry Site, species with active bud protection over winter increase in cover more than species with passive or no protection
- In the Barrow Wet Site, species with late leaf burst increase in cover; early species show no change
- In the Atqasuk Wet Site, species with relatively less floral development over winter increase in cover, while species with more development show no change
- Further study is needed to develop a model for predicting plants' response to warming in a variety of tundra habitats



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Thank you!

