DOCUMENTING TUNDRA PLANT COMMUNITY CHANGE IN NORTHERN ALASKA

Jeremy May

Grand Valley State University

Advisor: Bob Hollister

Why study the Arctic?

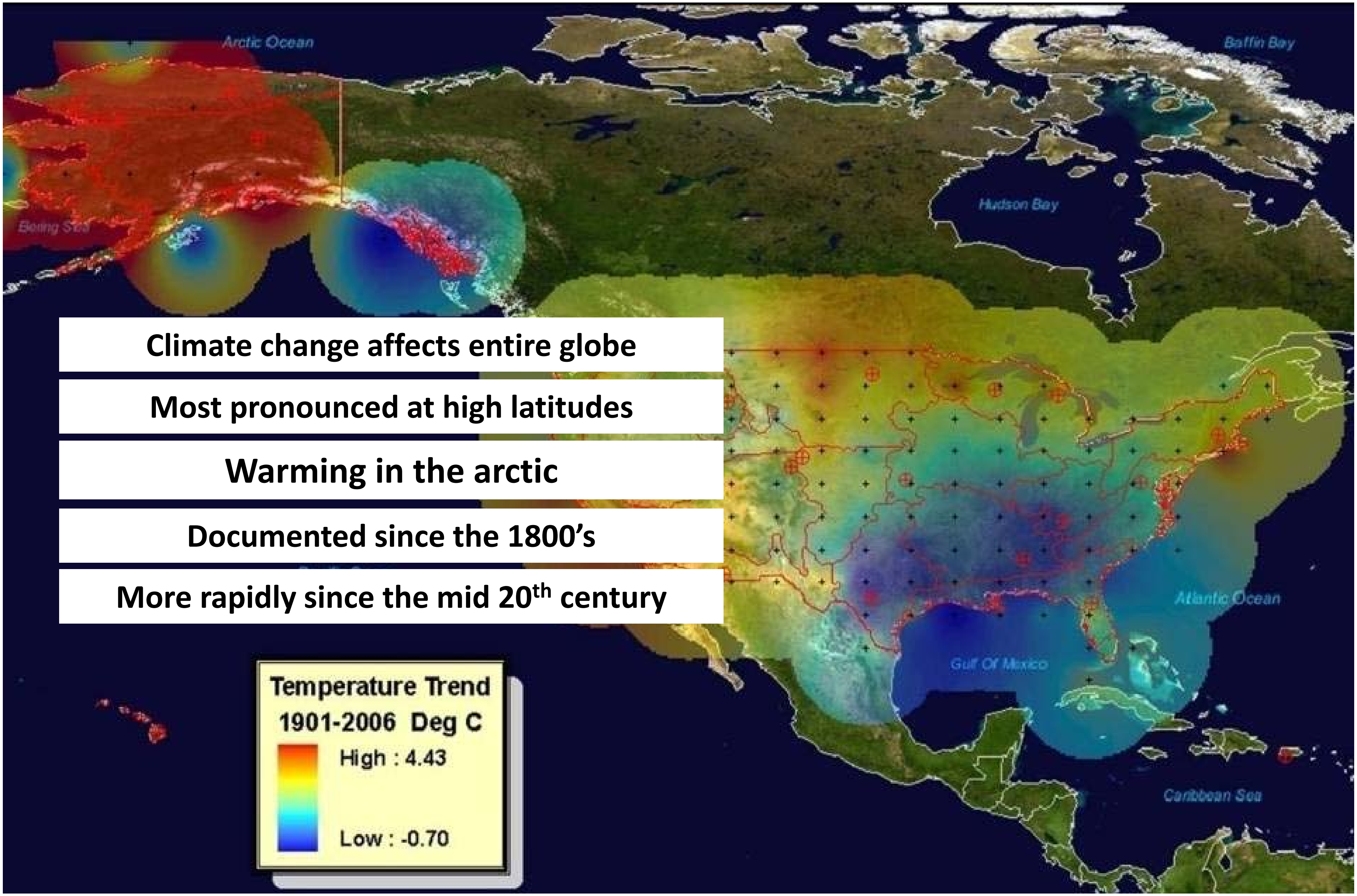
Climate change affects entire globe

Most pronounced at high latitudes

Warming in the arctic

Documented since the 1800's

More rapidly since the mid 20th century



Effects of Warming on Tundra Plants

Even small variations in the environment effect community composition and water/nutrient cycling

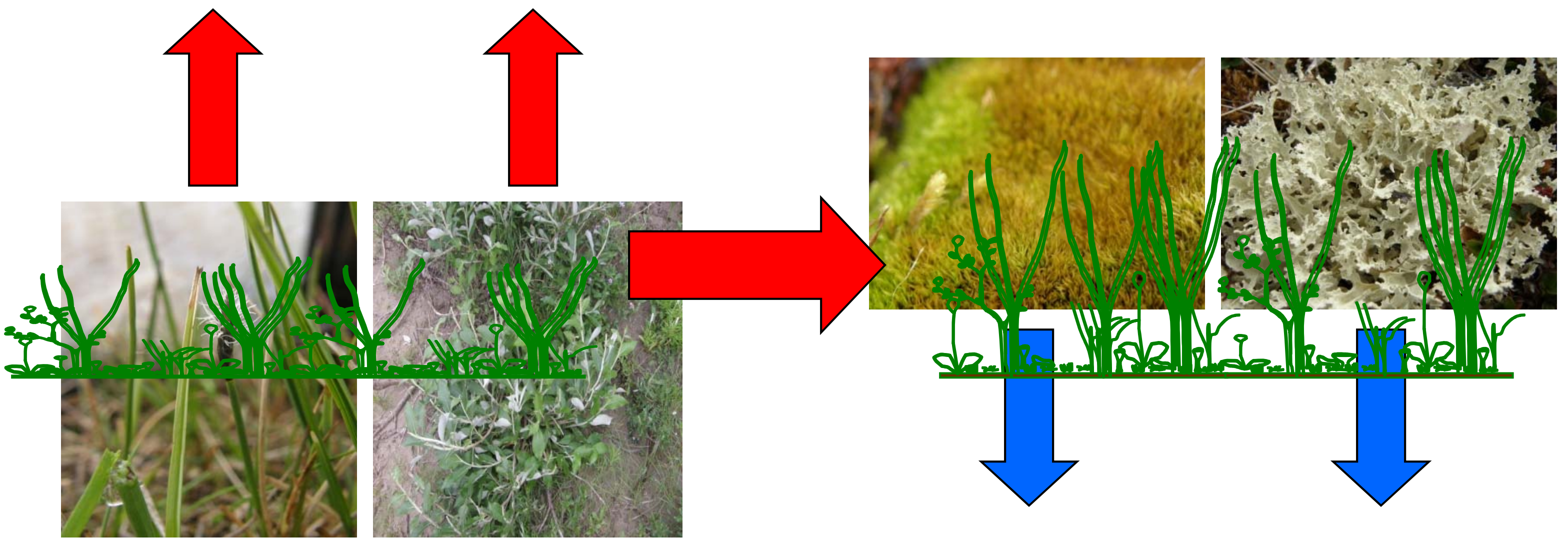
(Chapin and Shaver, 1985)

Warming shifts community control from facilitation to competition

Graminoids and Shrubs often increase in response to warming, while bryophytes and lichens decrease

(Arft et al, 1999; Hobie and Chapin, 1998)

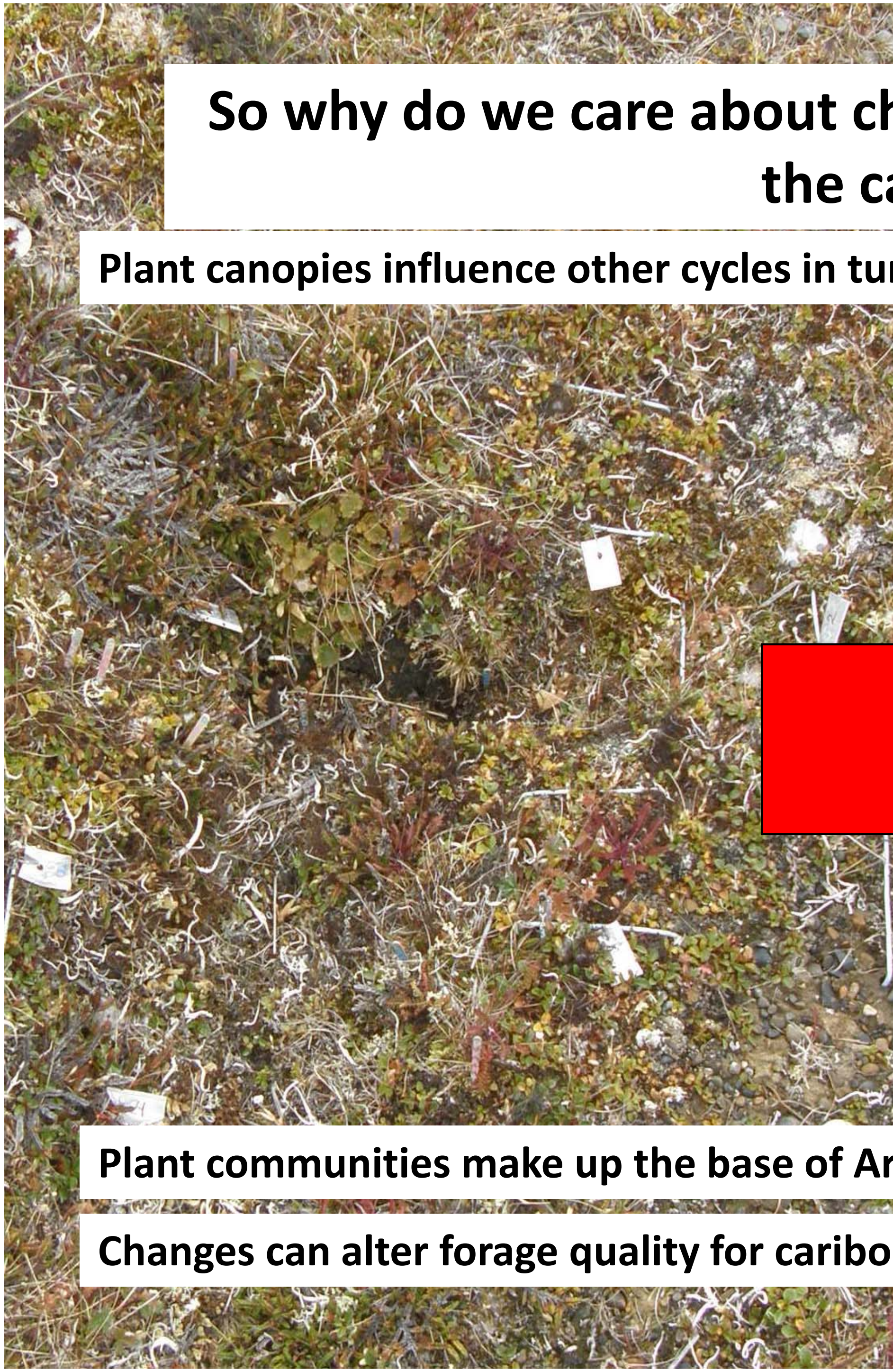
Increases in tall and decreases in short plants should increase canopy height and cause canopy to fill in

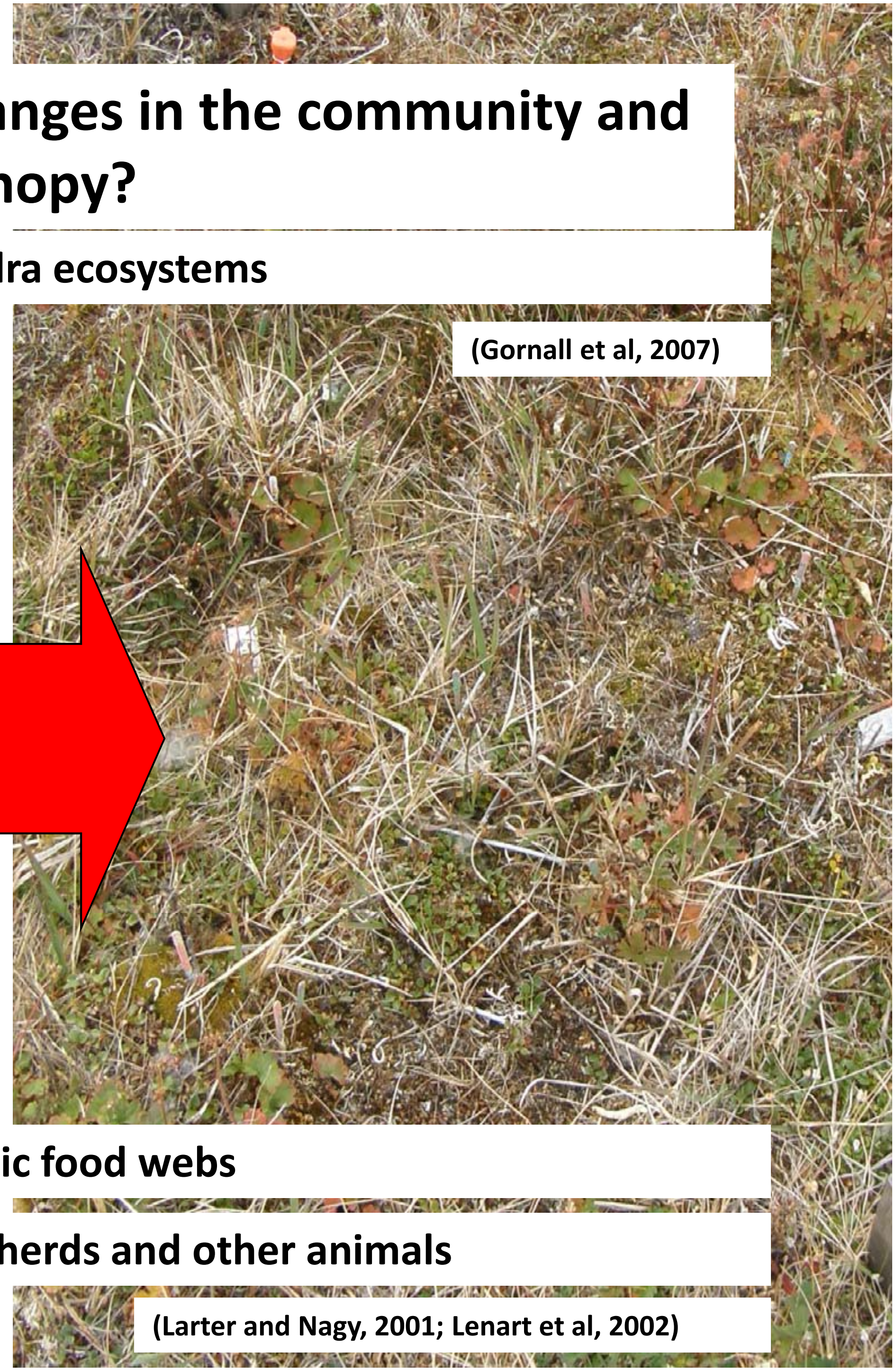


So why do we care about changes in the community and the canopy?

Plant canopies influence other cycles in tundra ecosystems

(Gornall et al, 2007)





Plant communities make up the base of Arctic food webs

Changes can alter forage quality for caribou herds and other animals

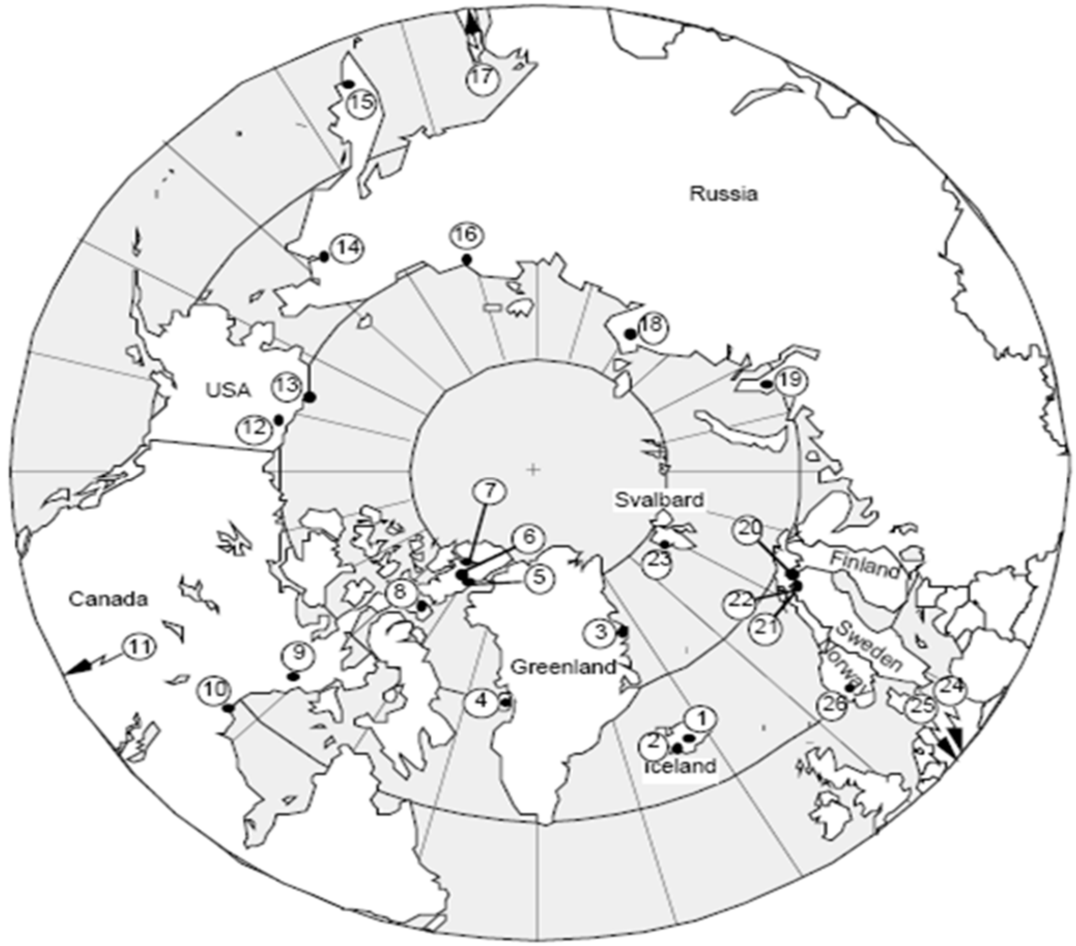
(Larter and Nagy, 2001; Lenart et al, 2002)

This project is part of ITEX

International Tundra Experiment

It is a network of arctic researchers from over 11 countries

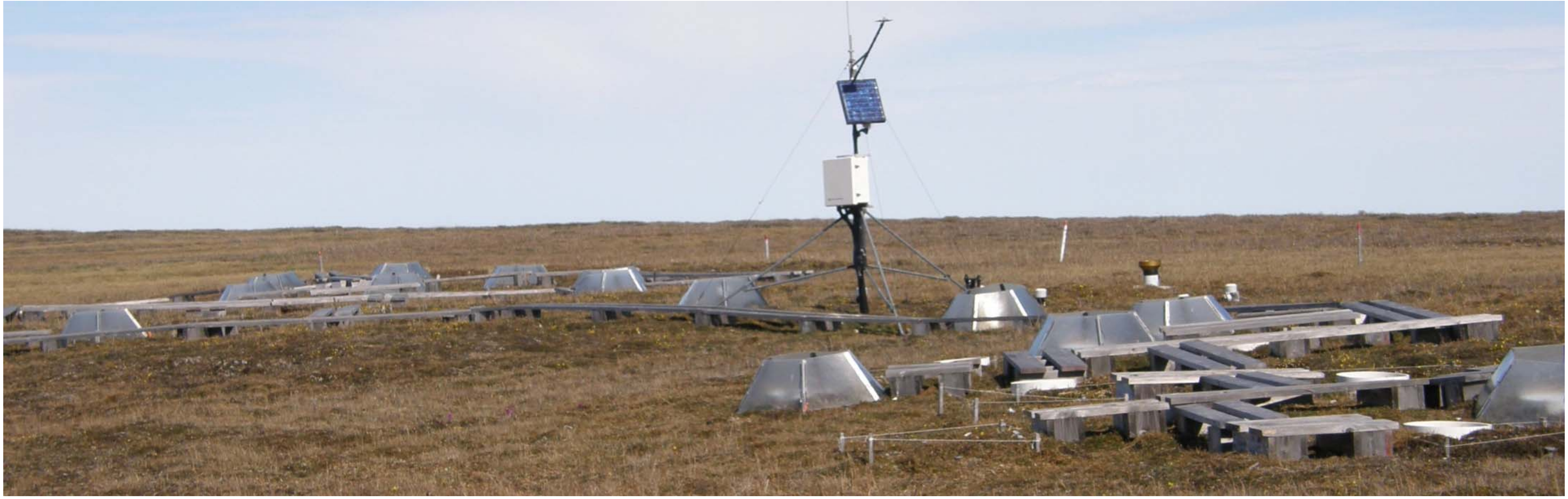
All investigating the effects of climate change on the tundra biome



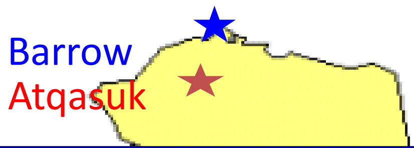
This project

Three parts:

1. Assessing the accuracy of top and bottom point frame method vegetation sampling
2. Determine the ability of early warming responses to predict later warming responses
3. Investigated changes in control plots and in response to warming over 15 years



Site Locations



Barrow

DRY

Atqasuk

WET

Site Setup and Warming

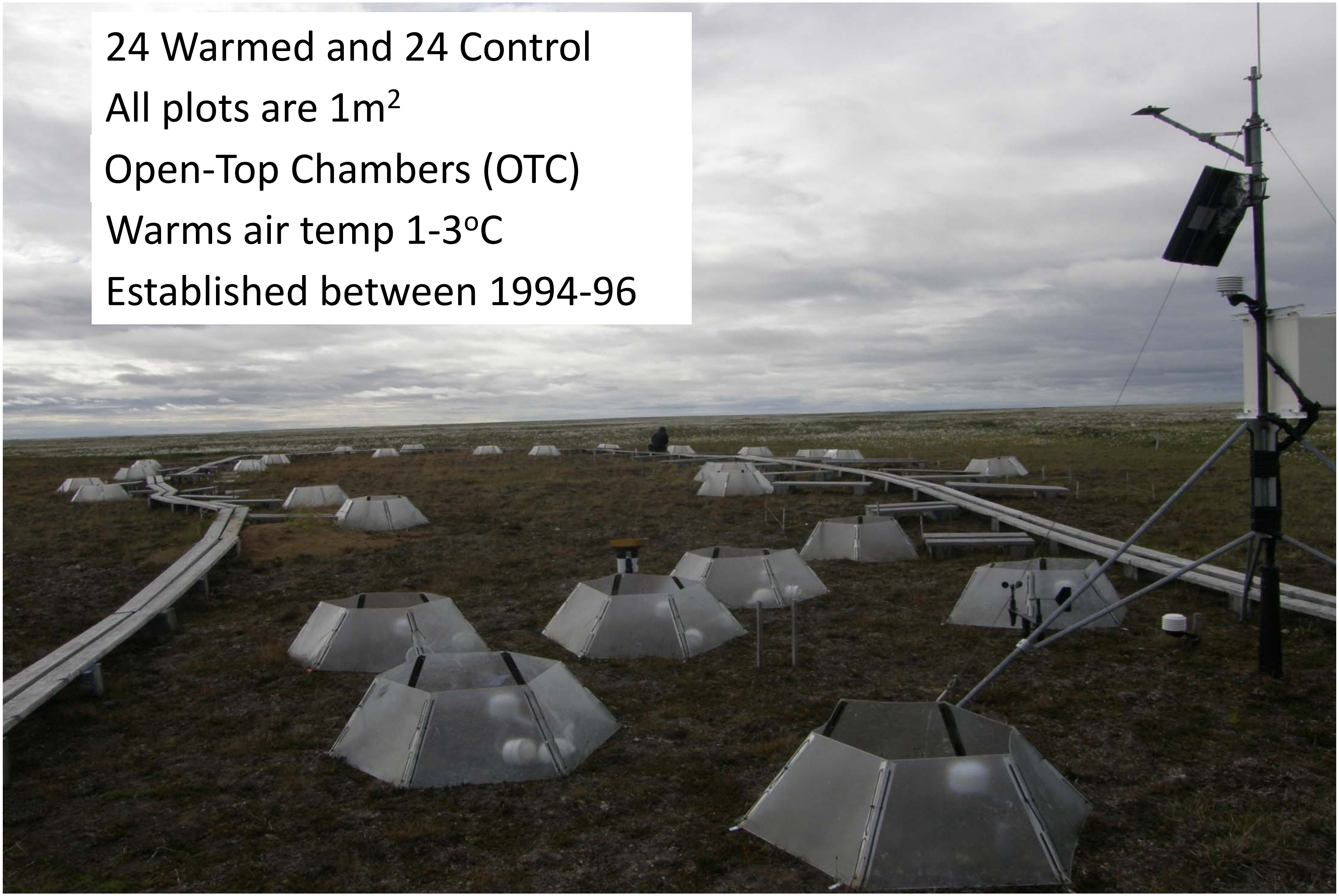
24 Warmed and 24 Control

All plots are 1m^2

Open-Top Chambers (OTC)

Warms air temp 1-3^{o}C

Established between 1994-96



Part I: Assessment of Top and Bottom Point Frame Method Accuracy

Many variations of the point frame method of vegetation sampling have been used to monitor a variety of systems

The ITEX standard of vegetation monitoring is the top and bottom only method which includes on the uppermost and lowermost contacts

(Walker 1996)

This method has been used in over 20 published studies

But no one has tested it against the more time and labor intensive all contacts method

Part I: Assessment of Top and Bottom Point Frame Method Accuracy

I evaluated the difference between the Top and Bottom Contacts only and All Contacts

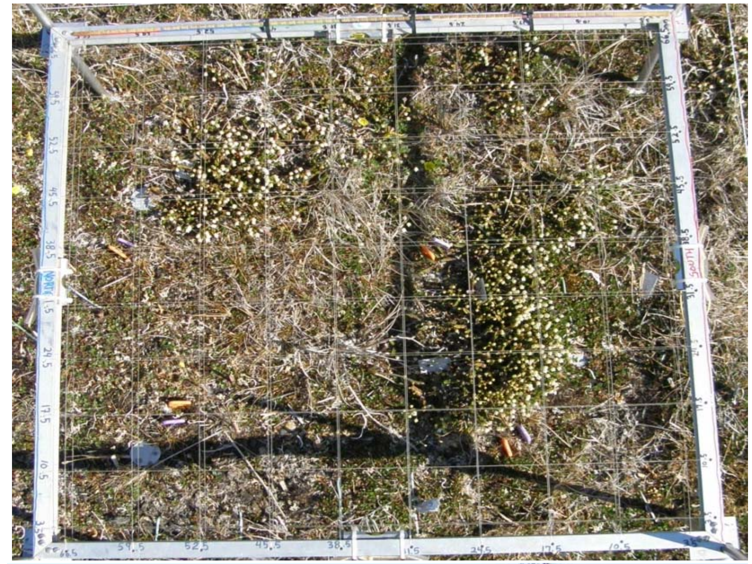
Allowing the assessment of whether Top and Bottom method is accurate in monitoring plant communities

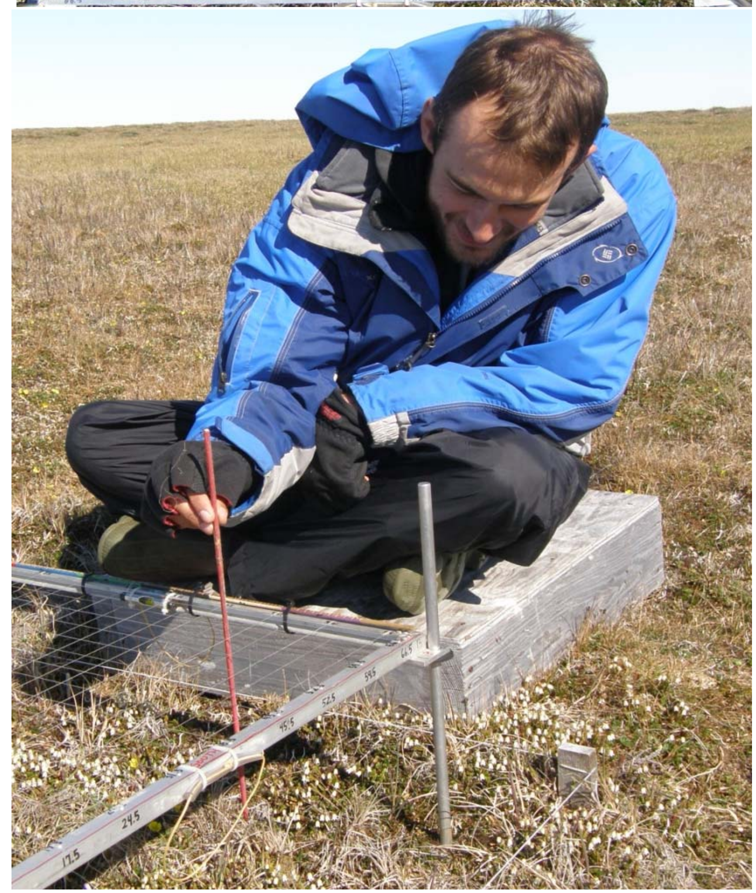
Types of Comparisons

All comparisons were done between All contact and Top and Bottom only methods

1. Comparison of Absolute Cover for all growth forms and ability to detect community change
2. Species Diversity (Richness, Shannon)
3. Biomass estimation using both methods

Point Frame Method





Point Frame Grid

- -75cmX75cm
- -100 points
- -Oriented and leveled above each plot

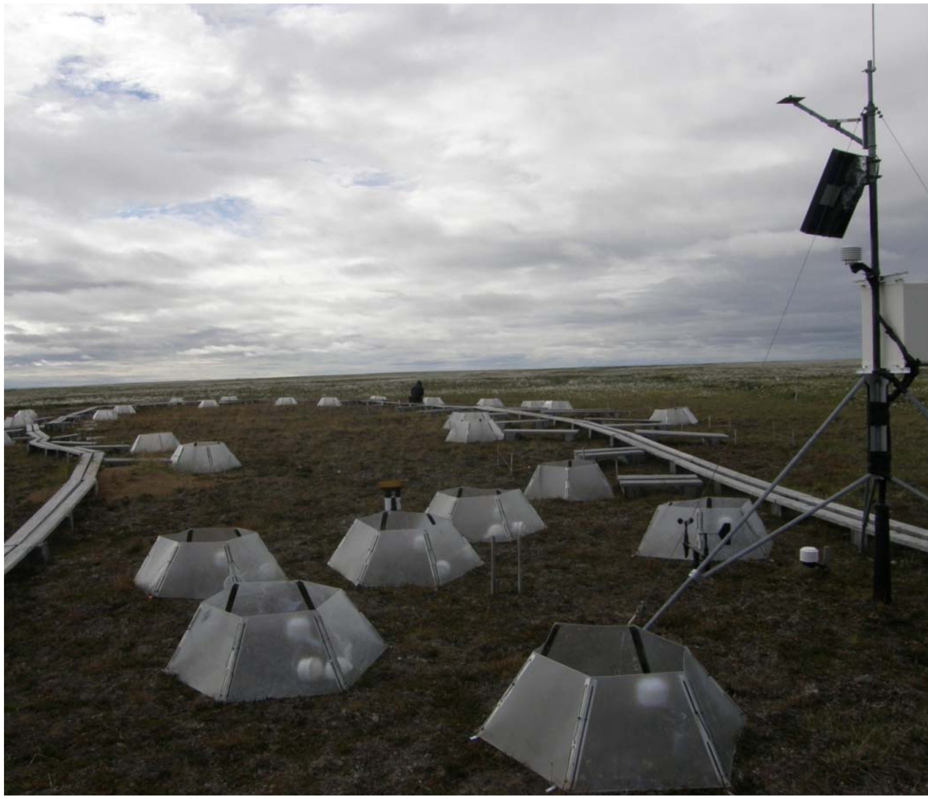
Measurements

- -At each point all contacts were recorded
  - Species
  - Live/Dead Status
  - Height

Data was then separated into top and bottom only and all contact method

(Hollister et al, 2005)

Biomass Estimation



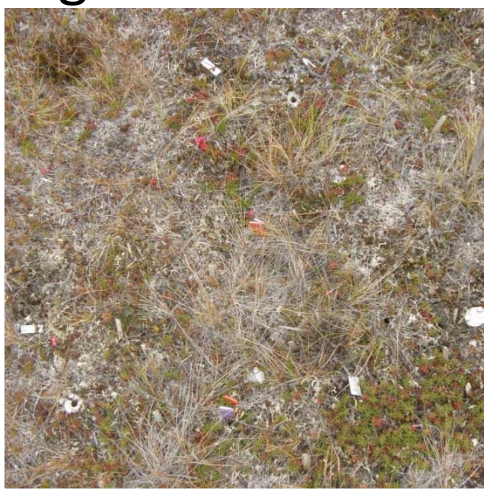
Our sites are for long term monitoring

So we couldn’t harvest plant biomass out of them

Biomass collection

Established 6 new biomass plots outside of each site

Each was pointframed, aboveground biomass harvested, sorted, dried and weighed



Data Analysis

Cover differences and warming differences were analyzed using 1-way ANOVAs

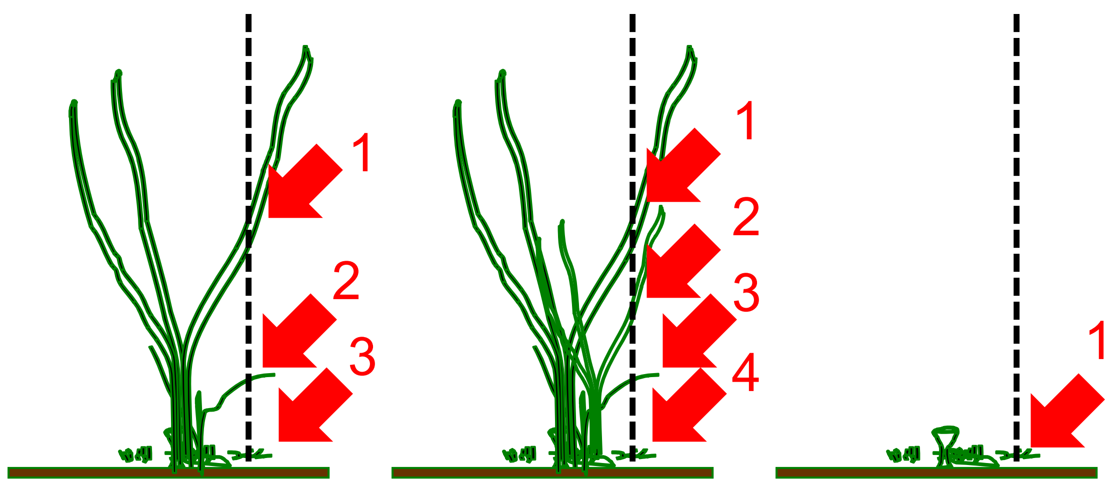
Diversity Indices were calculated using PC-ORD 4.0 and analyzed using 1-way ANOVAs

Biomass mass estimations were analyzed using simple linear regressions

Difference between methods

* Denotes statistically significant difference between methods

	Cover	Difference
		Method
	AC	TB
		Atqasuk Dry site
Live	142.18	-10.51*

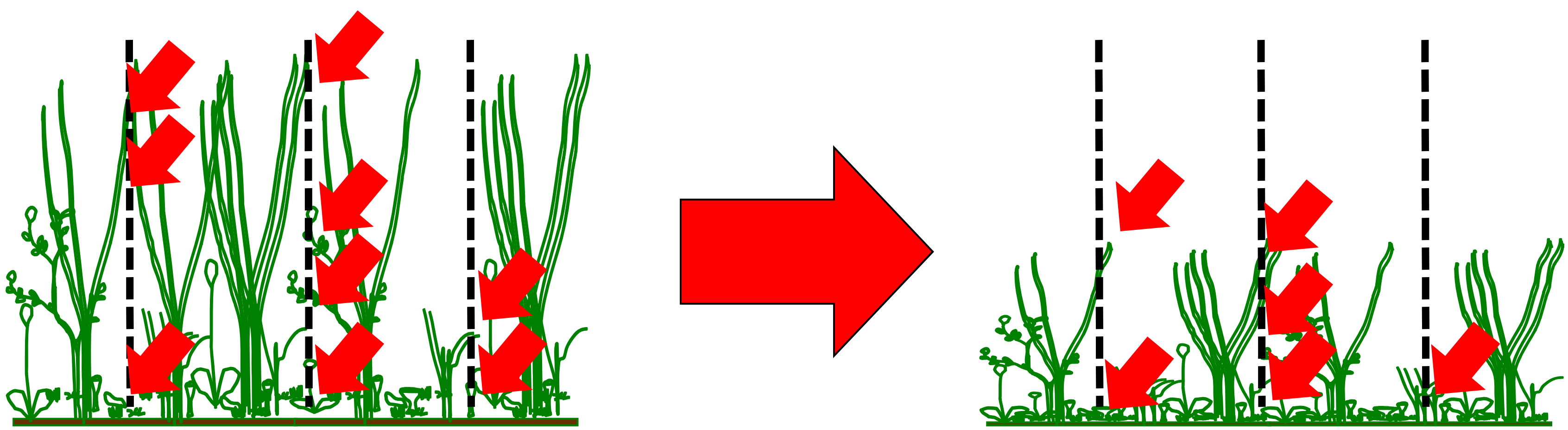


All contact method
Top and bottom method

Ability to detect change

* Denotes statistically significant difference treatments

	Difference	
	Treatment	
	AC	TB
Atqasuk Dry site		
Live	-10.08*	-6.46



Control

Warmed

All contacts

Top and Bottom Only

Community Indices

Many differences between the 2 methods

Most differences are in the 2 wet sites

There were only 2 differences in ability to detect change between the 2 methods

	Cover	Difference		
		Method	Treatment	
	AC	TB	AC	TB
		Atqasuk Dry site		
Live	142.18	-10.51*	-10.08*	-6.46
Dead	38.02	-6.90*	4.46	4.83
Richness	9.26	-0.02	-0.91	-0.89
Shannon	1.78	0	-0.02	-0.02
		Atqasuk Wet site		
Live	201.18	-69.51*	15.71*	13.42*
Dead	57.06	-28.16*	11.38	-0.08
Richness	6.40	-0.01	-0.55	-0.57
Shannon	1.02	-0.04*	0	-0.01
		Barrow Dry site		
Live	141.42	-10.07*	-2.29	-6.71*
Dead	41.20	-3.50	17.46*	14.96*
Richness	8.66	-0.03	-3.02*	-3.01*
Shannon	1.72	-0.01*	-0.24*	-0.23*
		Barrow Wet site		
Live	136.66	-16.77*	-7.75	-6.75
Dead	80.10	-36.90*	21.13*	13.38*
Richness	10.75	-0.02	-1.45	-1.51
Shannon	1.81	-0.03*	-0.15*	-0.15*

Absolute Cover

	Baseline Cover AC	Difference Method TB	Difference Treatment AC	Difference Treatment TB
		Atqasuk Wet Site		
Deciduous Shrubs	0.67	0.00	-0.17	-0.17
Evergreen Shrubs	48.93	-3.49 *	-3.58	-2.55
Forbs	1.73	-0.11	0.71	0.71
Graminoids	29.38	-6.21 *	-5.03	-2.46
Lichens	50.95	-0.66 *	-1.99	-1.94
Bryophytes	10.53	-0.03 *	0.00	-0.04
		Atqasuk Wet Site		
Deciduous Shrubs	14.06	-4.17 *	-0.41	-1.04
Forbs	0.48	-0.16 ?	-0.26	-0.16
Graminoids	58.84	-12.61 *	9.13	7.13
Lichens	0.43	0.00 *	-0.08	-0.08
Bryophytes	127.47	-1.37 *	7.33	7.58
		Barrow Dry Site		
Deciduous Shrubs	30.55	-0.03	-4.42 ?	-4.46 ?
Evergreen Shrubs	32.79	-5.14 *	8.16	6.37
Forbs	13.48	-1.29 *	4.60 *	3.76 ?
Graminoids	19.73	-3.15 *	11.37 *	9.08 *
Lichens	32.71	-0.43 *	-16.55 *	-16.01 *
Bryophytes	12.15	-0.03 *	-5.38 *	-5.42 *
		Barrow Wet Site		
Deciduous Shrubs	1.34	0.00	1.75 ?	1.75 ?
Forbs	27.09	-1.39 *	2.54	2.55
Graminoids	89.05	-15.27 *	0.70	1.67
Lichens	5.85	-0.16 *	-3.80 *	-3.59 *
Bryophytes	19.19	-0.10 *	-8.92 *	-8.84 *

Many differences between methods (29-44% of taxa)

Most were small, but still significant

Biggest differences were in graminoids and dominant shrubs

Both methods were similar in ability to detect change

Only one difference (out of 118 taxa/growth form)

Biomass estimation regressions

Simple linear regressions show growth forms that comprise >5% of BM

Top and Bottom method method has higher r^2 values overall

Both methods have the same number of significant r^2 values (14 out of 27 cases)

Taxon	N	AC Method C/BM	AC Method r^2	TB Method C/BM	TB Method r^2
Atqasuk Dry site					
Evergreen Shrub	6	BM=1.5c+12.7	0.15	BM=1.6c+12.1	0.17
Cassiope tetragona	5	BM=0.7c+32.2	0.01	BM=2.2c+18.7	0.07
Diapensia lapponica	4	BM=4.1c+10.6	0.58	BM=4.1c+10.6	0.58
Vaccinium vitis-idaea	6	BM=0.7c+5.0	0.16	BM=0.9c+4.1	0.18
Graminoid	6	BM=1.2c-1.5	0.72*	BM=1.2c-1.2	0.61*
Lichen	6	BM=4.3c+8.7	0.20	BM=4.3c+8.7	0.20
Atqasuk Wet Site					
Deciduous Shrub	5	BM=1.6c-3.7	0.76	BM=3.2c-12.4	0.70
Graminoid	6	BM=0.5c+0.6	0.80*	BM=0.7c+0.5	0.81*
Single Graminoid	6	BM=0.5c+0.6	0.80*	BM=0.7c+0.5	0.81*
Eriophorum angustifolium	5	BM=0.2c+0.7	0.95*	BM=0.3c+0.5	0.96*
Bryophyte	6	BM=0.8c+0.4	0.76	BM=0.8c+0.1	0.74
Barrow Dry site					
Deciduous Shrub	6	BM=2.6c-36.9	0.84*	BM=2.7c-37.2	0.88*
Salix rotundifolia	6	BM=2.6c-36.9	0.84*	BM=2.7c-37.2	0.88*
Evergreen Shrub	4	BM=2.9c+15.6	0.76	BM=3.2c+15.8	0.75
Cassiope tetragona	4	BM=2.9c+15.6	0.76	BM=3.2c+15.8	0.75
Graminoid	6	BM=0.7c+0.5	0.78*	BM=0.9c+0.2	0.78*
Bryophyte	5	BM=14.8c+64.5	0.24	BM=14.8c+64.5	0.24
Lichen	6	BM=0.2c-8.1	0.88*	BM=0.2c-8.1	0.88*
Barrow Wet site					
Forb	6	BM=0.4c-0.2	0.66*	BM=0.4c+0	0.60*
Erect Forb	6	BM=0.5c-0.6	0.94*	BM=0.5c-0.6	0.95*
Mat Forb	6	BM=0.2c+0.8	0.03	BM=0.1c+1.5	0.00
Stellaria spp.	6	BM=0.2c+0.8	0.03	BM=0.1c+1.5	0.00
Graminoid	6	BM=0.6c-1.0	0.80*	BM=0.8c-1.3	0.86*
Single Graminoid	6	BM=0.6c-1.0	0.80*	BM=0.8c-1.3	0.86*
Carex aquatilis comp.	6	BM=0.5c+2.3	0.11	BM=1.1c-5.1	0.43
Dupontia fisheri	6	BM=0.4c+0.5	0.83*	BM=0.6c+0.1	0.67*
Bryophyte	6	BM=2.3c-8.1	0.99*	BM=2.3c-8.1	0.99*

Point Framing Summary

There were frequent differences between the two methods

Top and bottom only method omitted intermediate contacts

The Top and Bottom method may under represent layered growth forms (shrubs and graminoids)

Both methods were virtually identical in their ability to detect community changes

Both methods were accurate in estimating aboveground biomass

Bottom line, the top and bottom method is a time-saving and accurate way to monitor tundra plant communities

Part II: Predictions

Examined the ability of early warming responses to predict changes in plant communities in later years

Specifically in community indices, canopy heights, and individual plant growth forms

Part II: Predictions

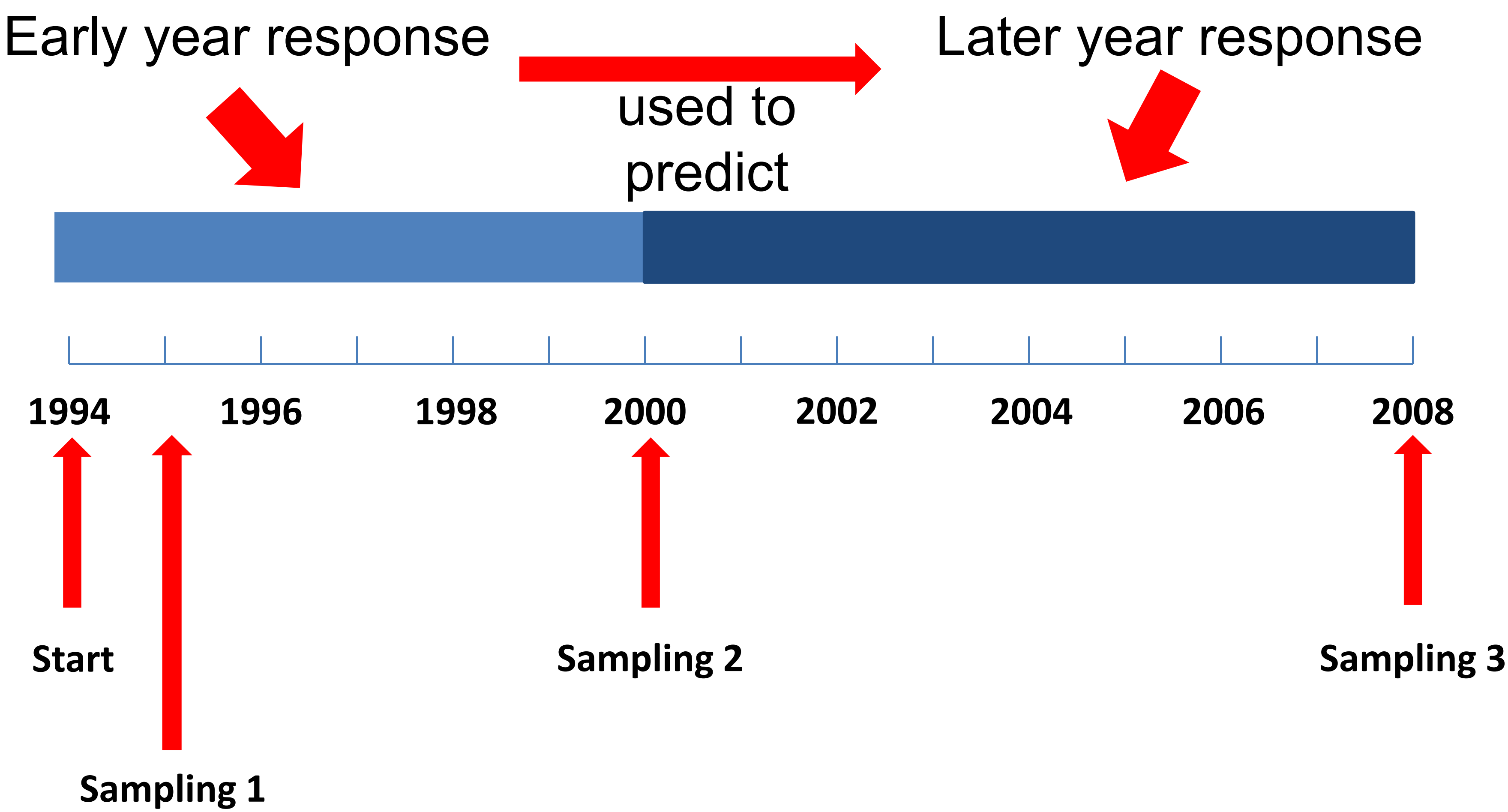
Warming responses were divided three ways:

W1 – overall warming response through sampling 1

W2 – overall warming response through sampling 2
W_s – warming response at sampling 2 relative to the observed changes in control plots

All predictions were compared to the community conditions in warmed plots at sampling 3 (E3)

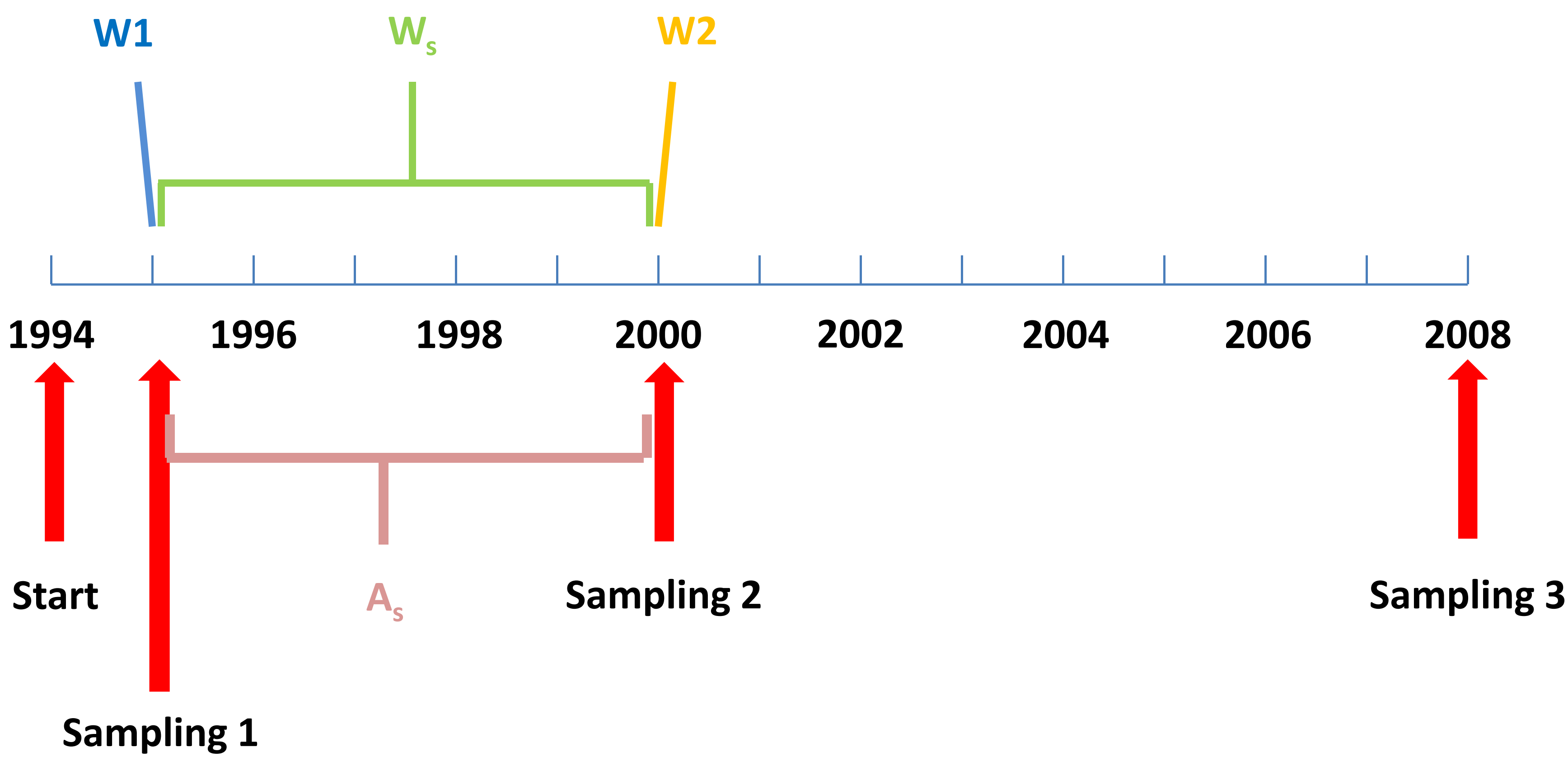
Using early year response to predict later years



Let's use the Barrow Dry Site as an example

Calculating Estimates For Predictions

Used plant cover averages at each site for each growth form



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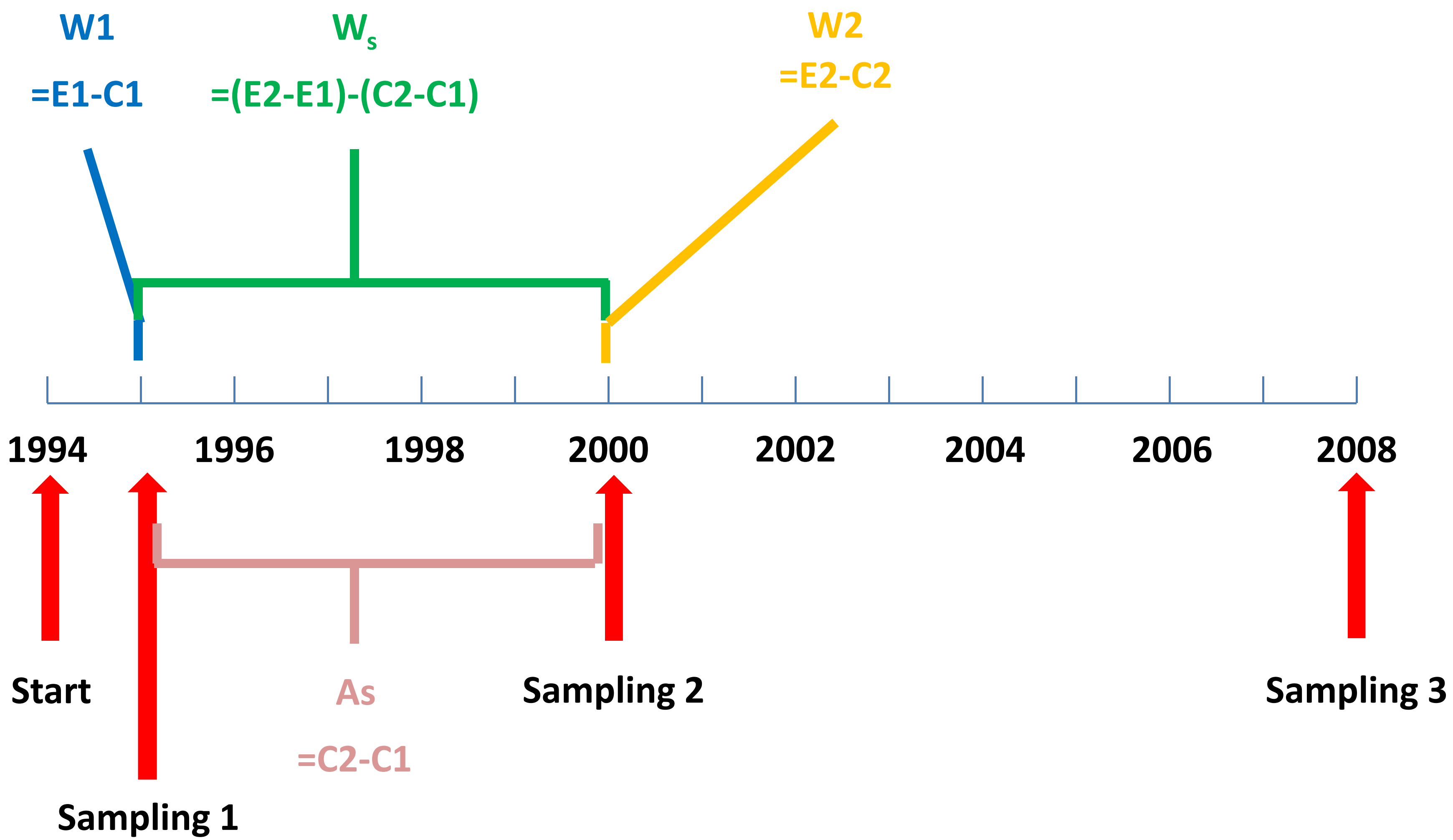
Calculating Estimates For Predictions

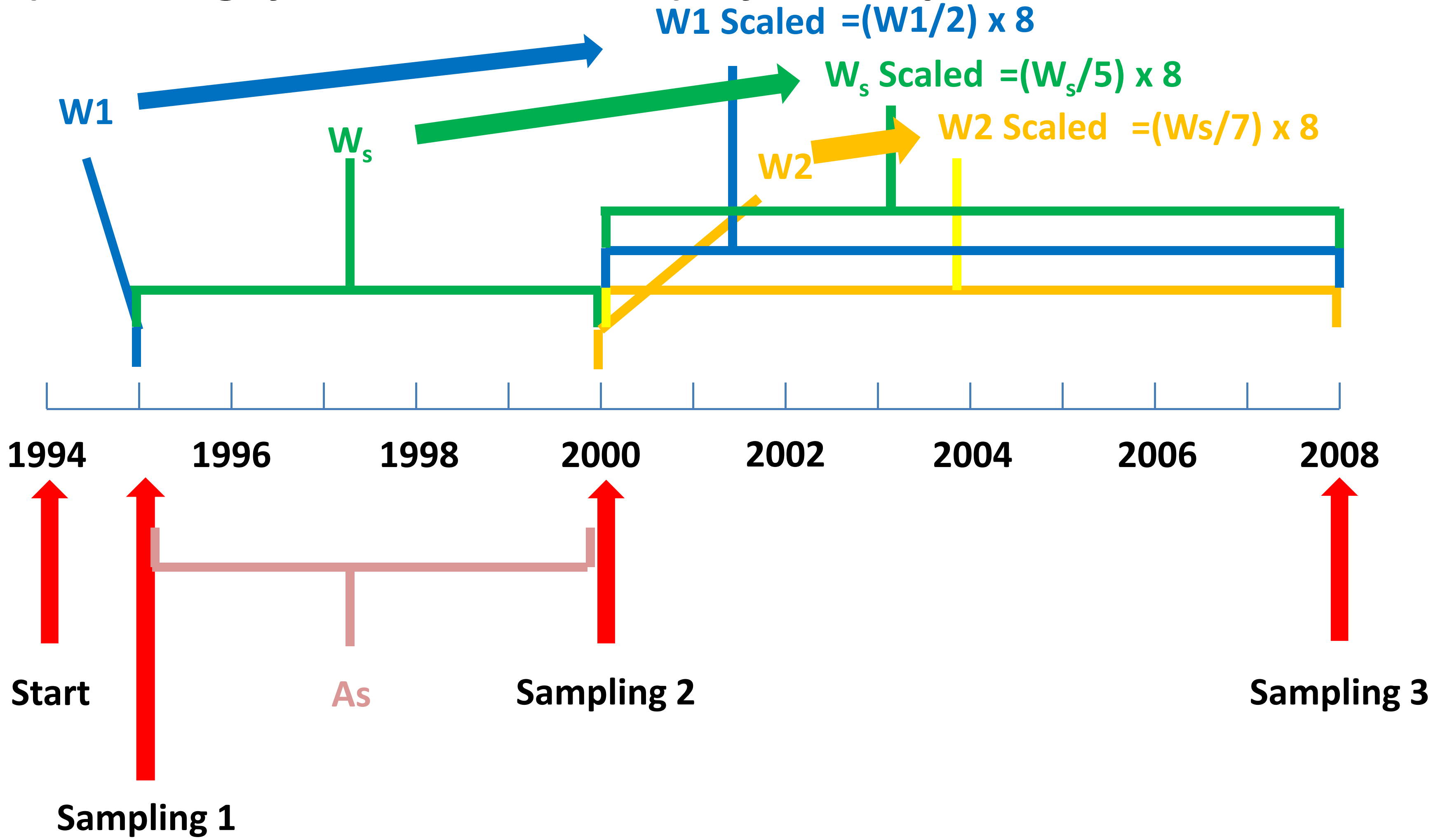


Let's use the Barrow Dry Site as an example

Calculating Estimates For Predictions

Scale Wi and Ws to the length of Wt

=(Warming/years of treatment) x years of prediction

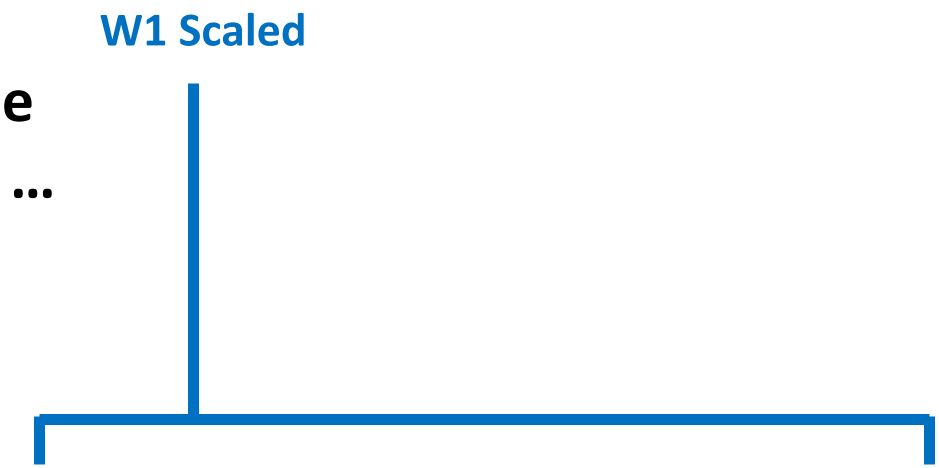


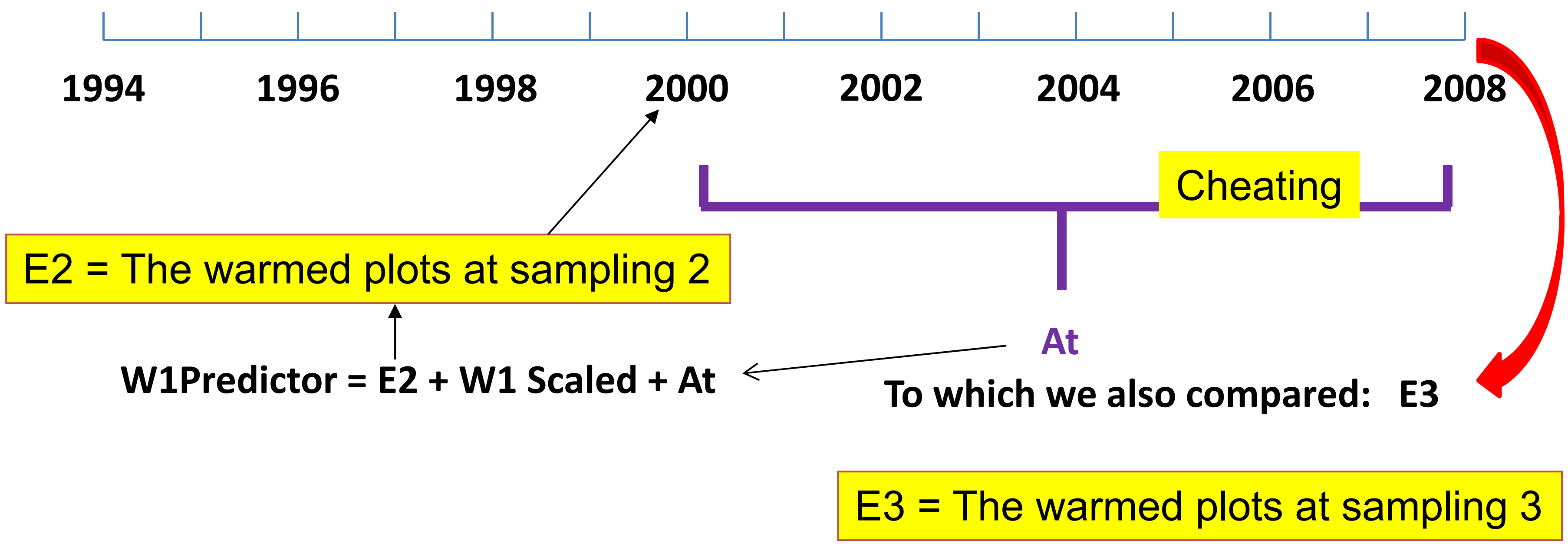
Let's use the Barrow Dry Site as an example

Calculating Estimates For Predictions

Now that we have all of the warming responses scaled …

We have to add warming and ambient responses together to get predicted values





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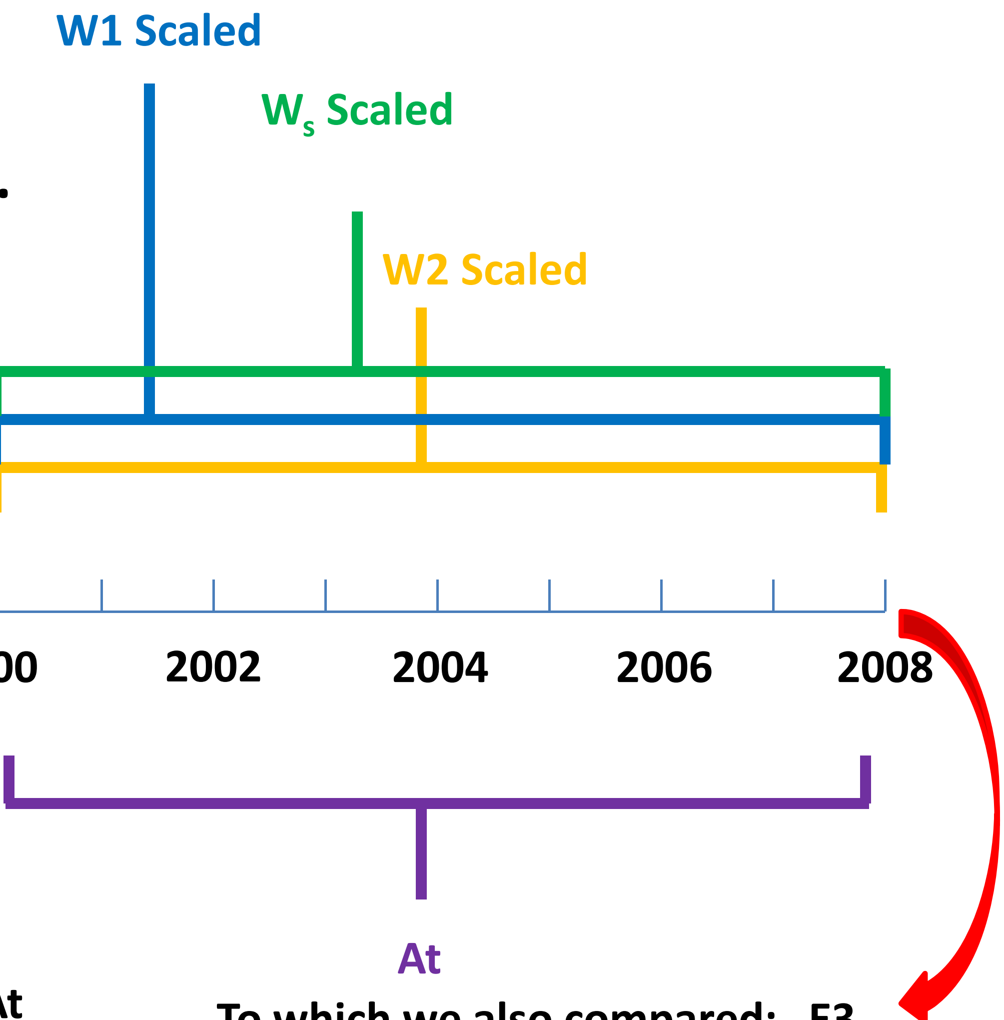

W1Predictor = E2 + W1 Scaled + At

W_sPredictor = E2 + Ws Scaled + At

W2Predictor= E2 + W2 Scaled + At

To which we also compared: E3

using a analysis of variance with Tukey's post hoc analysis

Community Index Predictions

Index	E3	W1	W_s	W2
Live Cover				
AD	96.13 A	134.75 B	86.77 A	102.76 A

Predictions were considered to be accurate if they were not statistically different from E3 values

Community Index Predictions

Predictions were considered to be accurate if they were not statistically different from E3 values

Index	E3	W1	W_s	W2
Live Cover				
AD	96.13 A	134.75 B	86.77 A	102.76 A
AW	141.38 A	115.85 B	139.70 A	131.75 AB
BD	92.42 A	86.92 A	63.19 B	69.13 B
BW	78.42 A	62.63 AB	46.99 B	51.46 B
Dead Cover				
AD	31.83 A	42.94 B	31.49 A	35.31 A
AW	27.63 A	50.98 C	31.51 AB	38.00 B
BD	48.21 A	55.38 C	41.32 B	44.83 AB
BW	85.96 A	96.08 B	88.68 AB	90.8 B
Litter Cover				
AD	13.21 AB	6.40 A	15.07 B	12.18 AB
AW	3.67 A	13.48 B	8.23 C	9.98 C
BD	12.38 A	23.38 B	12.32 A	15.08 A
BW	24.71 A	28.5 AB	38.53 B	35.67 B
Vascular Plant Cover				
AD	50.88 A	59.54 A	57.43 A	57.98 A
AW	47.08 AB	33.69 A	55.20 B	48.08 AB
BD	70.25 A	79.25 A	58.92 B	64.37 AB
BW	60.46 A	47.38 B	46.98 B	47.11 B
Nonvascular Plant Cover (including Bare Ground)				
AD	45.25 AB	75.21 A	29.34 B	39.21 AB
AW	94.29 A	82.02 B	84.57 AB	83.01 AB
BD	22.17 A	7.67 B	4.28 B	5.78 B
BW	17.79 A	15.5 A	-0.43 B	3.56 B
Species Richness				
AD	15.38 A	15.42 A	15.85 A	15.71 A
AW	11.29 A	8.85 B	10.68 A	10.07 AB
BD	16.96 A	15.71 A	16.82 A	16.54 A
BW	14.79 A	13.42 A	17.18 B	16.11 AB
Shannon Index				
AD	2.39 A	2.37 A	2.41 A	2.40 A
AW	1.84 A	1.89 A	1.85 A	1.86 A
BD	2.22 A	2.31 AB	2.43 C	2.40 BC
BW	2.13 A	2.22 A	2.25 A	2.24 A

Community Index Predictions

Overall the ability to predict E3 varied greatly depending on site and index

W2 was the best predictor

W1: 16 out of 28 cases

W_s: 17 out of 28 cases

W2: 18 out of 28 cases

Statistical predictions still not highly accurate

Best predictions were Shannon diversity

Index	E3	W1	W_s	W2
Live Cover				
AD	96.13 A	134.75 B	86.77 A	102.76 A
AW	141.38 A	115.85 B	139.70 A	131.75 AB
BD	92.42 A	86.92 A	63.19 B	69.13 B
BW	78.42 A	62.63 AB	46.99 B	51.46 B
Dead Cover				
AD	31.83 A	42.94 B	31.49 A	35.31 A
AW	27.63 A	50.98 C	31.51 AB	38.00 B
BD	48.21 A	55.38 C	41.32 B	44.83 AB
BW	85.96 A	96.08 B	88.68 AB	90.8 B
Litter Cover				
AD	13.21 AB	6.40 A	15.07 B	12.18 AB
AW	3.67 A	13.48 B	8.23 C	9.98 C
BD	12.38 A	23.38 B	12.32 A	15.08 A
BW	24.71 A	28.5 AB	38.53 B	35.67 B
Vascular Plant Cover				
AD	50.88 A	59.54 A	57.43 A	57.98 A
AW	47.08 AB	33.69 A	55.20 B	48.08 AB
BD	70.25 A	79.25 A	58.92 B	64.37 AB
BW	60.46 A	47.38 B	46.98 B	47.11 B
Nonvascular Plant Cover (including Bare Ground)				
AD	45.25 AB	75.21 A	29.34 B	39.21 AB
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Shannon Index				
AD	2.39 A	2.37 A	2.41 A	2.40 A
AW	1.84 A	1.89 A	1.85 A	1.86 A
BD	2.22 A	2.31 AB	2.43 C	2.40 BC
BW	2.13 A	2.22 A	2.25 A	2.24 A

Canopy Height Predictions

Examined ability to predict:

Maximum Canopy Height

Average Canopy Height

Maximum Canopy Height by Growth Form

Growth Form	E3	W1	W_s	W2
Atqasuk Dry Site				
Maximum	14.9A	19.5B	7.3C	11.0AC
Average	1.4A	0.8B	1.2A	1.2A
Evergreen Shrub	1.4A	0.0B	1.2A	1.1A

Canopy Height Predictions

Predictive accuracy again varies by site and canopy type

W2 was still the best predictor

- W1 - 4 out of 17 cases
- W_s – 13 out of 17 cases
- W2 - 14 out of 17 cases

Statistical predictions were still not highly accurate

Average canopy height was the best predicted values

Growth Form	E3	W1	W_s	W2
Atqasuk Dry Site				
Maximum	14.9A	19.5B	7.3C	11.0AC
Average	1.4A	0.8B	1.2A	1.2A
Evergreen Shrub	1.4A	0.0B	1.2A	1.1A
Graminoid	8.2A	11.4B	8.0A	8.5A
Atqasuk Wet Site				
Maximum	27.8A	36.5B	29.4A	31.8AB
Average	8.0A	8.3A	6.8A	7.4A
Deciduous Shrub	7.2A	10.0B	8.6AB	9.1AB
Graminoid	18.5A	26.0B	22.2AB	24.1B
Barrow Dry Site				
Maximum	12.8A	21.0B	12.6A	13.8A
Average	1.6AB	1.3A	2.8B	2.1AB
Deciduous Shrub	0.2A	0.0B	2.2C	1.8C
Forb	6.0A	1.5B	1.4B	1.5B
Graminoid	6.4A	9.0B	3.7C	5.3AC
Barrow Wet Site				
Maximum	15.0A	24.6B	13.1A	15.4A
Average	4.0AB	6.6A	3.0B	4.1AB
Forb	3.4A	9.5B	2.2A	4.0A
Graminoid	9.6AB	11.2A	8.6B	9.4AB

Cover Predictions

Growth Form	E3	W1	W_s	W2
		Atqasuk Dry Site		
Deciduous Shrub	0.46 A	-0.48 B	0.91 A	0.44 A

Cover Predictions

Predictive ability varies across sites and growth forms

W2 was still the best predictor

W1 – 13 out of 21 cases

W_s – 15 out of 21 cases

W2 – 16 out of 21 cases

Once again statistical predictions were not highly accurate

Graminoids were the best

Growth Form	E3	W1	W_s	W2
Atqasuk Dry Site				
Deciduous Shrub	0.46 A	-0.48 B	0.91 A	0.44 A
Evergreen Shrub	33.00 A	41.52 AB	43.93 B	43.13 B
Forb	1.54 A	1.44 A	2.02 A	1.83 A
Graminoid	15.88 AB	17.06 A	10.57 C	12.74 BC
Bryophyte	7.88 AB	11.19 A	4.11 B	6.47 B
Lichen	37.38 AB	64.02 C	25.23 A	38.16 B
Atqasuk Wet Site				
Deciduous Shrub	6.96 A	1.10 B	9.42 A	6.65 A
Forb	0.17 A	0.35 A	-0.08 A	0.06 A
Graminoid	39.96 A	32.23 B	45.86 A	41.32 A
Bryophyte	94.08 A	82.06 B	85.20 B	84.15 B
Lichen	0.21 A	-0.04 AB	-0.63 B	-0.43 AB
Barrow Dry Site				
Deciduous Shrub	20.00 A	19.79 A	14.90 A	16.13 A
Evergreen Shrub	23.08 A	36.63 B	21.85 A	25.54 A
Forb	10.92 A	4.96 B	5.13 B	5.08 B
Graminoid	16.25 A	17.88 A	17.04 A	17.25 A
Bryophyte	6.29 A	-5.50 C	1.39 AB	-0.33 B
Lichen	15.88 A	13.17 AB	2.89 C	5.46 BC
Barrow Wet Site				
Deciduous Shrub	1.75 A	1.29 A	1.36 A	1.34 A
Forb	15.71 A	2.96 B	12.63 A	9.86 AB
Graminoid	43.00 A	43.13 A	32.99 A	35.89 A
Bryophyte	16.08 A	14.67 A	-3.30 B	1.83 C
Lichen	1.71 A	0.83 A	2.87 A	2.29 A

Summary of taxa cover predictions

All three predictors could only statistically predict 58-67% of taxa cover (83 taxa total)

Of those W2 was the best

Statistically accurate predictions were categorized by how close they were to E3 values

	W1	W_s	**W2**
Statistically different	35	35	27
Not Statistically different	48	48	56
>5% (poor)	4	8	5
1 to 5% (fair)	20	28	29
<1% (good)	24	12	22

W1 had the highest number of “good” predictions however only for 29% of taxa (24 out of 83 cases)

Prediction Summary

Predictive ability of early warming responses varied greatly by site and measure

Overall warming response through sampling 2 (W2) was the best overall predictor however was still poor

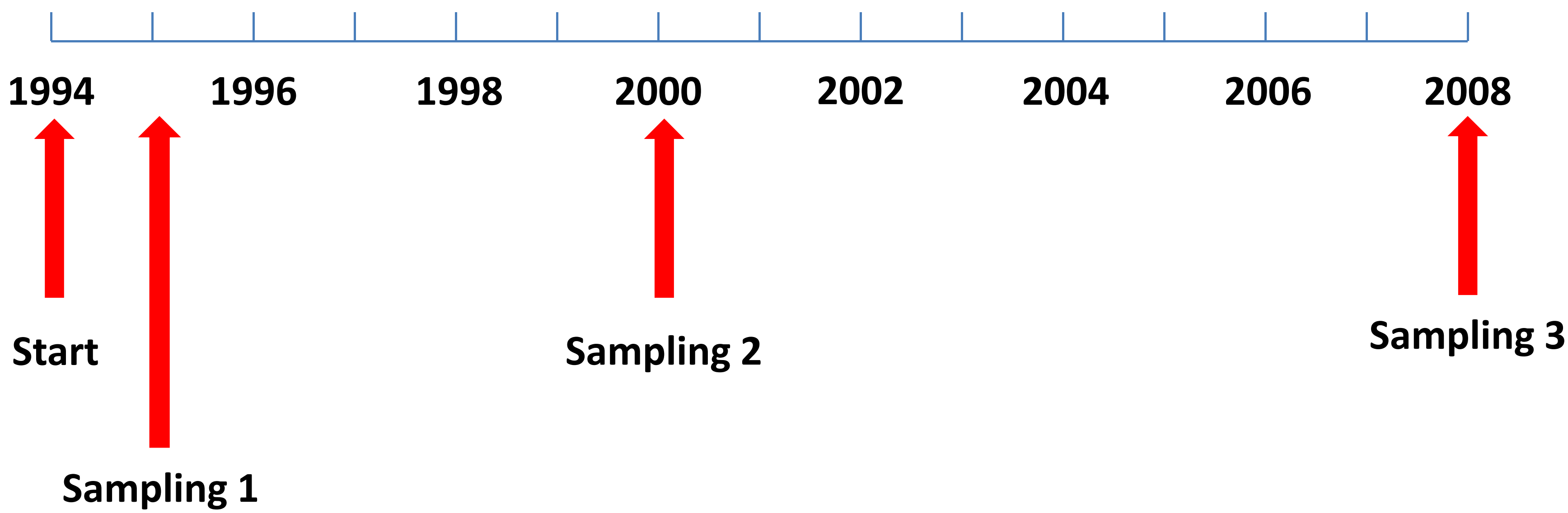
Now the question is, why are early warming responses such poor predictors of later warming responses?

The next step is to investigate any inconsistencies in warming responses over time and landscape

Part III: Community Change Over Time and in Response to Warming

Used point frame data to evaluate how changes in control plots and responses to warming differ over time and space

Once again focusing on community indices, canopy heights, and taxa/growth form cover but also climate data from both Barrow and Atqasuk

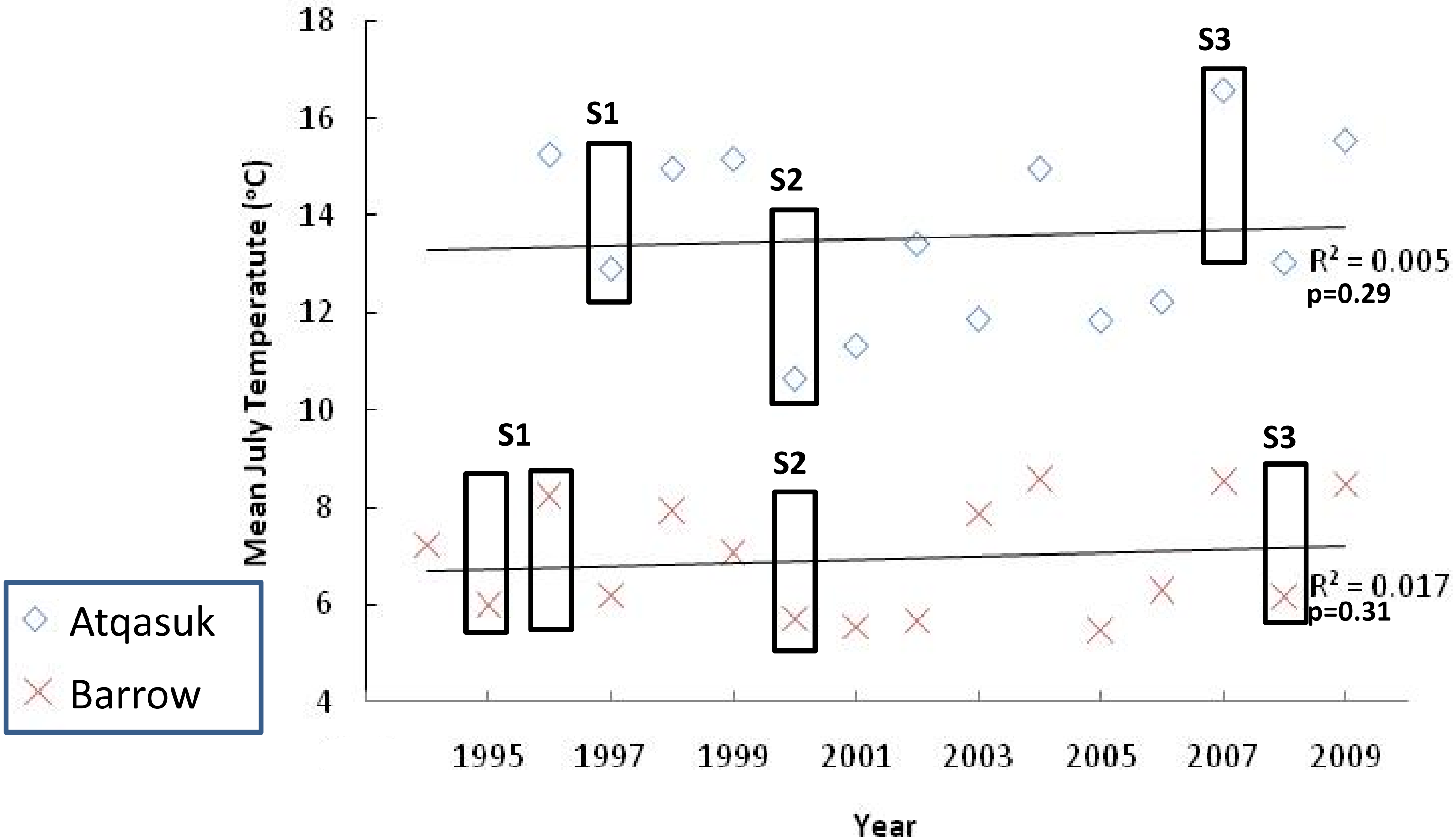


First lets look at climate data…

July mean temperatures for the duration of the study in both Barrow and Atqasuk

Data collected at a height of 2m

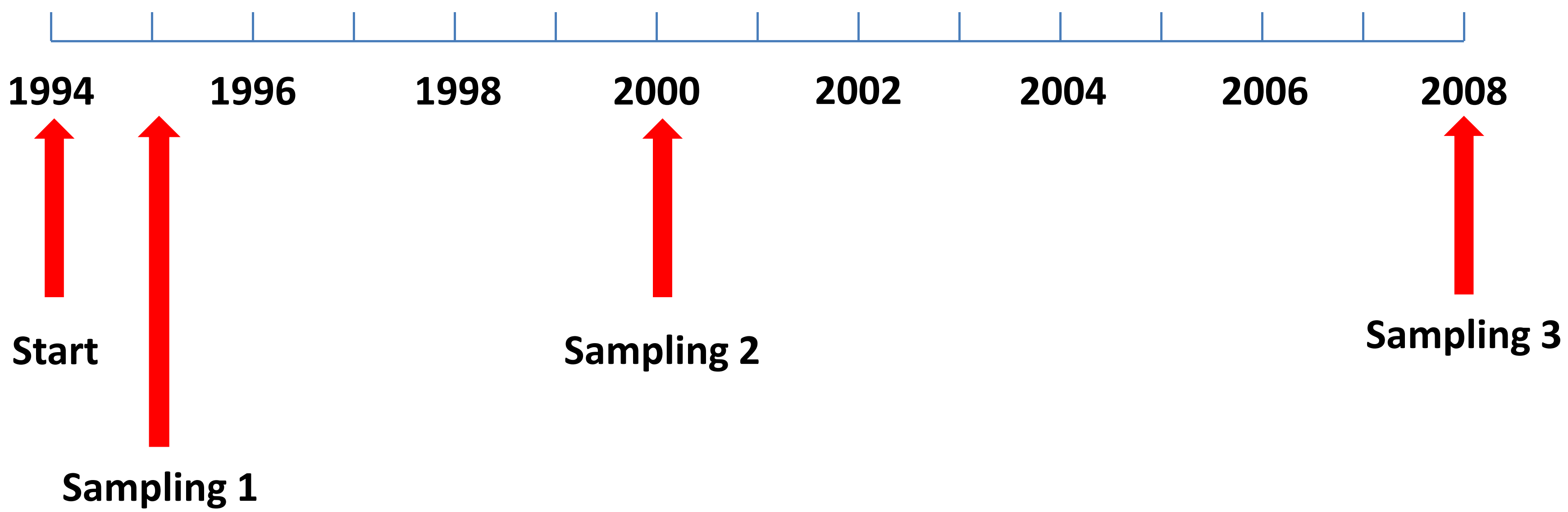
Climate Data



Both Barrow and Atqasuk show slightly increasing trends however neither are statistically significant

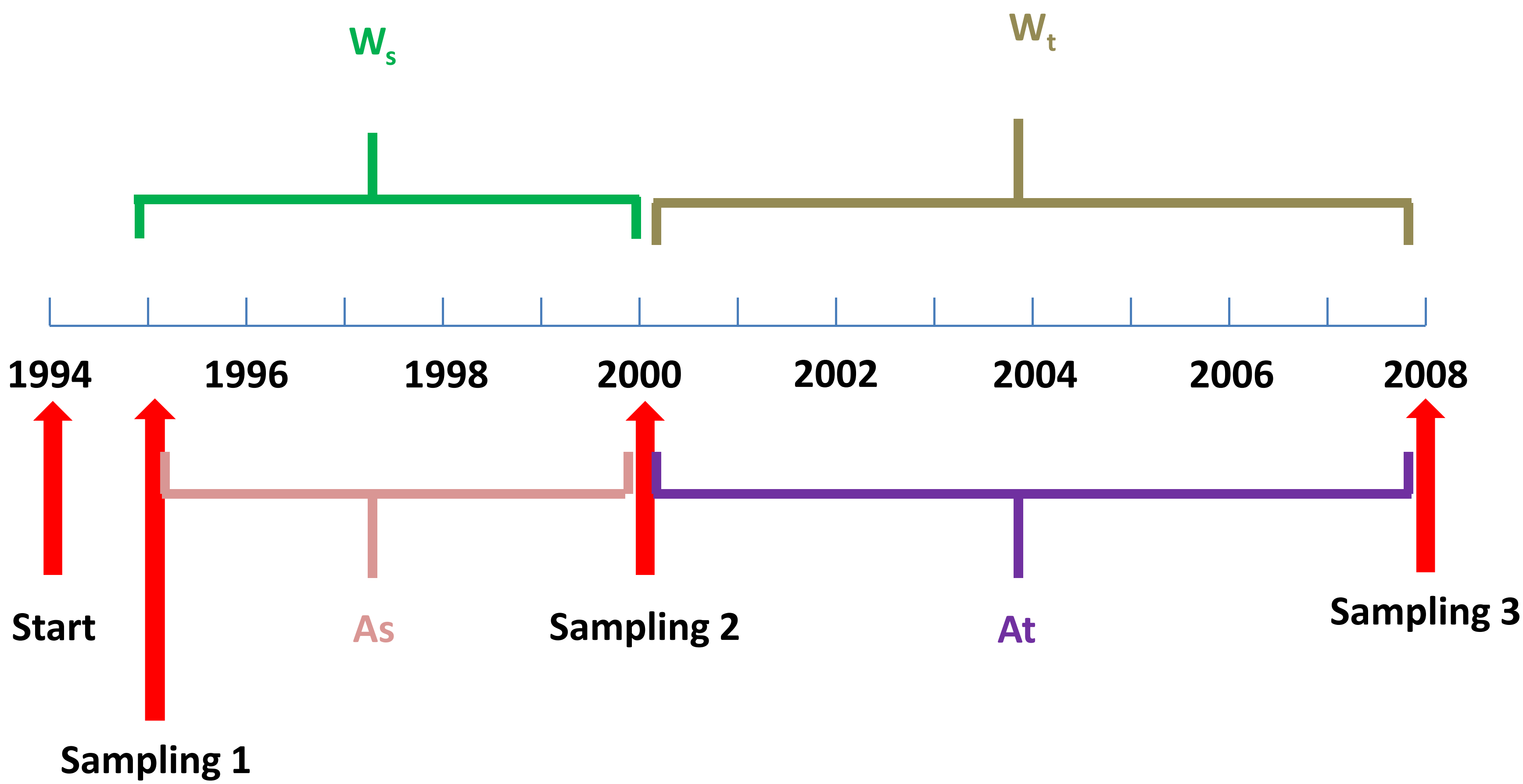
Part III: Community Change Over Time and in Response to Warming

Focus on Consistency over time



Part III: Community Change Over Time and in Response to Warming

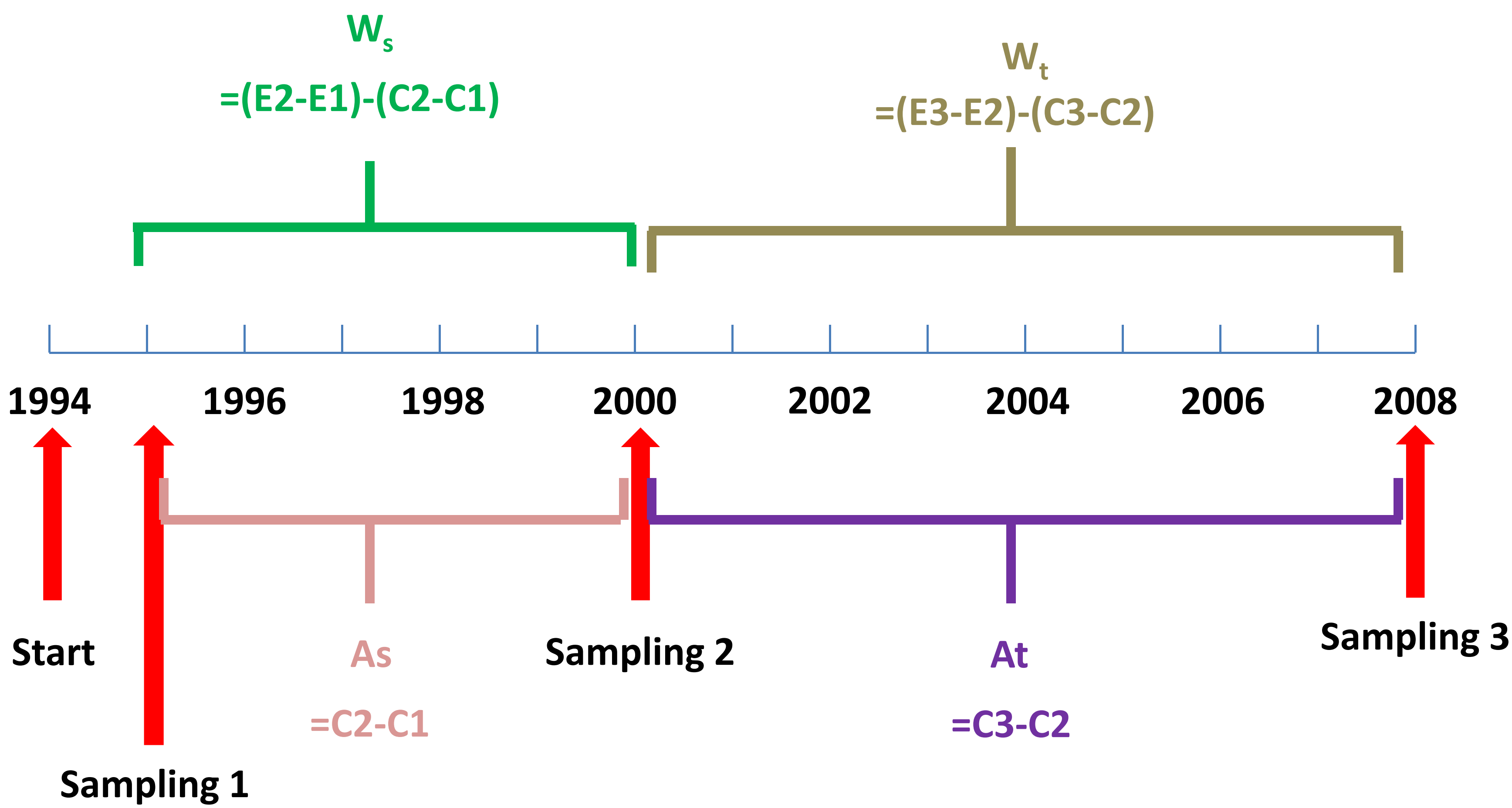
Focus on Consistency over time



Part III: Community Change Over Time and in Response to Warming

Calculations of change were made using similar methods as with predictions

Analysis of variance was used for all statistical analysis

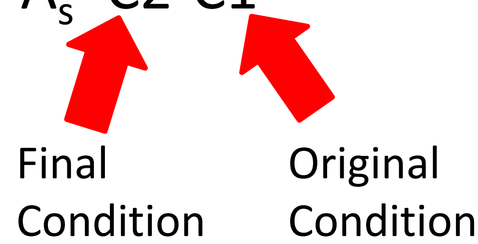


	Scaled			
	A_s	A_t	W_s	W_t
Live Cover				
AD	-41.42 *	3.35	-15.90	-6.54

Community Indices

Asterisks denote statistical differences between original and final condition

For example A_s=C2-C1



Values reported are scaled similarly to those of predictions

For example W_s Scaled =(W_s/5) x 8

	Scaled						
	A_s		A_t		W_s	W_t	
Live Cover							
AD	-41.42	*	3.35	I	-15.90	-6.54	C

Community Indices

Change in control plots and in response to warming were categorized one of three ways:

No Change (N)- Change of less than 1% of cover

Inconsistent (I)- Change in different directions or from no change to a change

Consistent (C)- Change in the same direction

Community Indices

	Scaled					
	A_s	A_t		W_s	W_t	
Live Cover						
AD	-41.42*	3.35	I	-15.90	-6.54	C
AW	-12.98	11.89*	I	9.99	11.67*	C
BD	198.00*	-29.78*	I	-20.89*	8.33	I
BW	125.83*	-83.40*	I	-22.47	8.96	I
Dead Cover						
AD	-25.81*	34.78*	I	0.66	1.00	I
AW	26.83*	-28.15*	I	-0.95	-4.83	I
BD	-12.83*	28.50*	I	2.28	9.17*	C
BW	-1.83	57.67*	I	7.60	4.88	C
Litter Cover						
AD	-37.19*	-2.77	C	4.16	2.29	C
AW	-15.02*	9.84*	I	-1.6	-6.17*	C
BD	-8.33	5.78*	I	-1.39	-1.33	C
BW	34.83*	28.07*	C	7.53?	-6.29?	I
Vascular Plant Cover						
AD	-35.58*	40.18*	I	0.80	-5.75	I
AW	-26.25*	21.73*	I	10.86*	2.75	C
BD	119.33*	-11.00	I	-0.83	10.50	I
BW	65.50*	-37.00*	I	-4.07	9.42	I
Nonvascular Plant Cover (including Bare Ground)						
AD	-5.83	-36.82*	C	-16.70*	-0.79	I
AW	13.27*	-9.84*	I	-0.80	8.92*	I
BD	78.67*	-18.78*	I	-20.06*	-2.17	C
BW	61.00*	-46.80*	I	-18.60*	-0.38	I
Species Richness						
AD	-2.92	-0.88	I	-0.15	-0.63	N
AW	-7.44*	0.44	I	-0.36	0.25	N
BD	1.83	0.11	N	-1.39	-1.25	C
BW	-10.83*	0.67	I	0.93	-1.46	I
Shannon Index						
AD	-0.03	-0.06	N	0.02	0.03	N
AW	-0.68	-0.20	C	-0.03	0.02	N
BD	-0.21	0.16	N	-0.01	0.12*	N
BW	-0.63*	0.20	I	-0.04	0.05	N

Changes in control plots and in response to warming were often inconsistent across time and landscape

Responses to warming were overall more consistent than changes in control plots

Most sites showed an overall increase in vascular plant cover and an overall decrease in nonvascular plant cover

Diversity indices were mixed

Canopy Height

	Scaled				
	A_s	A_t	W_s	W_t	
	Atqasuk Dry Site				
Maximum	**-9.0***	**9.9*** **I**	**-4.8***	**2.8**	**I**
Average	**-0.7**	**-0.8*** **C**	**0.0**	**0.2**	**N**
Evergreen Shrub	**0.5**	**-0.9*** **I**	**0.1**	**0.3**	**N**

Canopy Height

	Scaled					
	A_s	A_t		W_s	W_t	
	Atqasuk Dry Site					
Maximum	-9.0*	9.9*	I	-4.8*	2.8	I
Average	-0.7	-0.8*	C	0.0	0.2	N
Evergreen Shrub	0.5	-0.9*	I	0.1	0.3	N
Graminoid	-8.6*	6.5*	I	-0.3	-0.1	N
	Atqasuk Wet Site					
Maximum	-9.6*	8.7*	I	1.7	0.2	I
Average	-1.9	-2.9*	C	0.5	1.7*	I
Deciduous Shrub	0.1	1.1	I	1.2	-0.2	I
Graminoid	-4.6	4.4	I	2.1	-0.8	I
	Barrow Dry Site					
Maximum	7.4*	2.8	C	1.2	1.4	C
Average	-8.4*	-0.6*	C	1.2	0.0	I
Deciduous Shrub	-0.8	-0.9	N	1.3	-0.7	I
Evergreen Shrub	-3.0	1.5	I	0.4	0.0	N
Forb	-2.8	0.5	I	-0.8	4.0*	I
Graminoid	9.1*	0.2	I	-0.8	2.6	I
	Barrow Wet Site					
Maximum	9.9*	2.7	C	-1.5	0.4	N
Average	3.3*	-1.7*	I	-0.4	0.6	N
Forb	-4.8*	1.1	I	-1.2	0.0	I
Graminoid	8.8*	1.6	C	0.0	1.0	I

Once again changes in control plots and in response to warming were often inconsistent

Changes in control plots showed an overall greater change in canopy height than in response to warming and were more consistent

Despite varied responses to warming there was an overall increase in canopy height

Growth Form Cover

	Scaled					
Growth Form	A_s	A_t		W_s	W_t	
	Atqasuk Dry Site					
Deciduous Shrub	**-0.4**	**0.4**	**-**	**0.4**	**-0.1**	**-**

Growth Form Cover

Growth Form	Scaled A_s	A_t		W_s	W_t	
	Atqasuk Dry Site					
Deciduous Shrub	-0.4	0.4	-	0.4	-0.1	-
Evergreen Shrub	-22.8*	22.7*	I	4.9	-6.0	I
Forb	-1.0	0.8	-	0.7	0.3	-
Graminoid	-11.4	16.3*	I	-5.2	0.1	I
Bryophyte	6.6	-7.1*	I	-3.1	0.6	I
Lichen	-12.4	-29.8*	C	-13.6	-1.4	C
	Atqasuk Wet Site					
Deciduous Shrub	2.0	-1.0	I	2.0	-0.4	I
Forb	-0.1	-0.2	-	-0.3	0.0	-
Graminoid	-28.1*	23.0*	I	9.1*	3.2	C
Bryophyte	14.6*	-9.3?	I	-0.2	8.7*	I
Lichen	-1.3	-0.5	-	-0.6	0.3	-
	Barrow Dry Site					
Deciduous Shrub	53.8*	-5.3	I	-5.4*	-0.3	I
Evergreen Shrub	36.2*	-4.9	I	0.7	2.0	I
Forb	12.5*	-0.7	I	-1.0	4.8*	I
Graminoid	16.8*	-0.1	I	4.8*	4.0*	C
Bryophyte	35.2*	-10.8*	I	-4.3	0.6	I
Lichen	43.5*	-8.0*	I	-15.8*	-2.8	C
	Barrow Wet Site					
Deciduous Shrub	-0.5	-0.1	-	0.7	1.1	-
Forb	-12.7	-2.3	C	1.0	4.1	I
Graminoid	78.7*	-34.6*	I	-5.8	4.2	I
Bryophyte	58.0*	-50.3*	I	-17.5*	1.9	I
Lichen	3.0	3.5	C	-1.1	-2.3*	C

Changes in control plots and in response to warming were once again often inconsistent

Changes in control plots were larger overall than in response to warming

Vascular plant responses to warming were mixed but nonvascular often decreased in cover

Summary of Taxa Changes and Responses

	Ambient				Warmed			
	N	I	C-	C+	N	I	C-	C+
Site								
Atqasuk Dry	0	17	3	0	2	13	5	0

Summary of Taxa Changes and Responses

	Ambient				Warmed			
	N	I	C-	C+	N	I	C-	C+
Site								
Atqasuk Dry	0	17	3	0	2	13	5	0
Atqasuk Wet	0	13	0	1	1	7	0	6
Barrow Dry	1	23	0	1	3	15	3	4
Barrow Wet	1	19	1	2	0	19	4	0
Growth Form								
Deciduous Shrub	0	5	0	0	0	4	0	1
Evergreen Shrub	0	7	0	0	1	5	0	1
Forb	1	12	1	1	0	14	0	0
Graminoid	1	27	0	0	2	17	3	6
Bryophyte	0	16	0	1	1	12	3	1
Lichen	0	5	3	2	2	1	7	0
Total	**2**	**71**	**4**	**4**	**6**	**54**	**13**	**9**

Across all sites most changes in control plots and responses to warming were inconsistent

Responses to warming were more often consistent than changes in control plots

Consistent responders to warming varied by growth form

Euclidean Distance of Community Change

	A_s	A_t	W1	W2	W3	W_s	W_t
Measured Values							
AD	10.5	15.8	8.7	6.1	5.5	6.5	7.6
AW	12.4	14.4	3.0	4.4	9.3	5.1	7.0
BD	19.9	8.7	4.8	13.5	16.4	11.2	5.8
BW	17.5	27.0	6.0	9.8	12.6	9.4	8.4
Scaled to 5 Years							
AD	13.1	11.3	21.8	5.1	2.1	8.1	5.4
AW	15.5	10.3	7.4	3.6	3.6	6.4	5.0
BD	16.6	5.4	12.1	8.4	5.1	9.3	3.6
BW	17.5	16.9	15.1	7.0	4.2	9.4	5.3

Scaled values show changes in control plots were larger than responses to warming

Warming responses are larger in earlier years and taper later

Community Change Summary

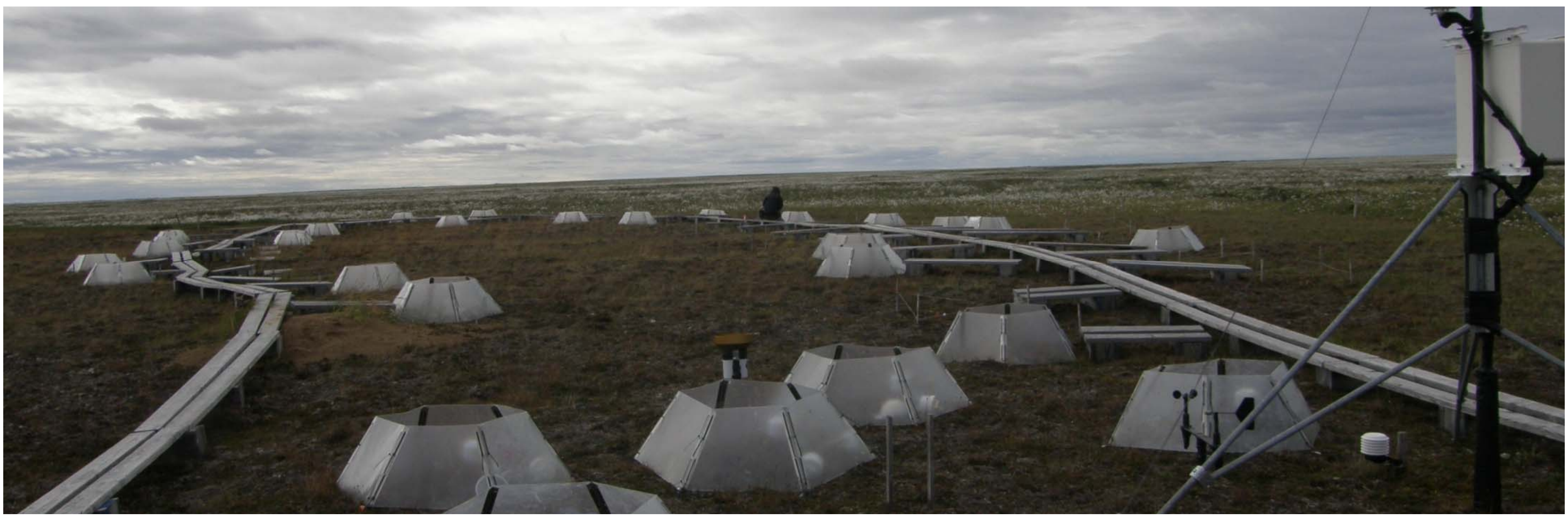
Temperature trends in Barrow and Atqasuk are similar to those in other high latitude areas

(IPCC 2007; Serreze et al 2000; Stafford et al 2000)

Changes in controls were often larger than responses to warming, possibly to due factors besides temperature

Such as soil moisture or sky conditions

(Cooper et al 2011; Phoenix and Lee 2004;Walker et al 1994)



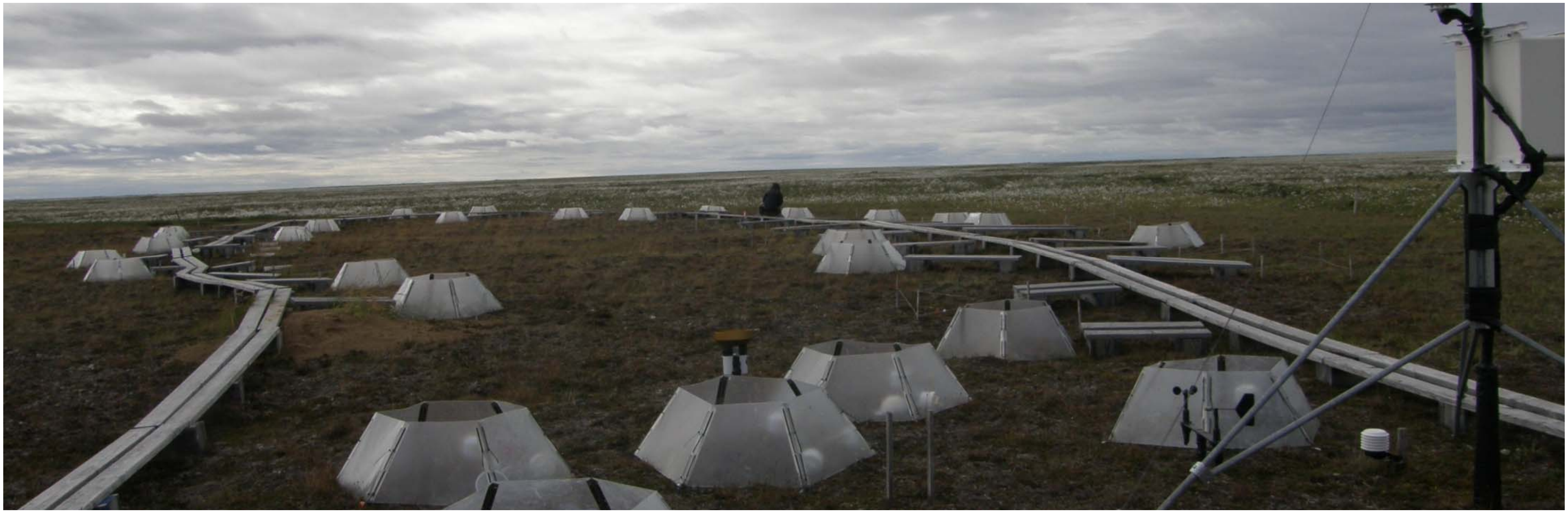
Community Change Summary

Responses to warming declined over time

- Early responses are increased growth and later responses are competitive shifts
- May also be a result of control changes due to regional warming Chapin et al 1995; Shaver and Jonasson 1999; Walker et al 2006)

Despite heterogeneity responses to warming are often more consistent than changes in control plots

- Graminoids and shrubs increase, nonvascular decrease



Conclusions

Top and bottom only method of point framing is an accurate and time saving method of vegetation sampling

Warming responses in early years are poor predictors of responses in later years

Community responses to warming are heterogeneous

- Responses declined over time
- Growth forms respond differently according to location and community

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Bob Hollister, Gary Greer, Jim Dunn, and Heather Rueth

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GVSU Biology department and my fellow grad students

My wife, Jessica, for her constant support


Questions?

Future work

Use different grouping scheme to see if trends were more consistent

i.e. early flowering plants or high/low arctic plants

Implications of community change

Forage quality could change (less lichens in the winter to sustain caribou)

Loss of mosses could effect soil moisture and decomposition rates