CASSIOPE TETRAGONA AS A DENDROECOLOGICAL PROXY: A RETROSPECTIVE ANALYSIS OF EXPERIMENTAL WARMING IN THE ARCTIC TUNDRA

THE UNIVERSITY OF BRITISH COLUMBIA

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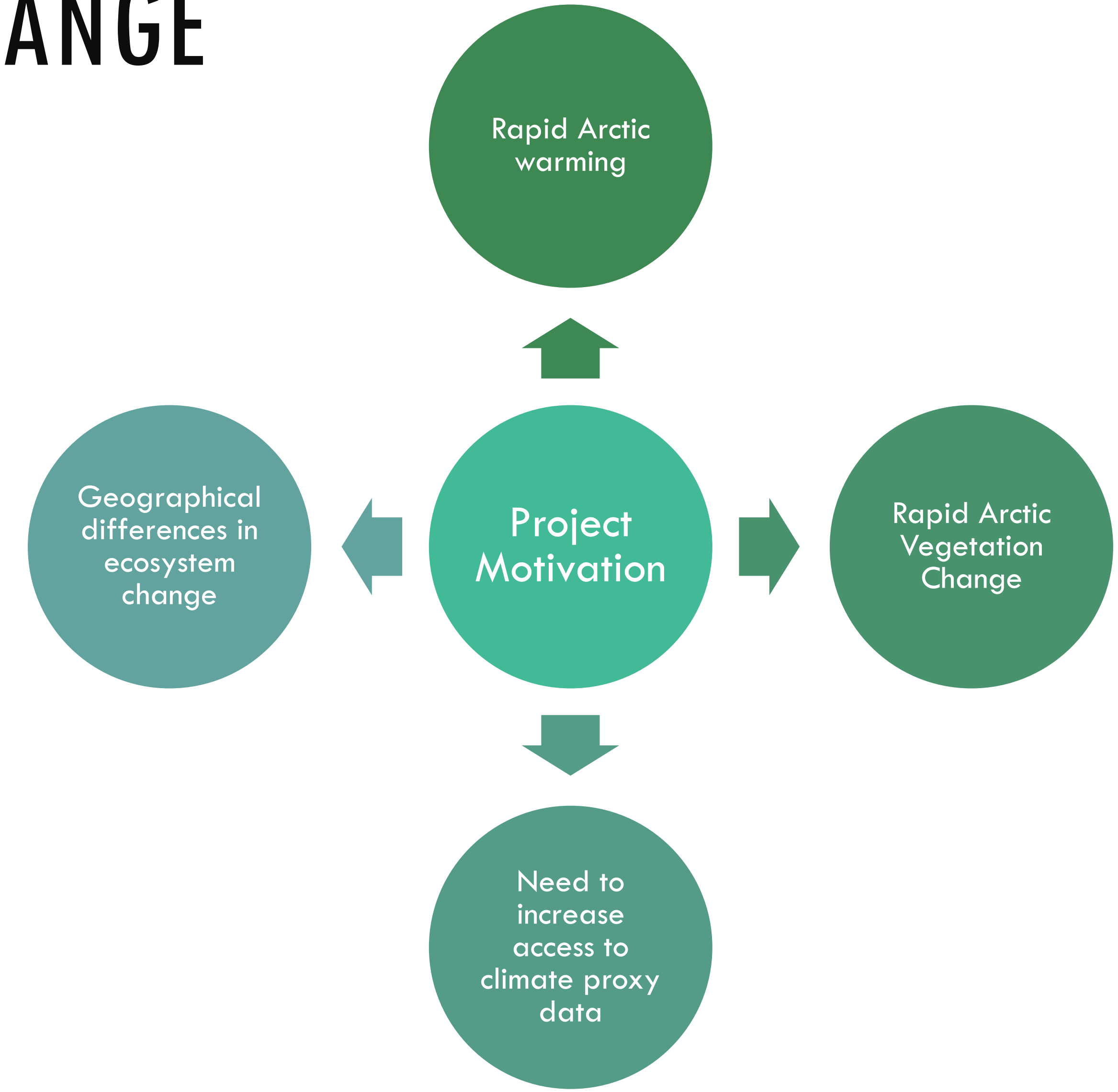
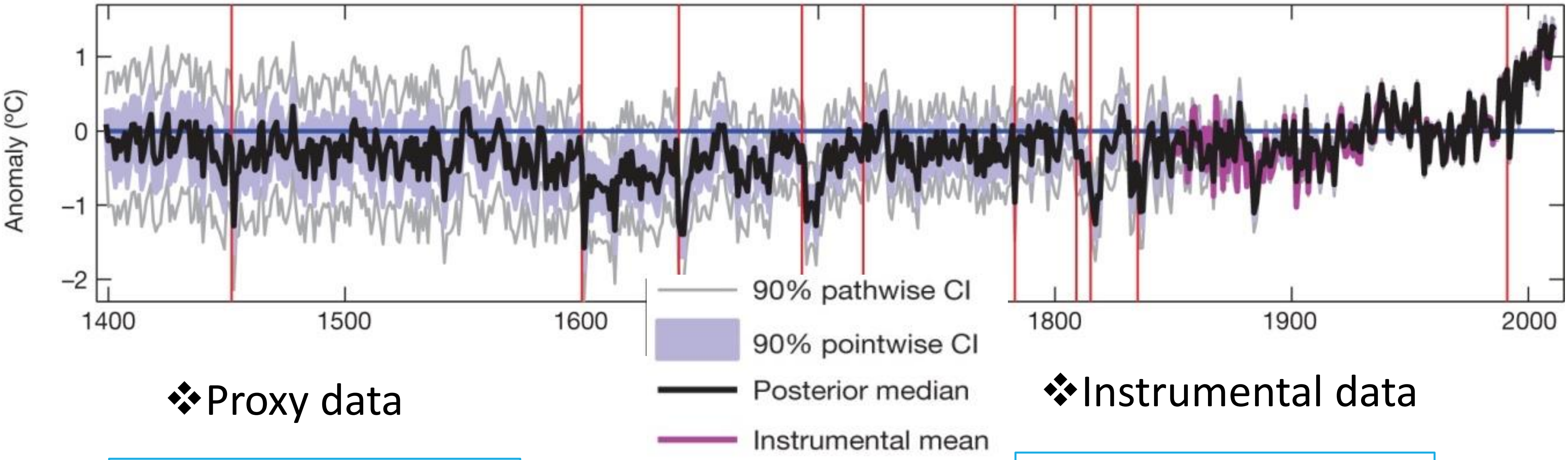
ARCTIC ECOSYSTEM CHANGE



Arctic climate & ecosystem data



❖Proxy data

-**Tree rings, ice core, lake sediments**

❖Instrumental data

-**Climate Stations geographically sparse**
-**Temporal limitations**

Tingley & Huybers, 2013

DENDROCHRONOLOGY

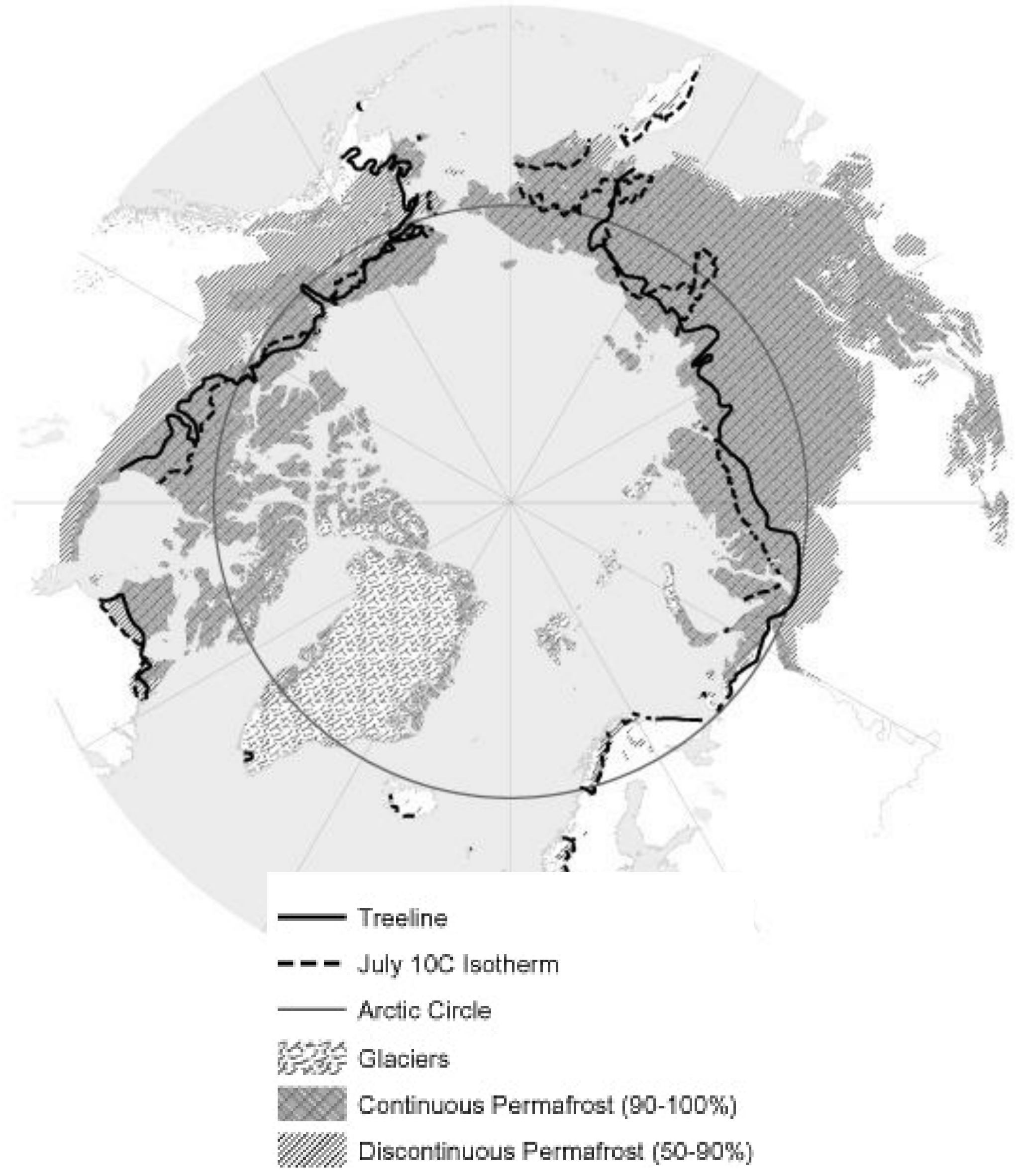
❖ **Fritts 1976:**

1) Widespread throughout the region of study

2) Sensitive to environmental variability

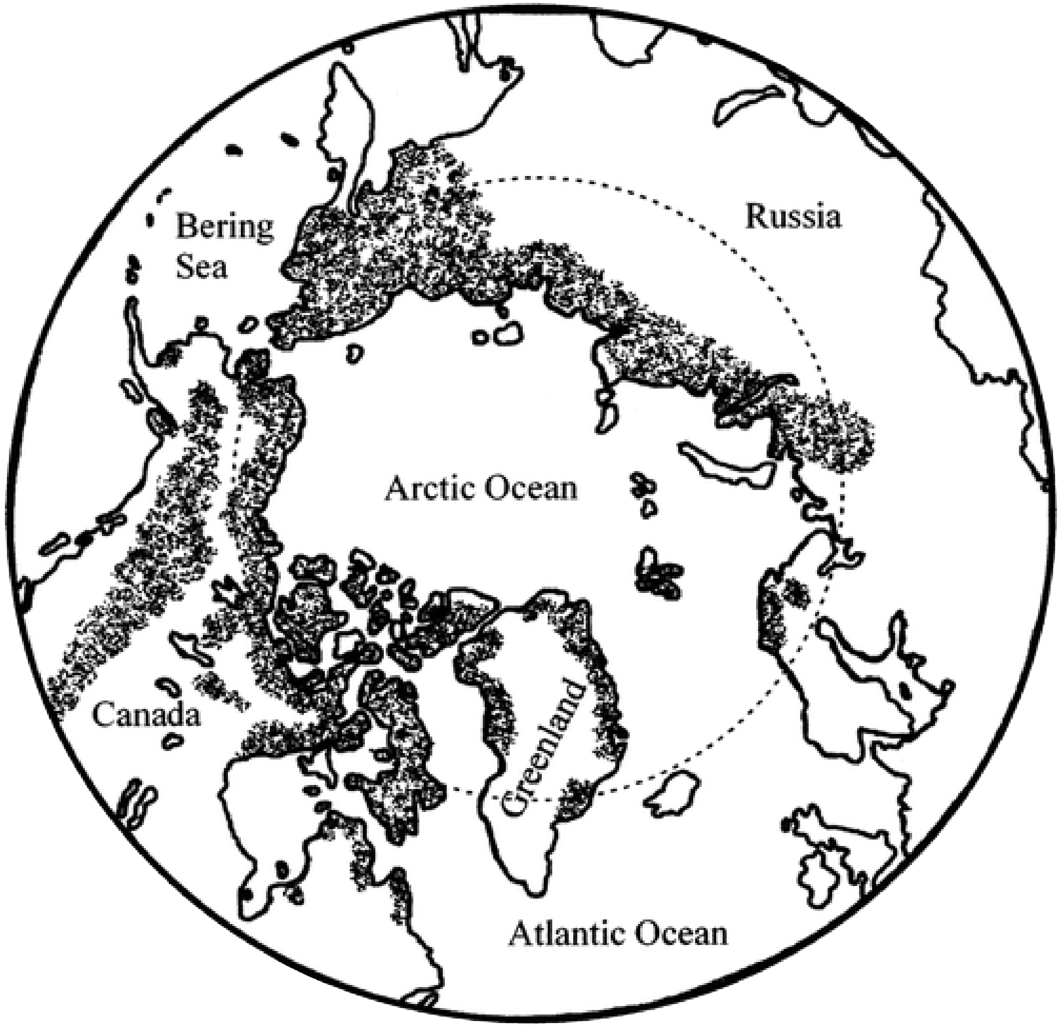
3) High resolution

4) Well preserved

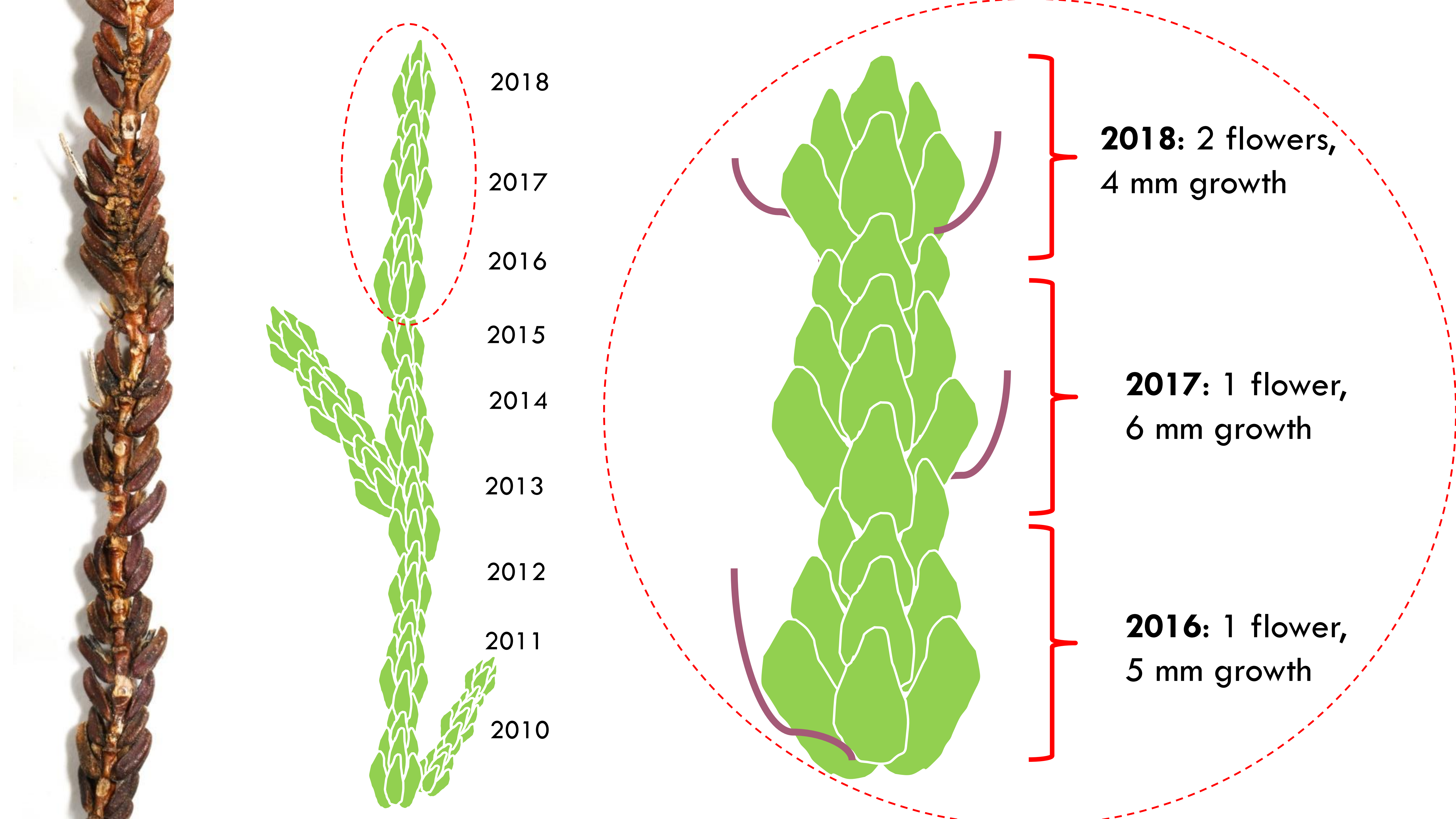


D'Odorico *et al.*, (2013)

CASSIOPE TETRAGONA



Rayback, S.A., & Henry, G.H.R. (2005)

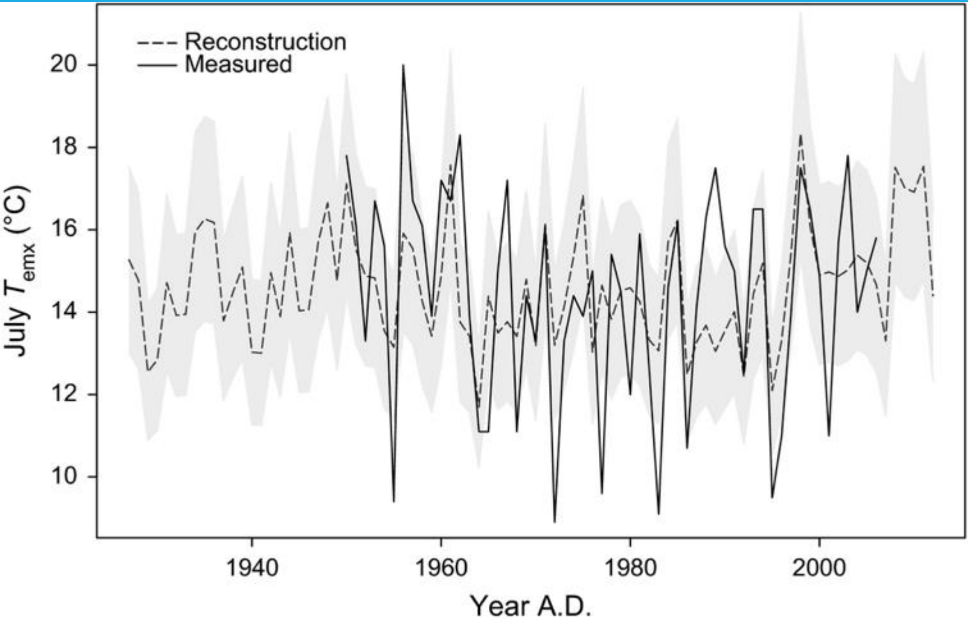

2018
2017
2016
2015
2014
2013
2012
2011
2010
2018: 2 flowers,
4 mm growth
2017: 1 flower,
6 mm growth
2016: 1 flower,
5 mm growth

1) Leaves removed from stem

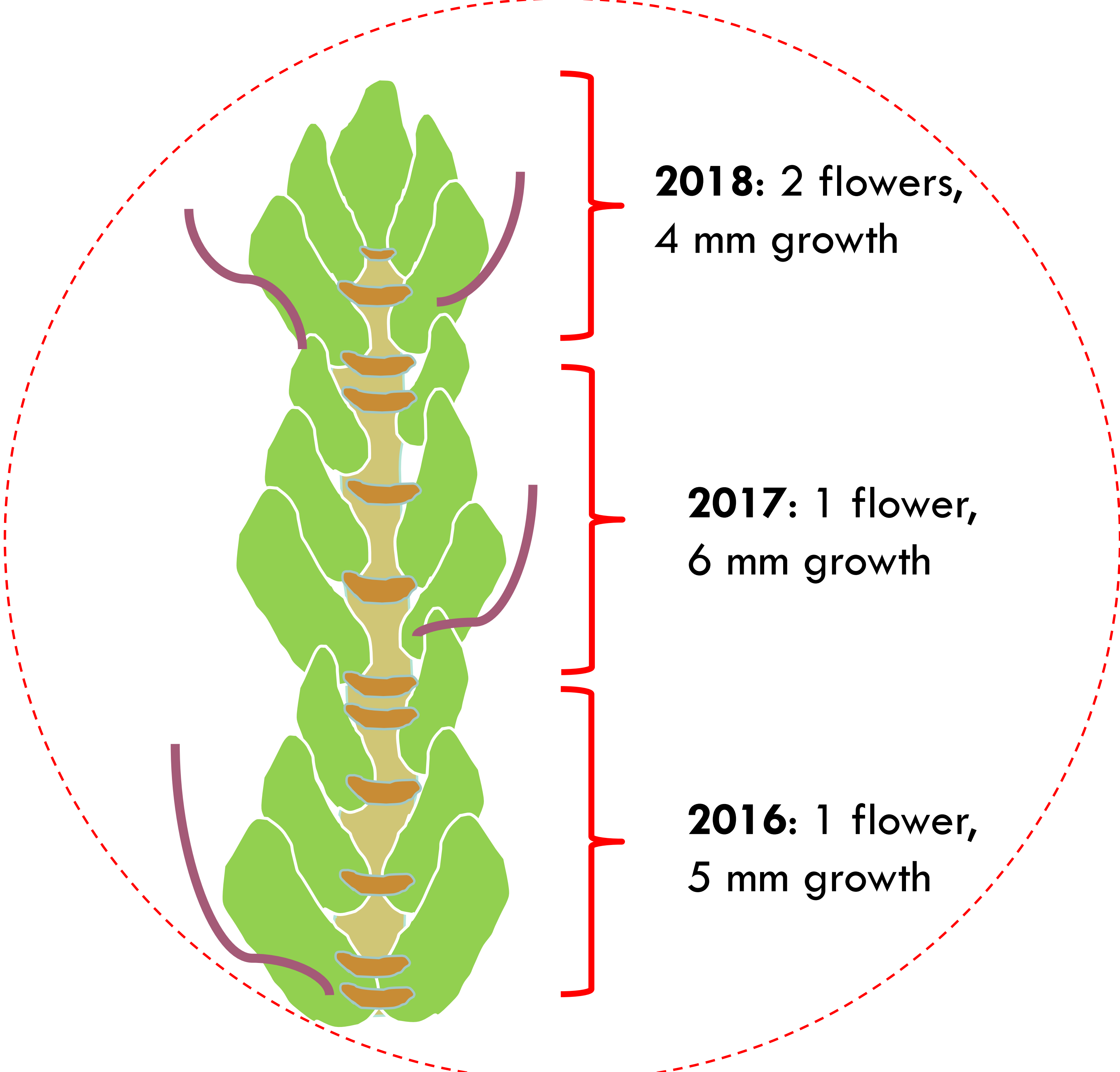
2) Distances between leaf scars measured, buds and peduncles counted

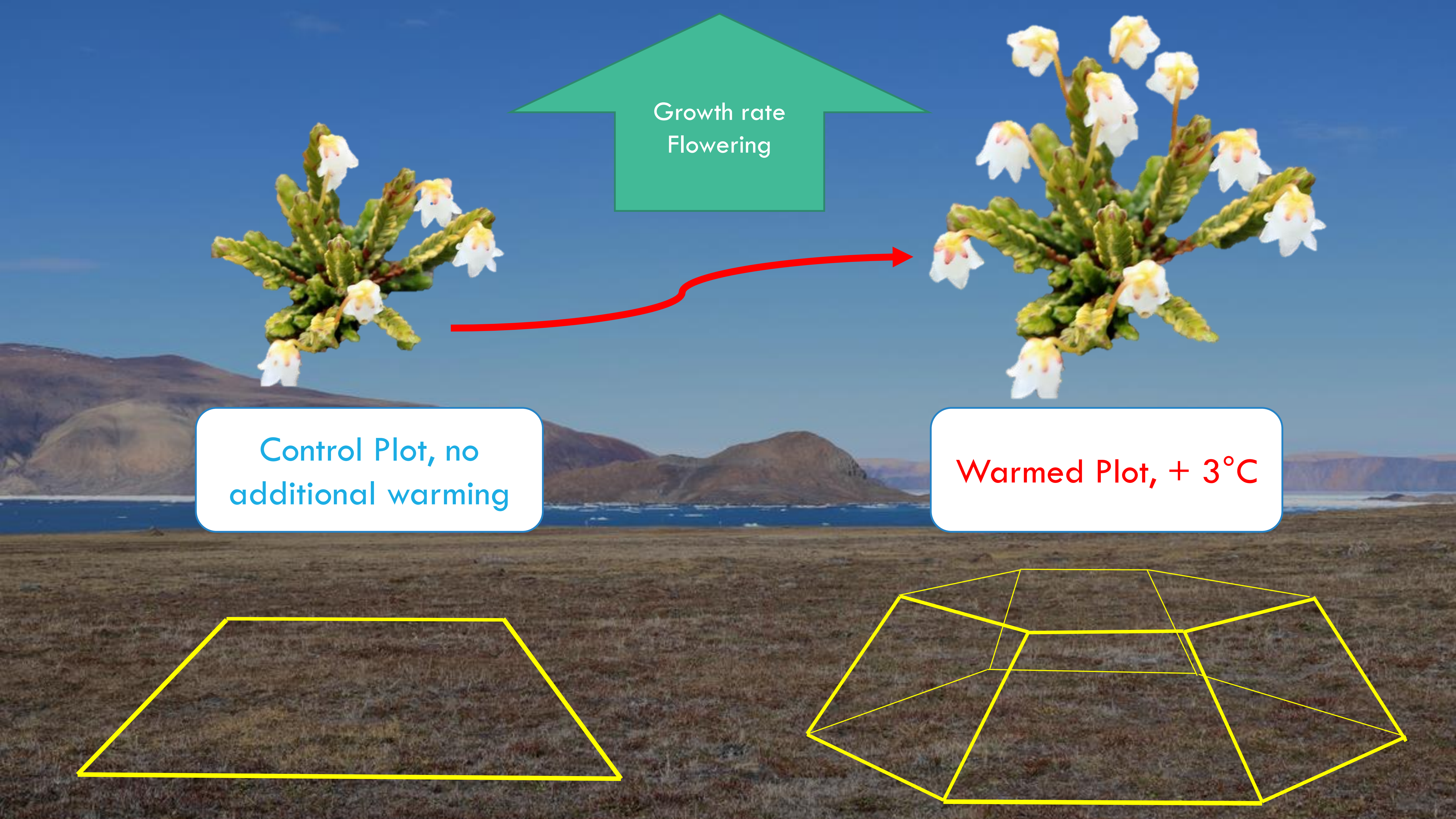
3) Wave-like pattern constitutes annual growth

4) Growth increments calibrated with climate data, e.g:



Weijers et al., 2017





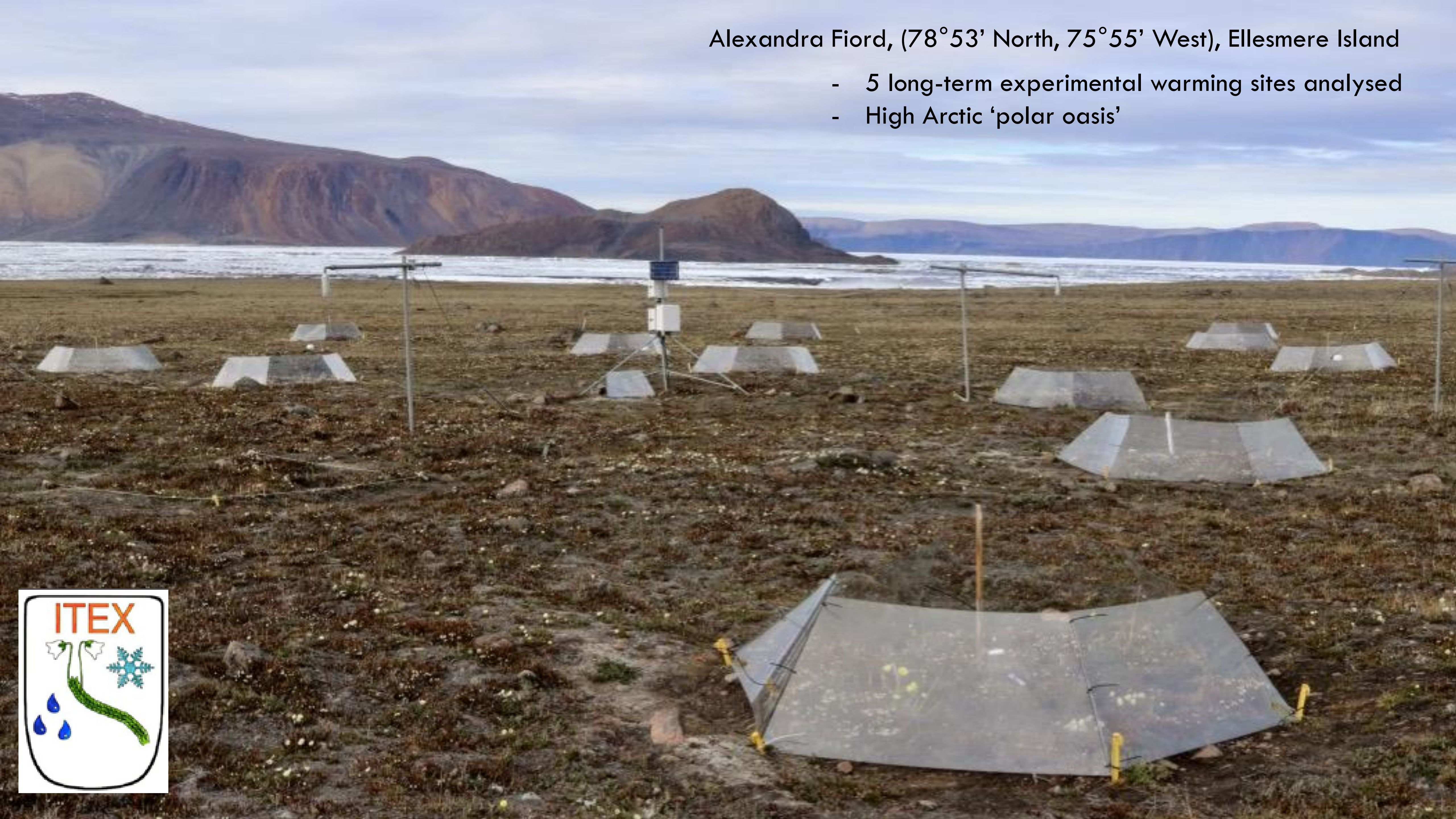
Growth rate
Flowering
Control Plot, no additional warming
Warmed Plot, + 3°C

RESEARCH QUESTION 1

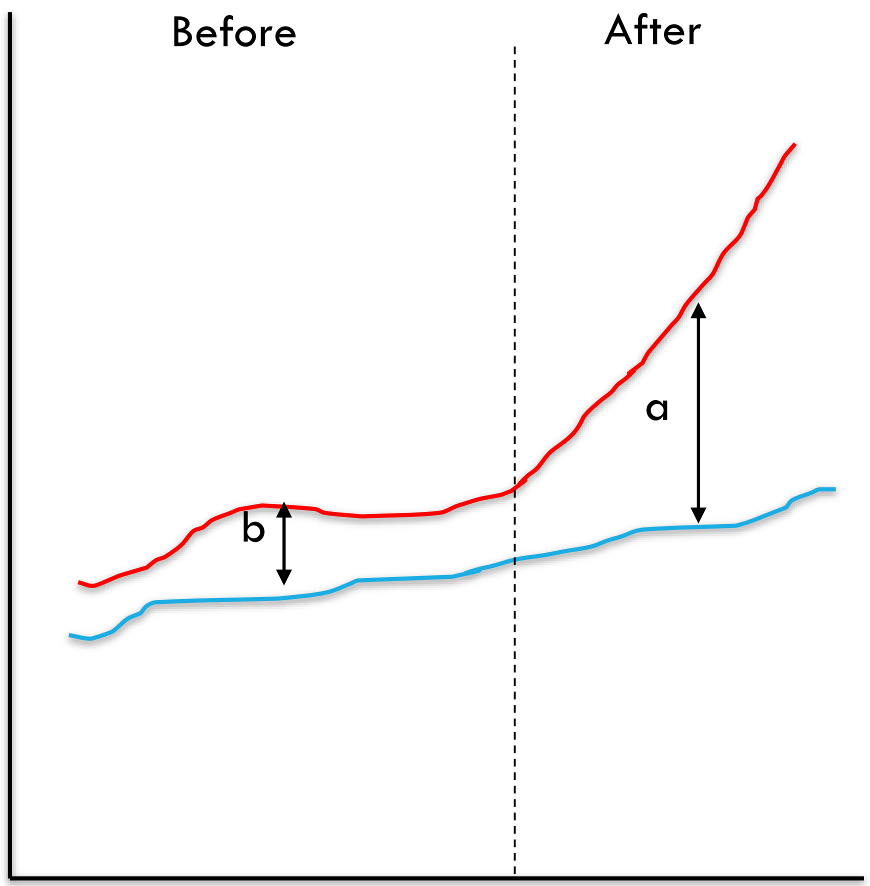
What is the effect of long-term experimental and ambient warming on the growth and reproductive efforts of Cassiope tetragona, from before the establishment of the warming experiment to the present day at Alexandra Fiord?

Alexandra Fiord, (78°53’ North, 75°55’ West), Ellesmere Island

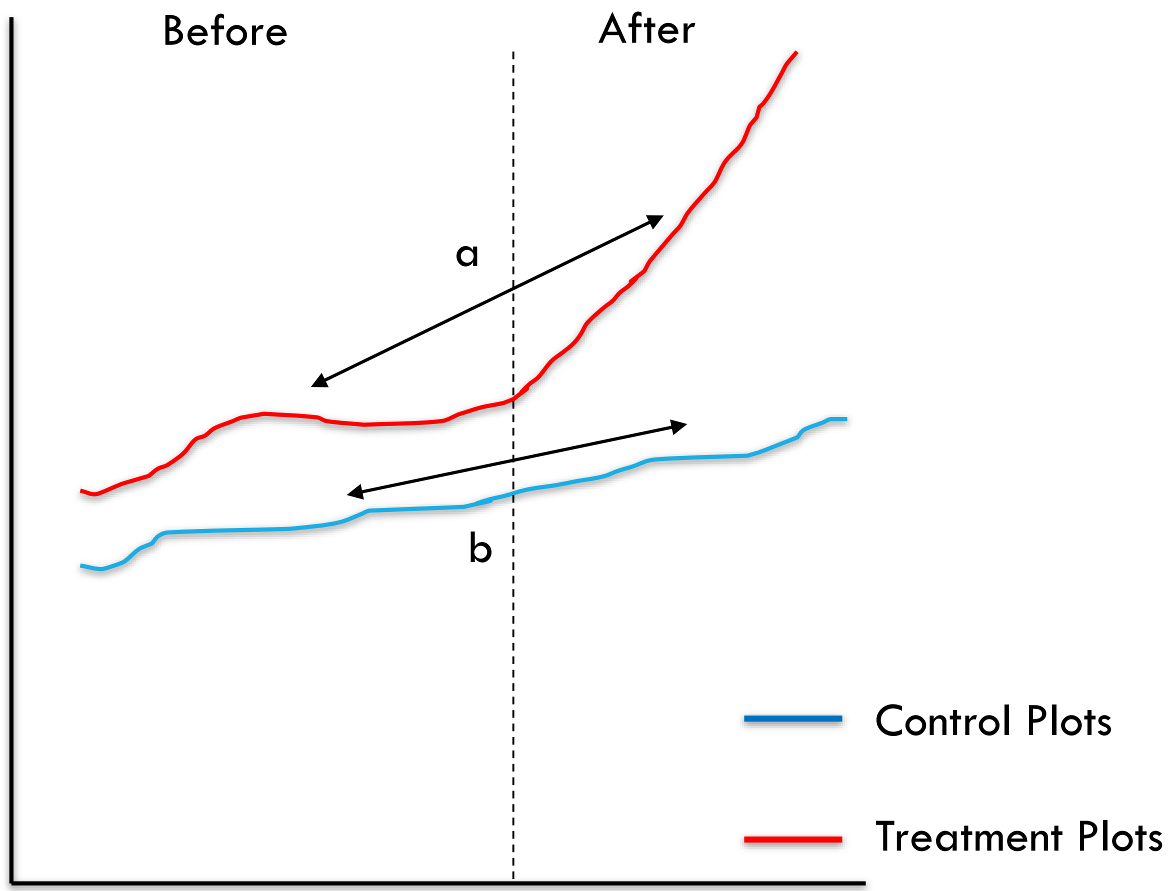
- 5 long-term experimental warming sites analysed
- High Arctic ‘polar oasis’



"BEFORE-AFTER-CONTROL-IMPACT" – HOW IT WORKS



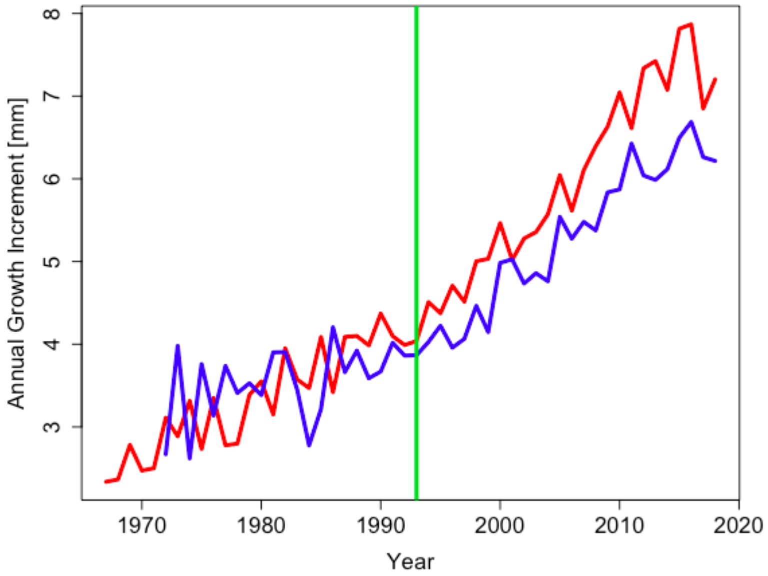
CI Divergence: mean(a) – mean (b)



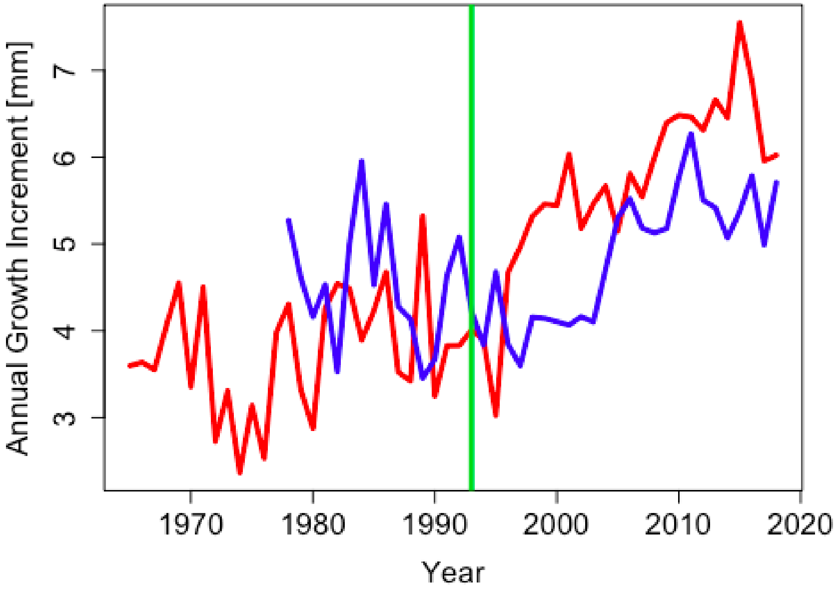
CI Contribution: mean(a) – mean (b)

ALEXANDRA FIORD FIELD SITES

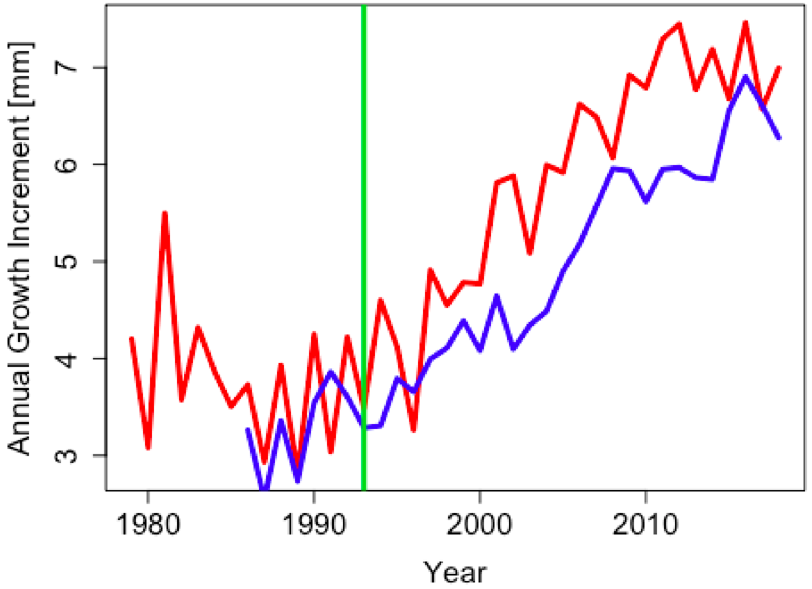
'Cassiope' Site



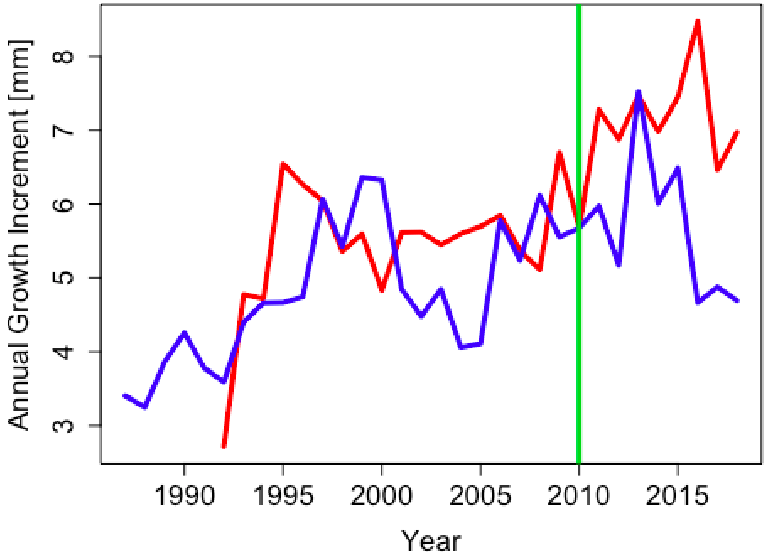
'Dryas' Site



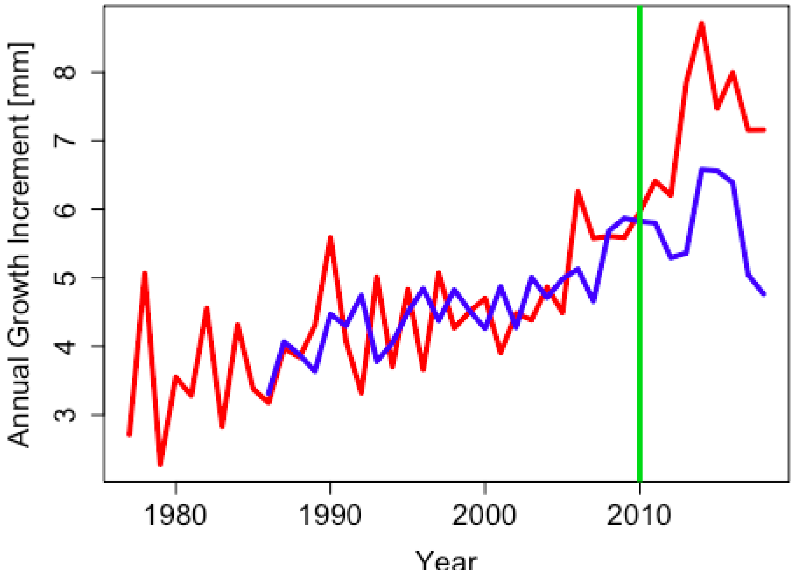
'Vaccinium' Site



'Migration' Site



'Annex' Site



Control Plots

Treatment Plots

Start of experiment

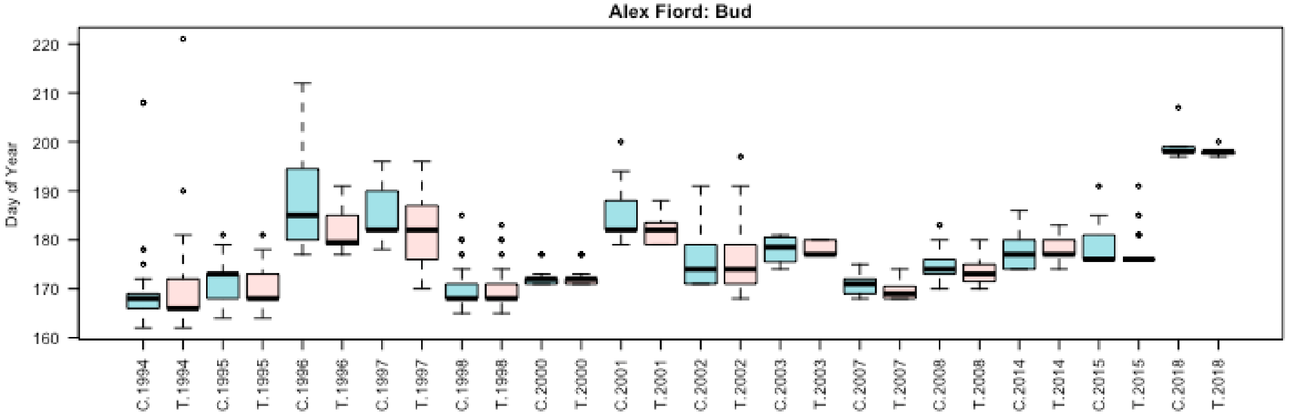
BEFORE-AFTER-CONTROL-IMPACT SUMMARY

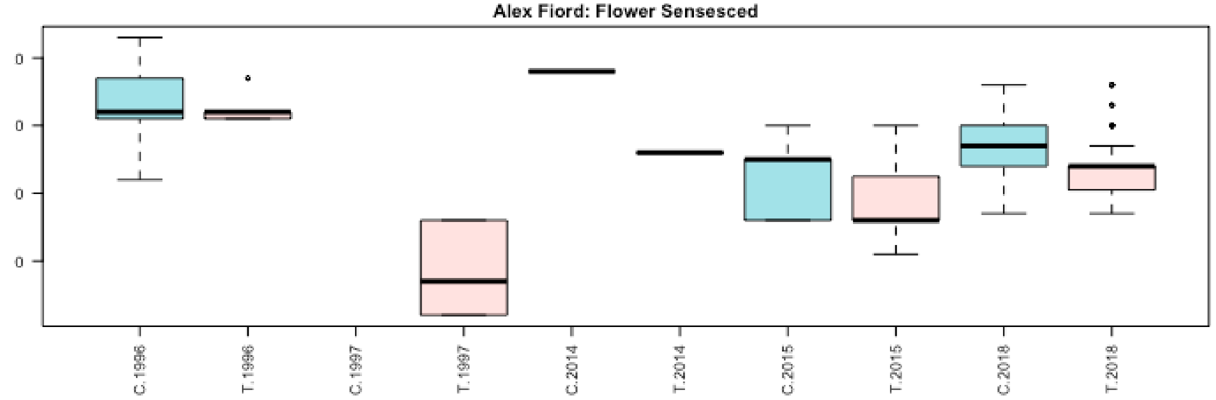
The mean difference in growth between the non-experimental (pre-OTC) and experimental (post-OTC) period was **+1.16 mm** for stems in the control plots, and **+2.12 mm** for stems in the treatment plots. All but 1 sites* show significant *CI Divergence*.

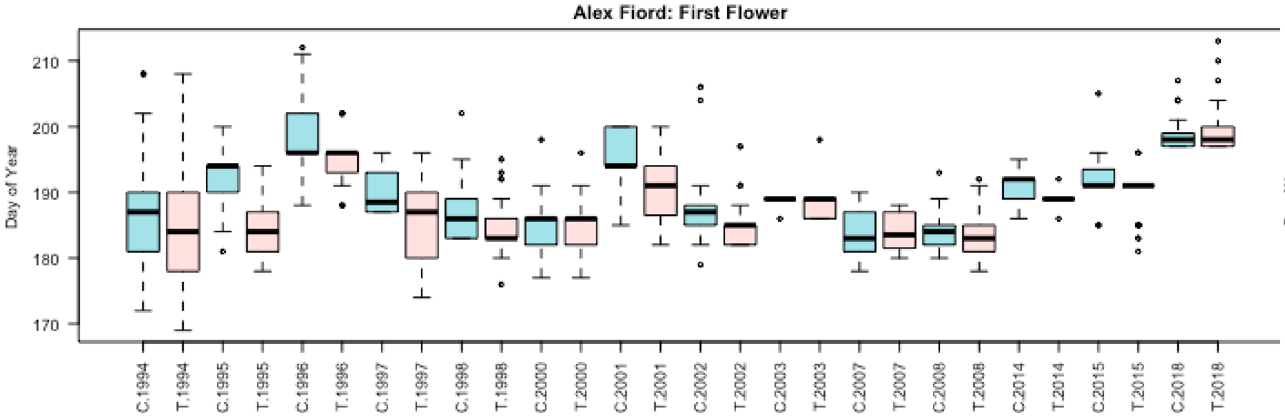
At each site, *CI Contribution* is positive – i.e. treatment consistently encourages amplified growth in comparison to ambient warming of the control plots.

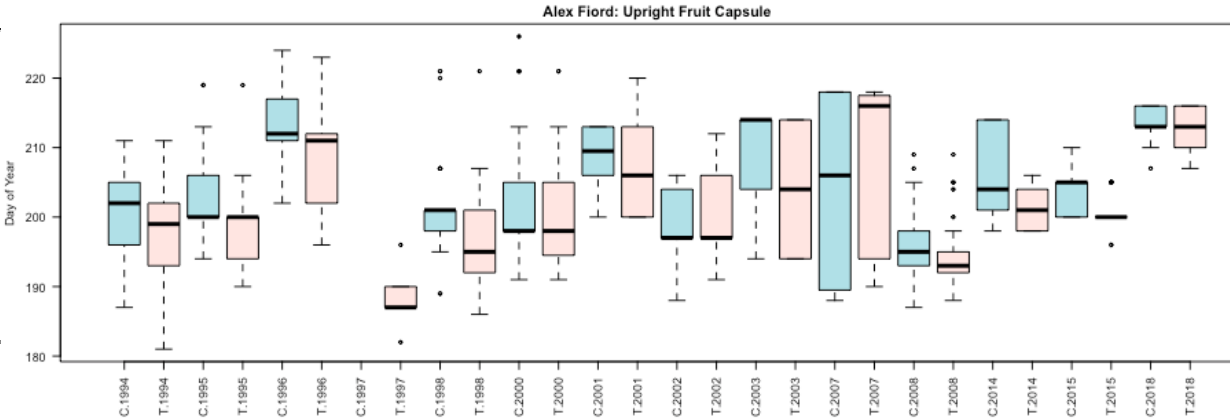
*the exception was 'Dryas'

Timing of phenology stage ~ Air temperature (June average) + Experiment | (1 | Site)









Bud-break:

2 Days earlier in OTC

Peak flower:

2 Days earlier in OTC

Senescence:

3 Days earlier in OTC

Fruit formation:

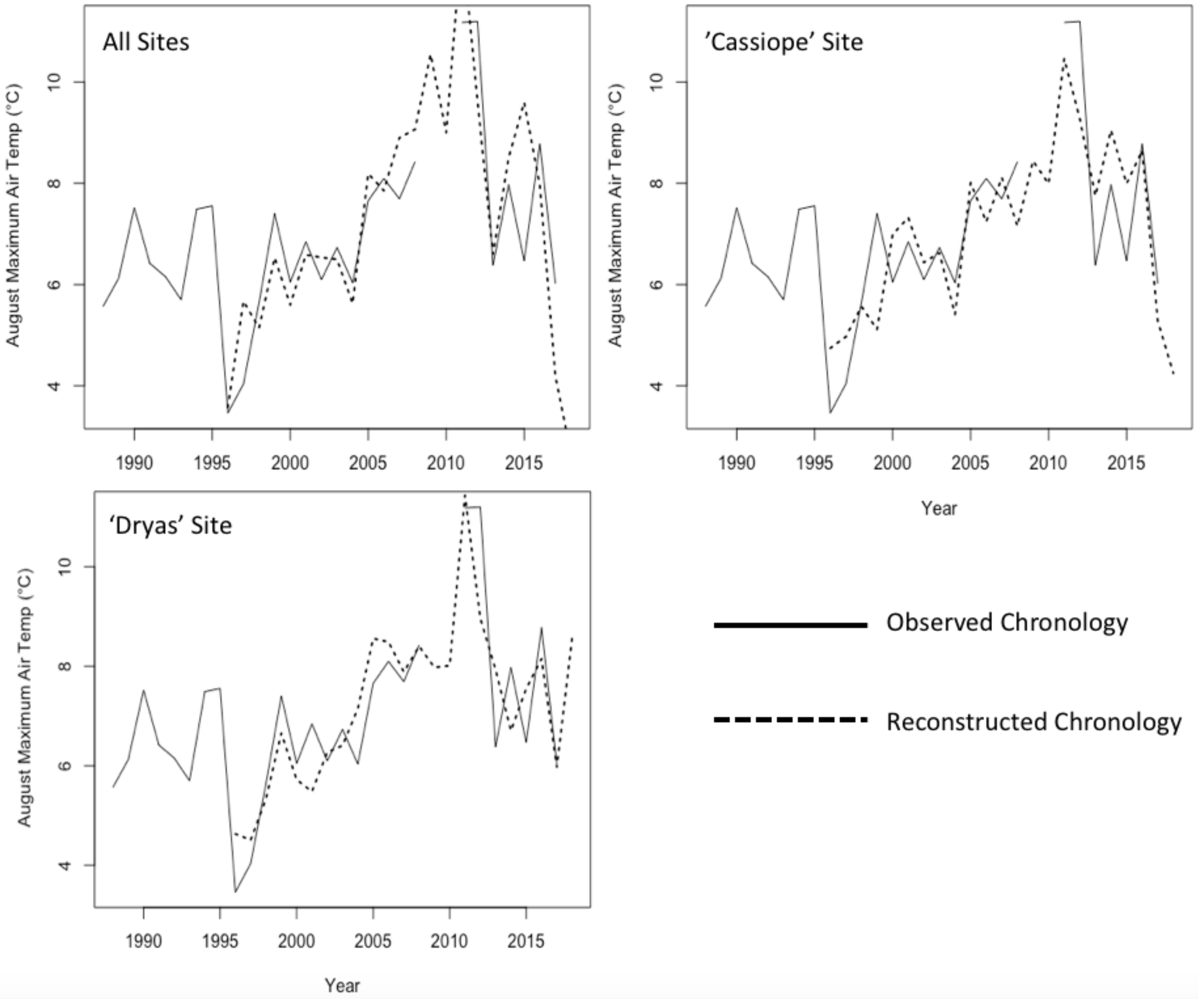
2 Days earlier in OTC

SUCCESSFUL CLIMATE RECONSTRUCTIONS:

Air temperature ~ stem growth + (flower x bud occurrence)

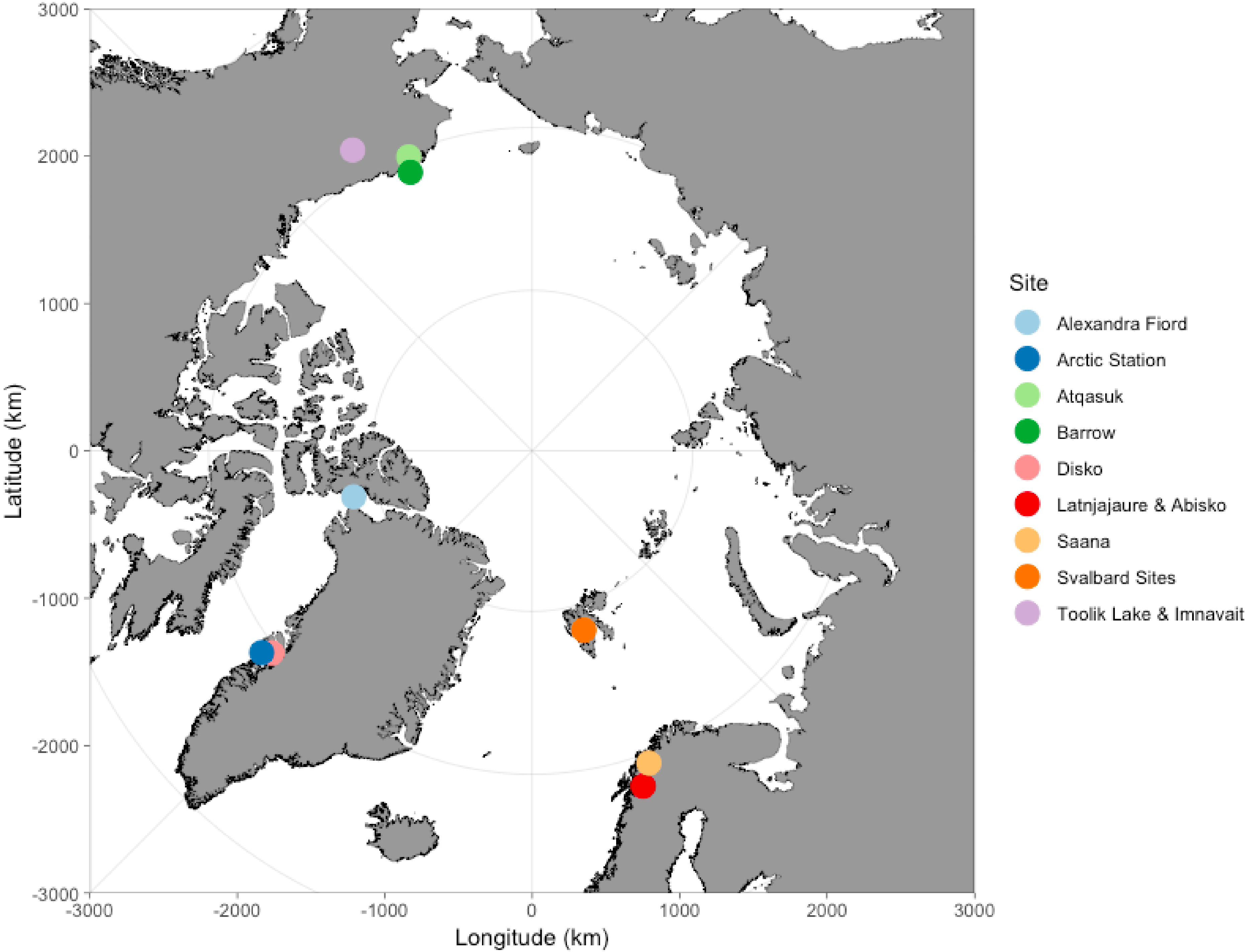
Multiple linear regression (variables including all stem growth and reproductive master chronologies from Alex Fiord):

69% of the variation in August Max Temperature can be predicted by Cassiope growth and reproduction chronologies (p = 0.0001).



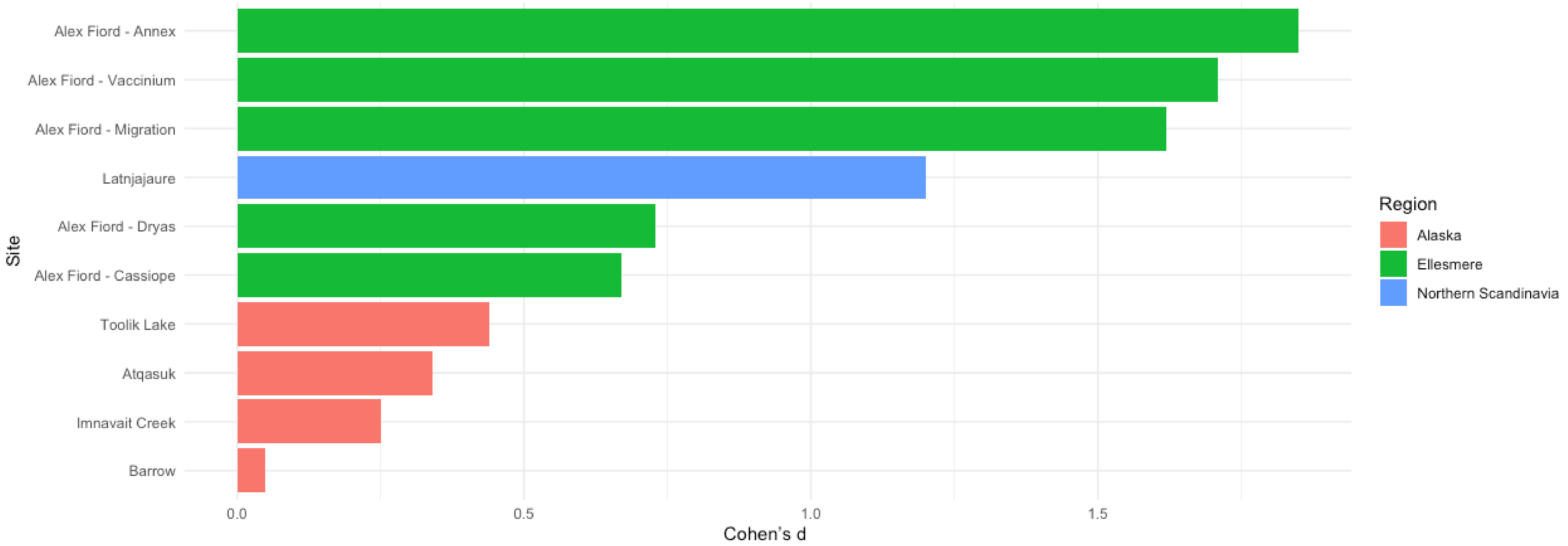
RESEARCH QUESTION 2

How does Cassiope tetragona's growth and reproductive response to experimental warming vary spatially across the Arctic?

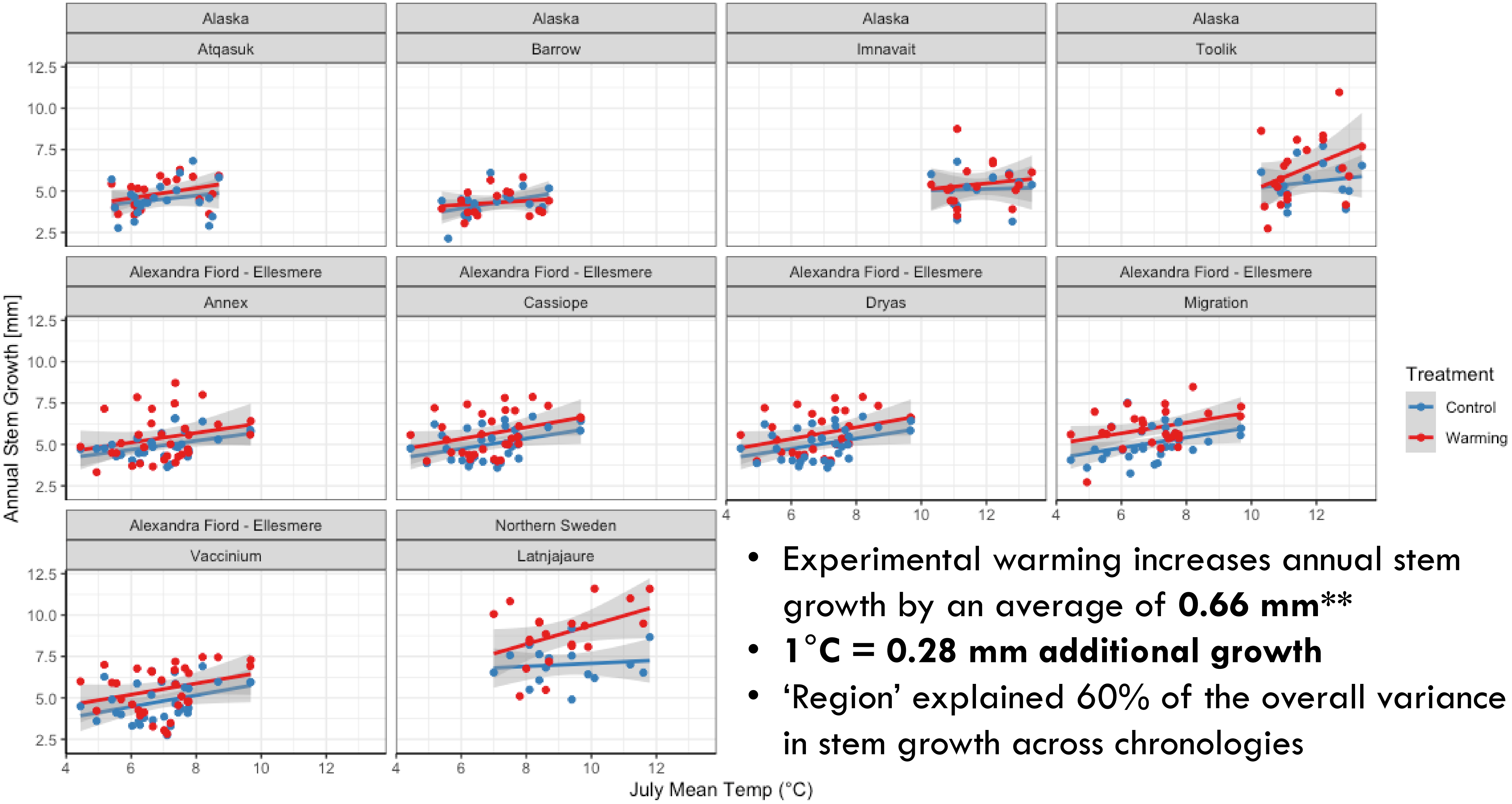

Latitude (km)
Longitude (km)
3000
2000
1000
0
-1000
-2000
-3000
-3000
-2000
-1000
0
1000
2000
3000
Site
Alexandra Fiord
Arctic Station
Atqasuk
Barrow
Disko
Latnjajaure & Abisko
Saana
Svalbard Sites
Toolik Lake & Imnavait

EFFECT SIZE

WHAT IS THE RELATIVE EXTENT OF STEM GROWTH CHANGE FORCED BY WARMING EXPERIMENTS?

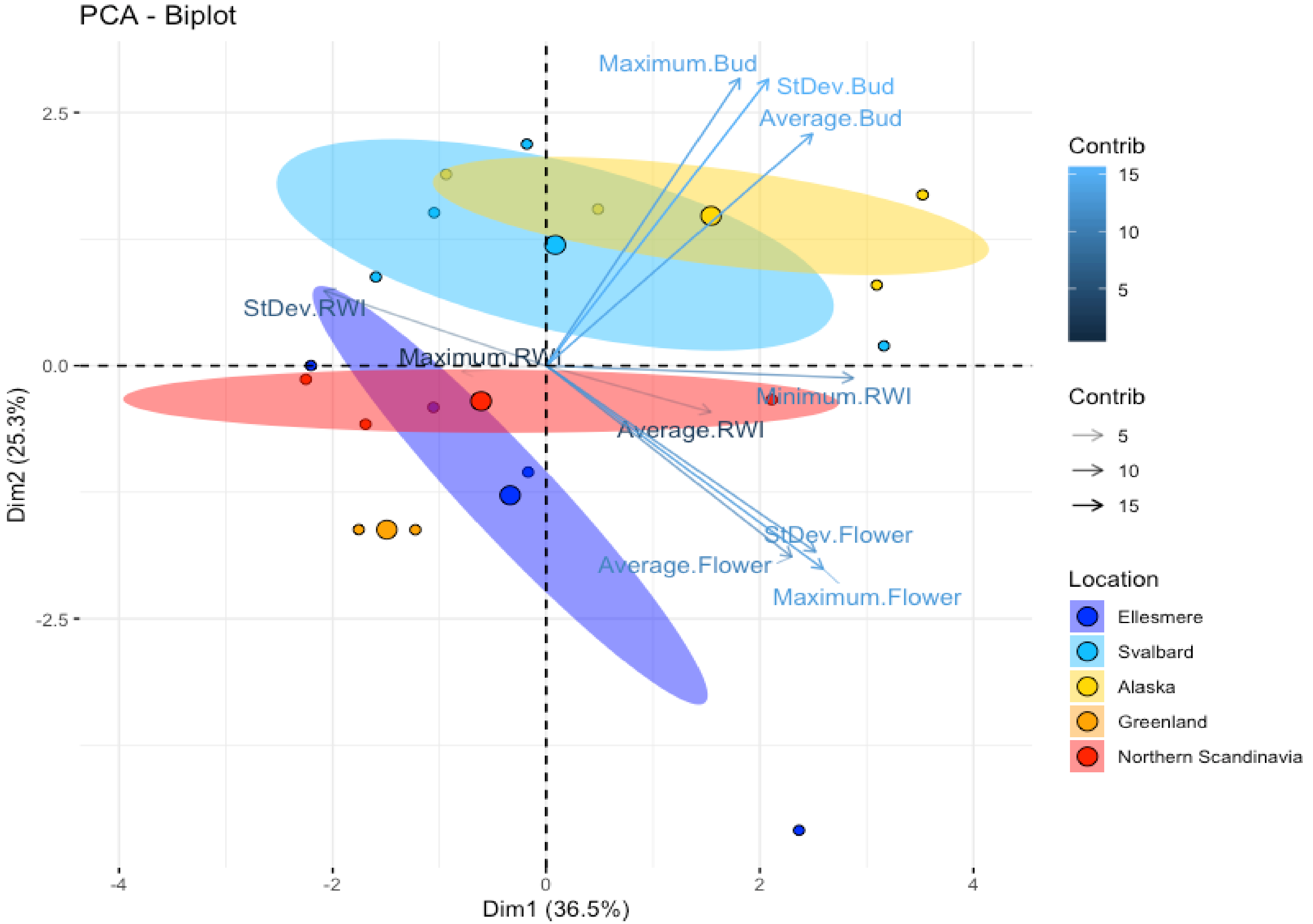


Stem growth ~ Air temperature + Experiment | (1 | Region) and (1 | Site)



- Experimental warming increases annual stem growth by an average of **0.66 mm****
- **1°C = 0.28 mm additional growth**
- 'Region' explained 60% of the overall variance in stem growth across chronologies

PRINCIPAL COMPONENT ANALYSIS



- Clustering of all (control and treatment) sites by **region** – not by soil moisture class.
- These regions are the same as the clustering of C. *tetragona* genotypes

RQ2: DISCUSSION

Climate Correlations	Experimental Impact	Regional Clustering
• No evidence of 'resistance' of High Arctic plants	• Positive everywhere – seems strongest in the High Arctic	• Follows grouping by genotype

CONCLUSIONS

Stem Growth

- Experiment increased growth by 0.66 mm across Arctic
- In general, 1 °C = 0.28 mm extra growth
- Greatest Effect in High Arctic

Reproduction

- Warming causes earlier reproduction
- Greatest Effect in High Arctic

Regional Clustering

- Growth & reproduction grouped by region
- Matches genetic distribution

RECOMMENDATIONS

1) Repeated study design using other common tundra shrubs

2) Further investigation into regional distributions

3) Further consideration of micro-site conditions, perhaps using the following variables:

- **Local / Regional air temperature**
- **Local / Regional precipitation**
- **Snow Depth / Date of Snow Melt**
- **Incoming solar radiation**
- **Cloud Cover**
- **Experiments (warming, water, nutrients, shading etc)**
- **Biotic Factors: competition, community composition**
- **Permafrost active layer depth**

THANK YOU!

NSERC CRSNG

ArcticNet ᐅᑭᐅᖅᑕᖅᑐᒥᒃ ᑐᑭᓯᓂᐊᖅᑎᑦ

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ITEX

LEVERHULME TRUST