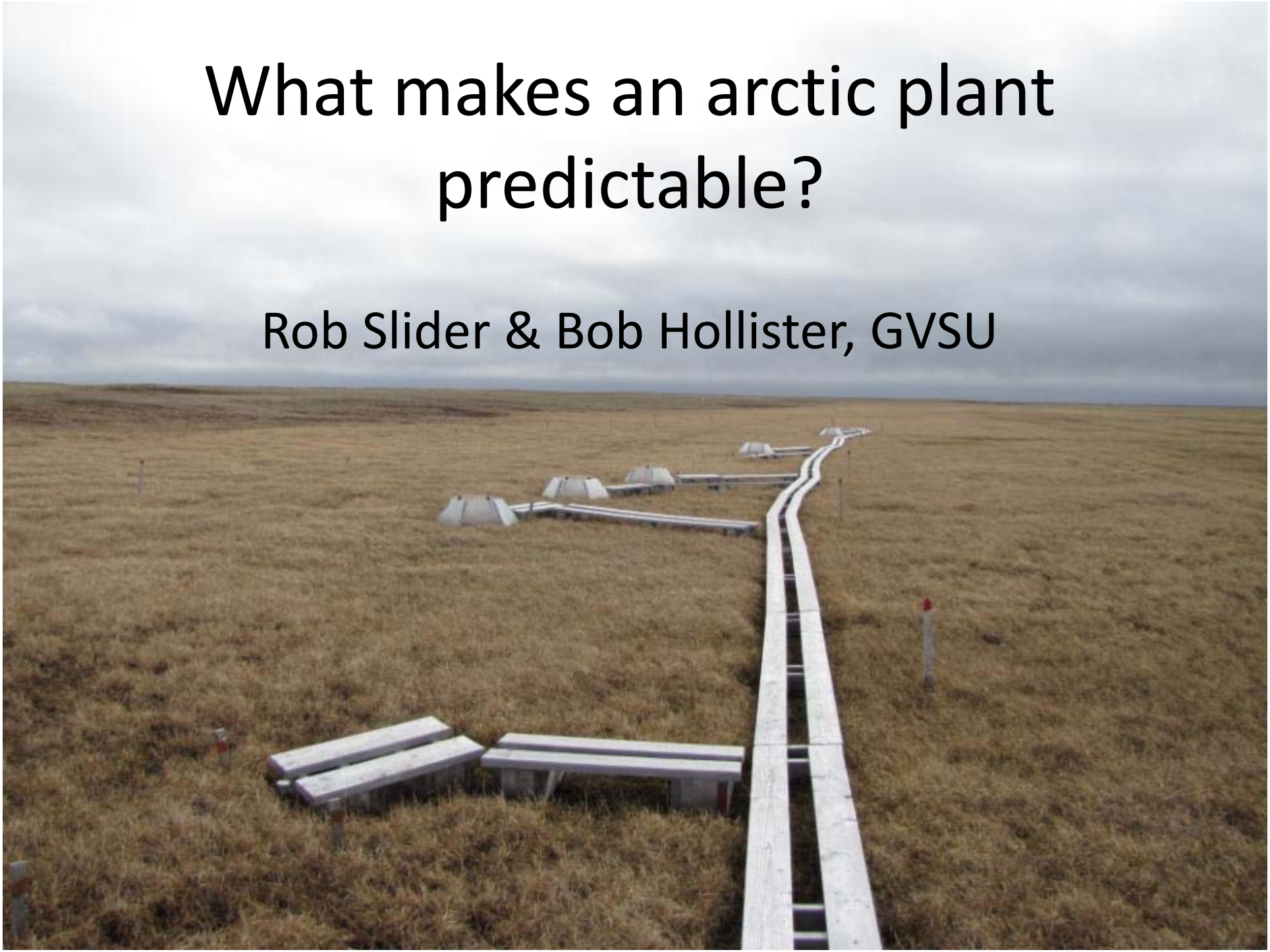
What makes an arctic plant predictable?

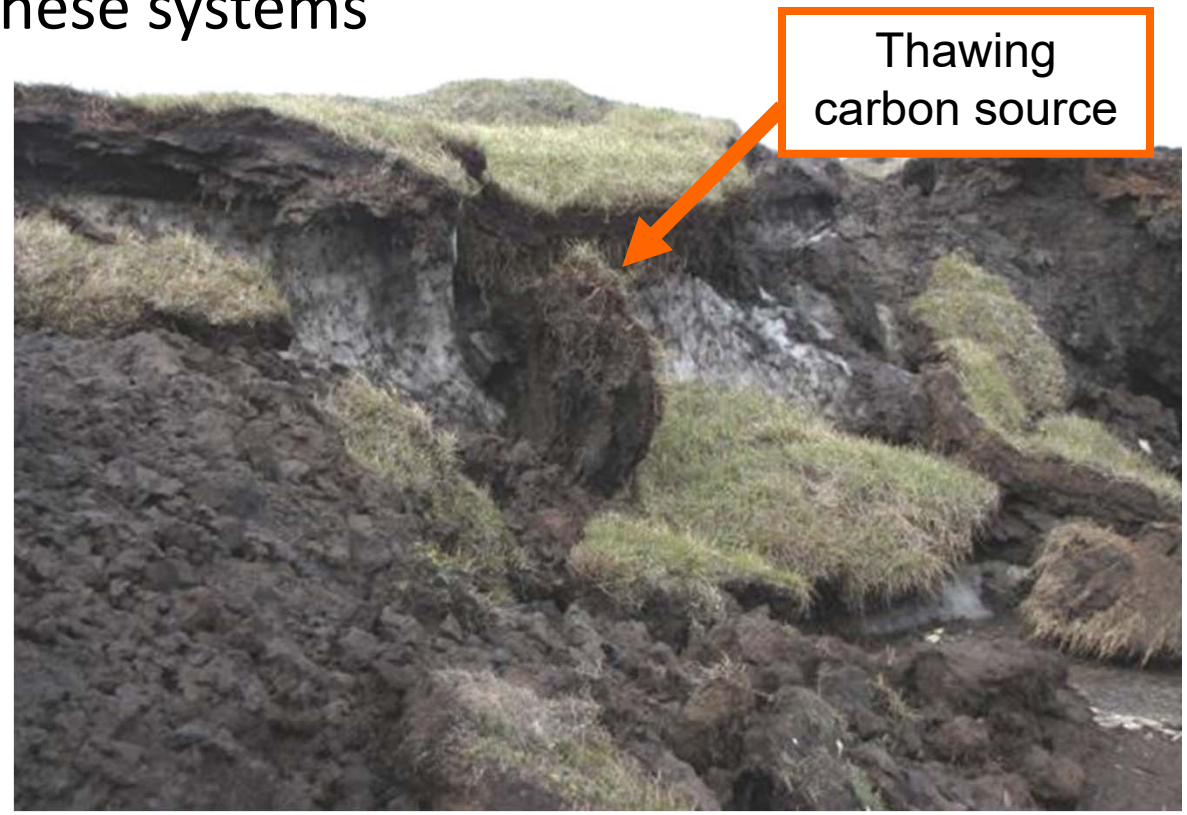
Rob Slider & Bob Hollister, GVSU



Predicting plant responses to warming is important

- Arctic plants play critical roles in local and global systems
- Predicting plant responses to climatologic factors can improve models of these systems

Arctic food web



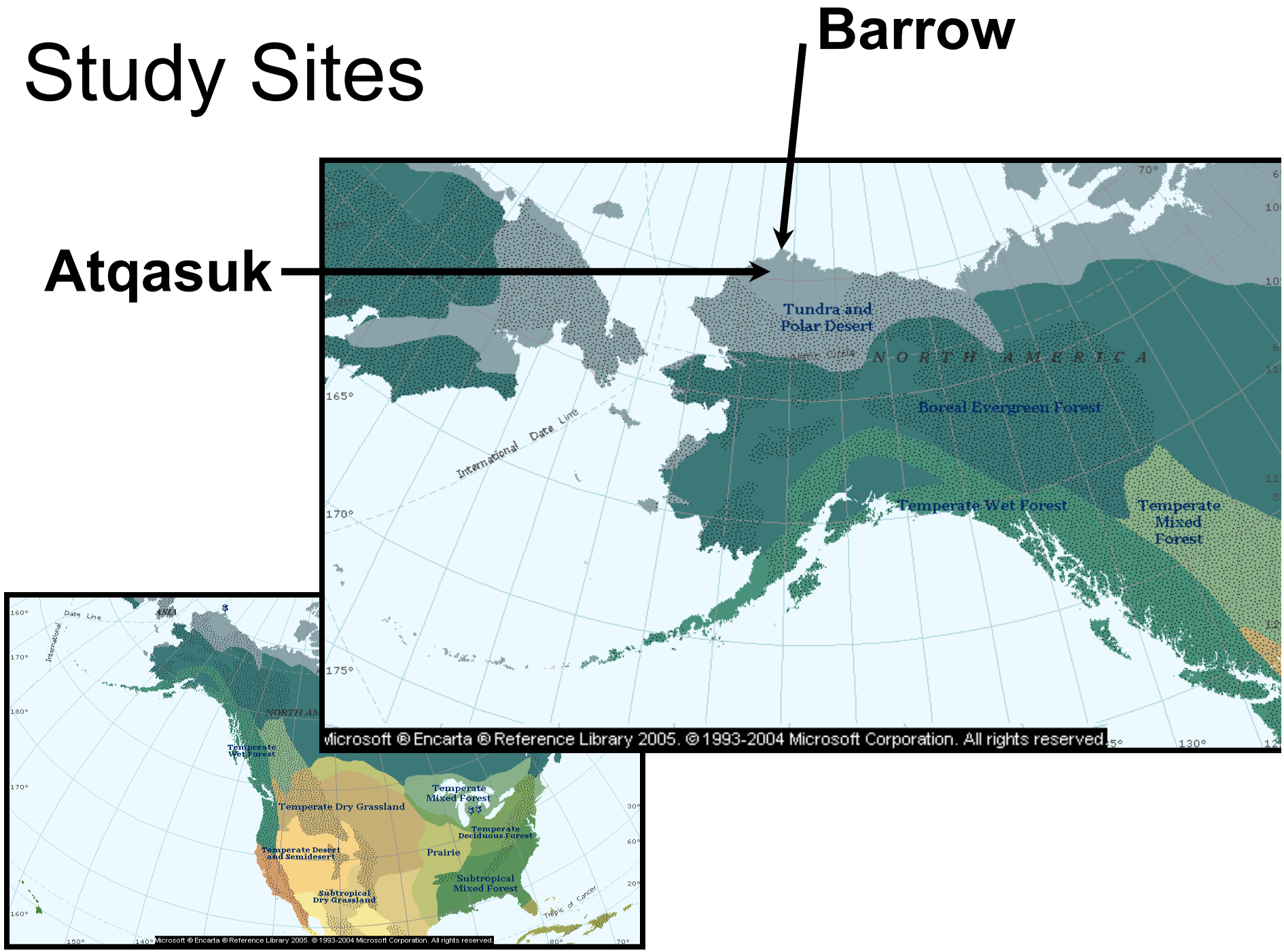
Study Questions:

Since predicting plant responses to warming is important…

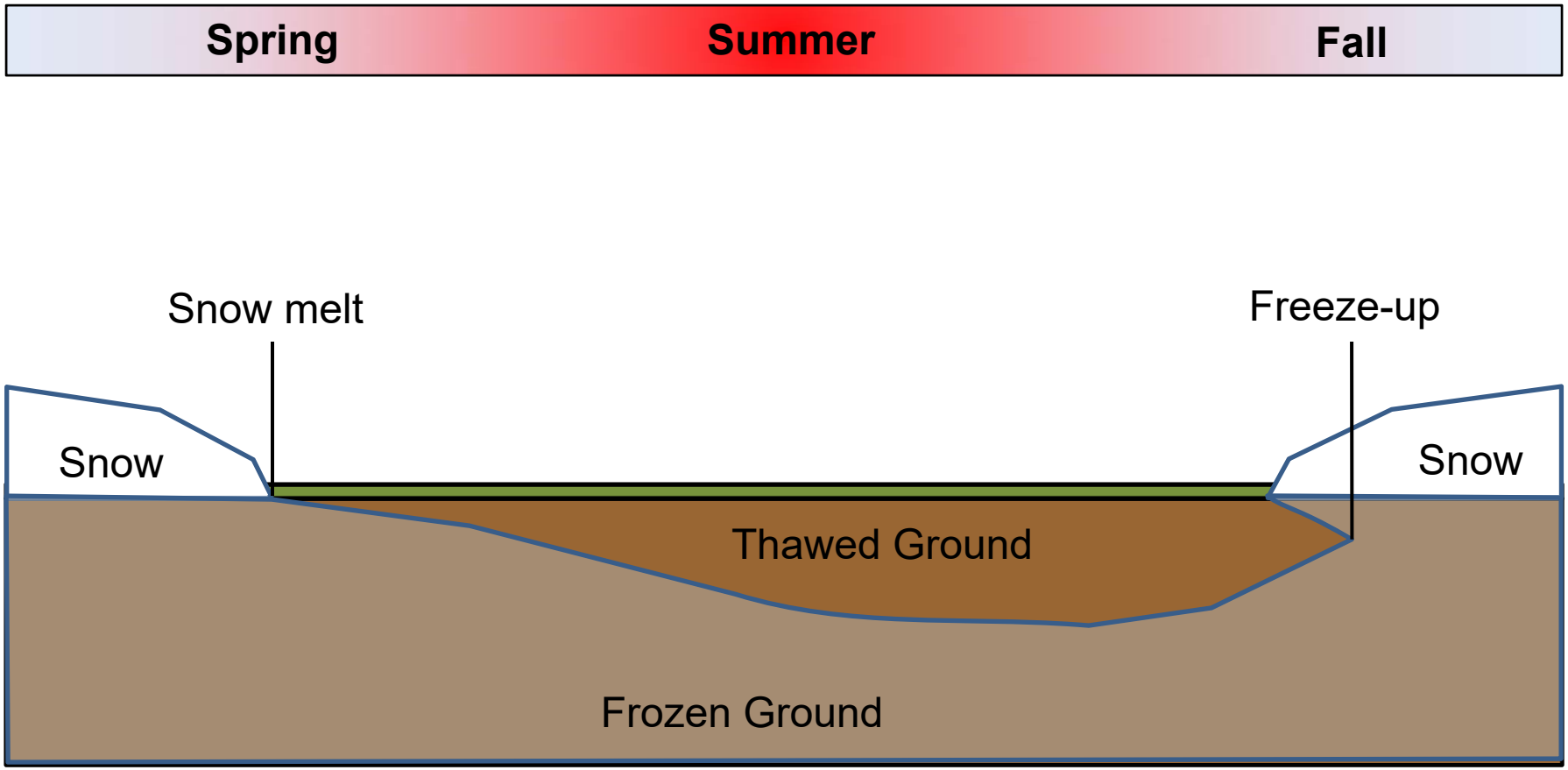
Which abiotic factors can we use to predict them?

Why may a factor predict traits for one species but not for another?

Study Sites

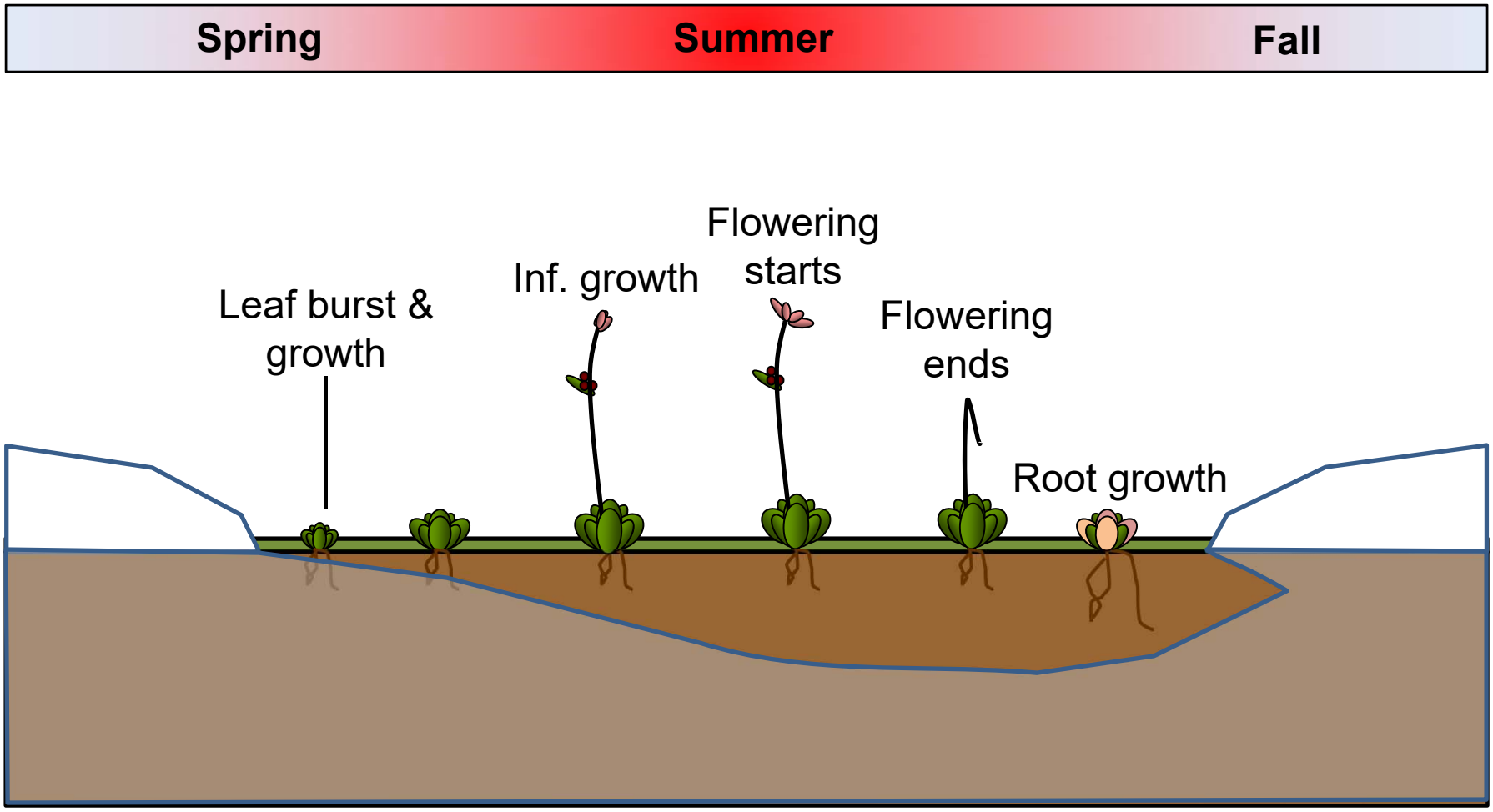

Barrow
Atqasuk
Tundra and Polar Desert
N O R T H A M E R I C A
Boreal Evergreen Forest
Temperate Wet Forest
Temperate Mixed Forest
International Date Line
Temperate Dry Grassland
Temperate Mixed Forest
Temperate Deciduous Forest
Temperate Desert and Semidesert
Prairie
Subtropical Mixed Forest
Subtropical Dry Grassland
Tropic of Cancer
Microsoft ® Encarta ® Reference Library 2005. © 1993-2004 Microsoft Corporation. All rights reserved.

Arctic growing season

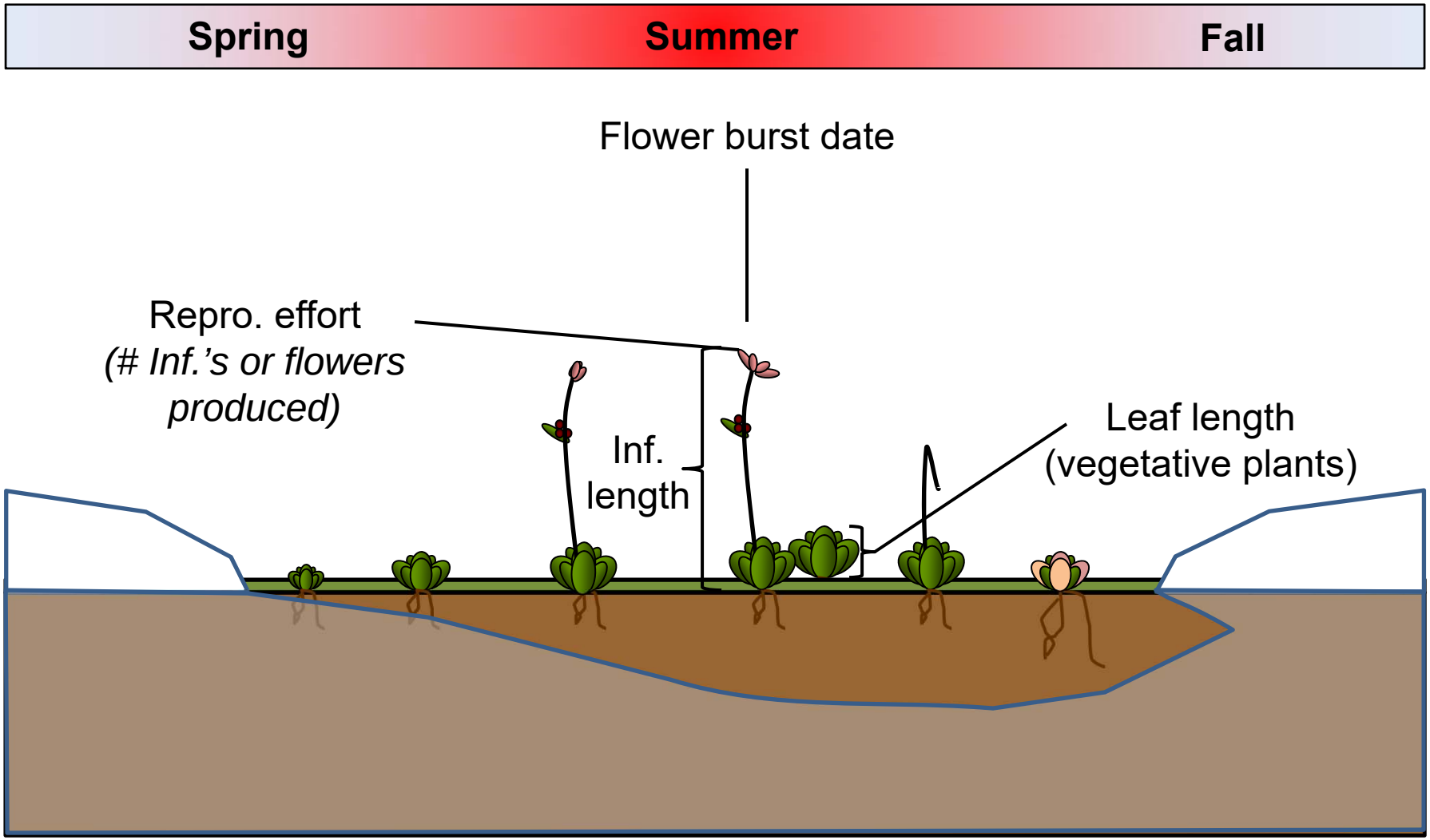


Arctic growing season

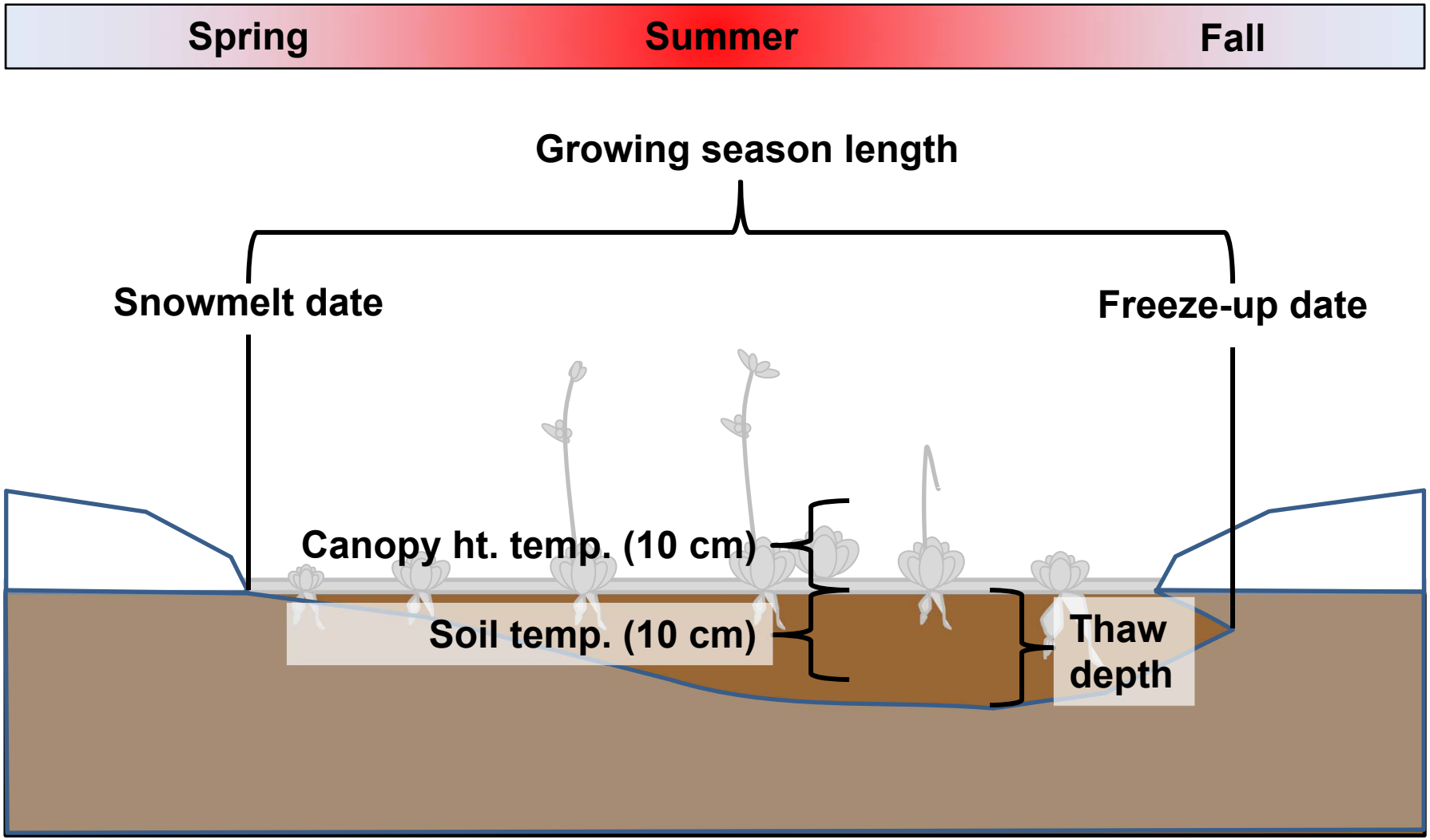
from a plant's perspective



Plant traits examined



Abiotic factors examined



Methods

- **Control plot data (5-24 plots)**
- **4 sites x 5 years**

  (Years <u>all</u> climatologic factors were collected)

- **Collected flowering data 1-3x / week**
- **Leaf length & Inflorescence height at the end of the season (after peak)**
- **Calculating degree days from snowmelt**
  - Various base temp (-5 ˚C to 2 ˚C)
  - Two periods:
    - Spring & Summer, Fall (just soil)
- **Linear regressions** in R ($\alpha = 0.05$)

Species used

Trait Key

Fl = Flowering date **RE** = Reproductive effort
In = Inflorescence height **Le** = Leaf length

Deciduous Shrubs

Species	Site	Traits
Salix rotundifolia (F)	BD	Fl,RE,In
Salix rotundifolia (M)	BD	RE,Le

Evergreen Shrubs

Species	Site	Traits
Cassiope tetragona	AD	RE,Le
Cassiope tetragona	BD	RE,Le
Diapensia lapponica	AD	Fl,RE,In,Le
Ledum palustre	AD	Fl,RE,Le
Vaccinium vitis-idaea	AD	Fl,RE, Le

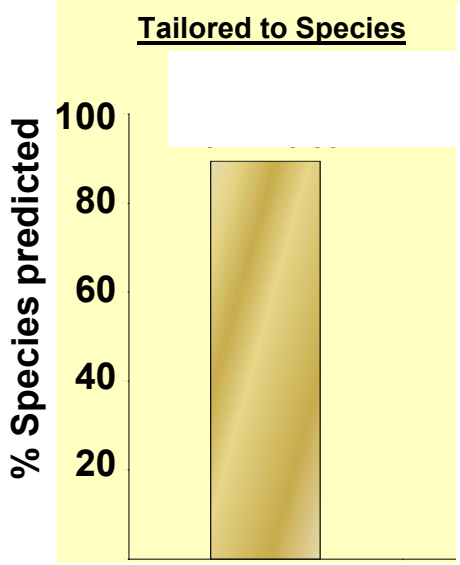
Forbs

Species	Site	Traits
Draba lactea	BW	Fl,RE,In
Papaver hultenii	BD	Fl,RE,In
Pedicularis sudetica	AW	Le
Polygonum bistorta	AD	RE,In,Le
Potentilla hyparctica	BD	Fl,RE,In,Le
Saxifraga cernua	BW	Le
Saxifraga foliolosa	BW	In
Saxifraga hieracifolia	BW	RE,In,Le
Saxifraga hirculus	BW	RE,In,
Saxifraga punctata	BD	Fl,RE,In,Le
Senecio atropurpureus	BD	In,Le
Stellaria laeta	BD	Fl,RE,In,Le

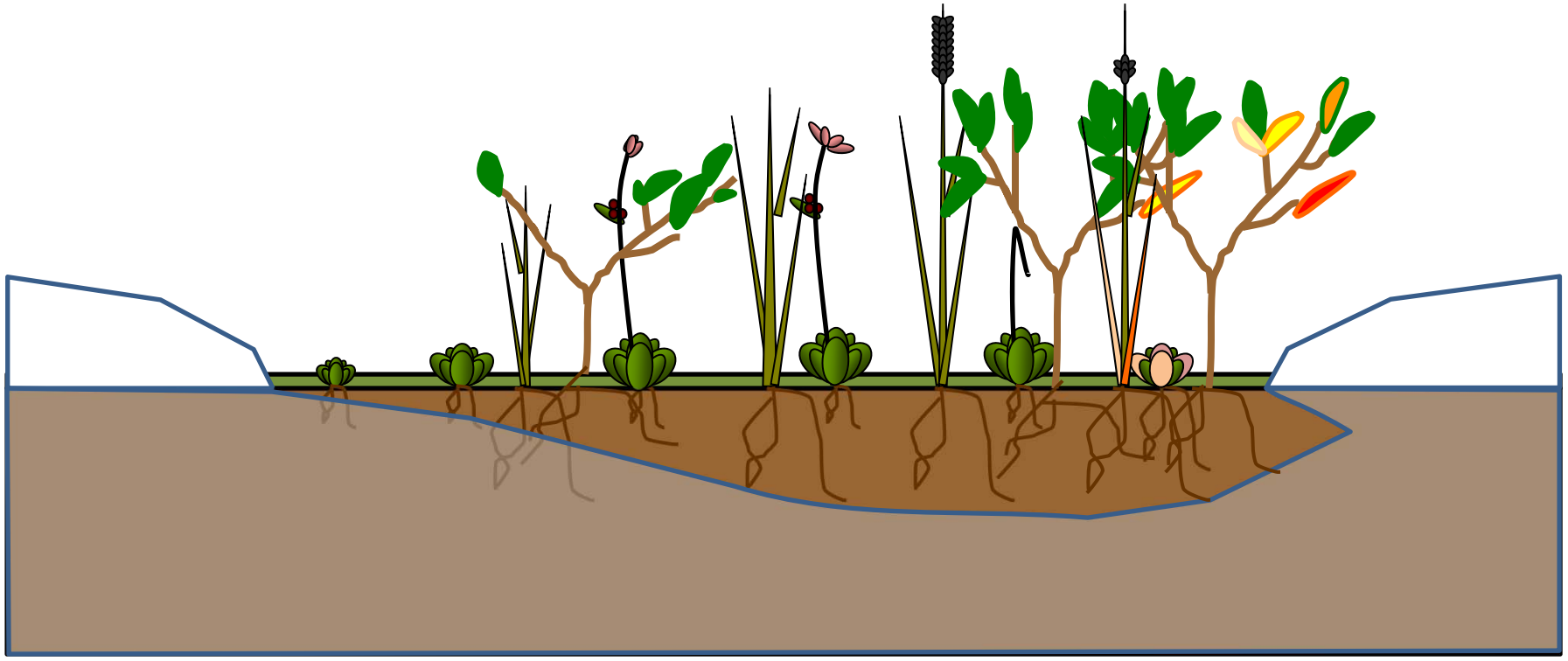
Graminoids

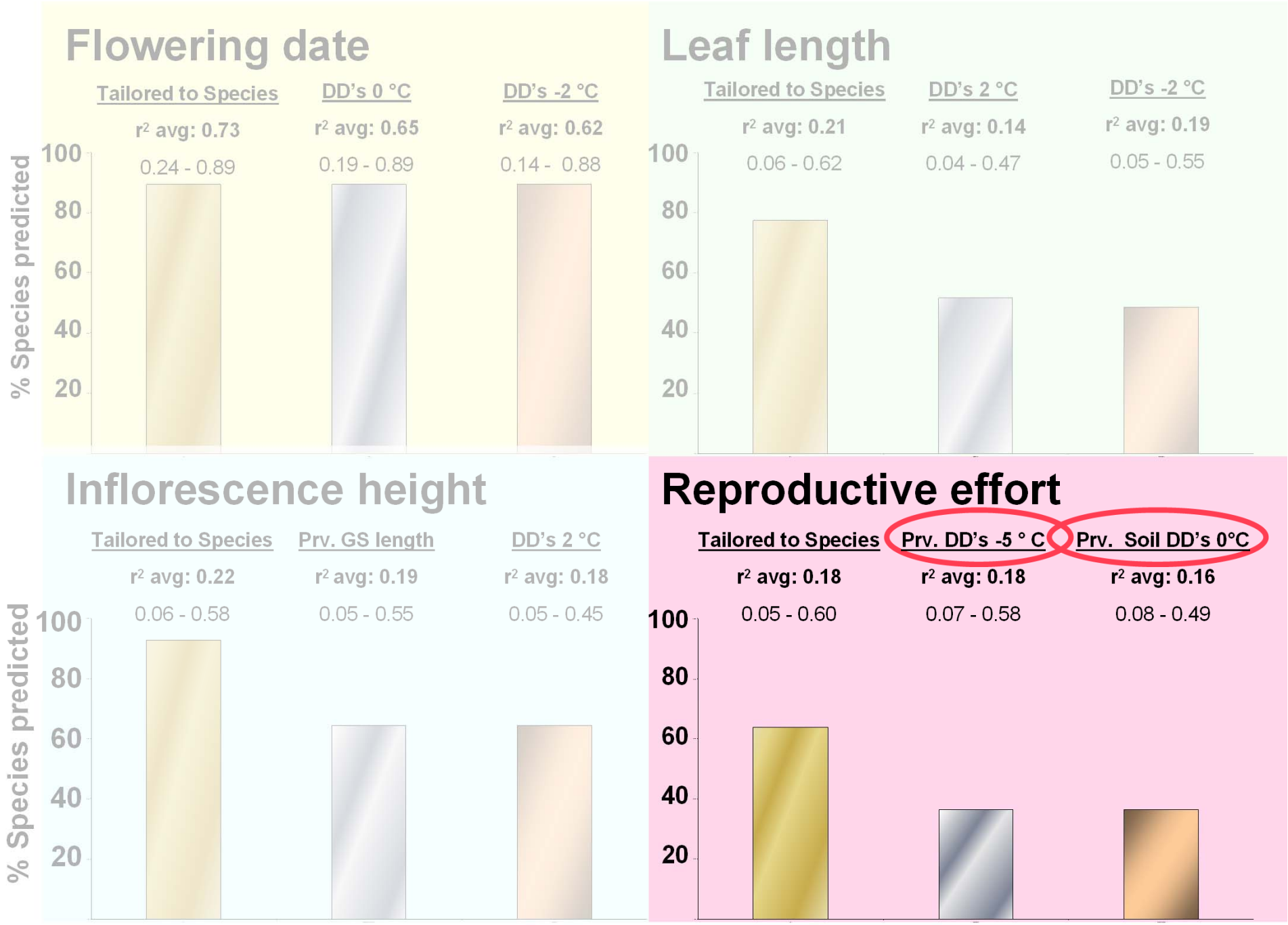
Species	Site	Traits
Arctagrostis latifolia	BD	RE,In,Le
Carex aquatilis	AW	Fl,RE,In,Le
Carex bigelowii	AD	Le
Carex stans	BW	Fl,RE,In,Le
Dupontia fisheri	AW	Le
Dupontia fisheri	BW	Fl,RE,In,Le
Eriophorum angustifolium	AW	RE,In,Le
Eriophorum russeolum	AW	RE,In,Le
Eriophorum russeolum	BW	Le
Eriophorum triste	BW	Fl,RE,In,Le
Hierochloe alpina	AD	Fl,RE,In,Le
Hierochloe pauciflora	BW	Fl,RE,In,
Juncus biglumis	BW	RE
Luzula arctica	AD	RE,In,Le
Luzula arctica	BD	Fl,RE,In,Le
Luzula arctica	BW	Fl,RE,In,
Luzula confusa	AD	Fl,RE,In,Le
Luzula confusa	BD	Fl,RE,In,Le
Luzula confusa	BW	RE
Poa arctica	BD	RE,In,Le
Poa arctica	BW	RE,In,
Trisetum spicatum	AD	Le

Flowering date



Including a variety of abiotic factors increased number of species predicted & amount of variation explained




Flowering date
Tailored to Species
r² avg: 0.73
0.24 - 0.89
DD's 0 °C
r² avg: 0.65
0.19 - 0.89
DD's -2 °C
r² avg: 0.62
0.14 - 0.88
Leaf length
Tailored to Species
r² avg: 0.21
0.06 - 0.62
DD's 2 °C
r² avg: 0.14
0.04 - 0.47
DD's -2 °C
r² avg: 0.19
0.05 - 0.55
Inflorescence height
Tailored to Species
r² avg: 0.22
0.06 - 0.58
Prv. GS length
r² avg: 0.19
0.05 - 0.55
DD's 2 °C
r² avg: 0.18
0.05 - 0.45
Reproductive effort
Tailored to Species
r² avg: 0.18
0.05 - 0.60
Prv. DD's -5 ° C
r² avg: 0.18
0.07 - 0.58
Prv. Soil DD's 0°C
r² avg: 0.16
0.08 - 0.49
% Species predicted
100
80
60
40
20

The ability of an abiotic factor to predict a species' traits relates to its ecological behavior

Example: *Cassiope tetragona* uses resources from previous year for reproduction this year

Cassiope tetragona
(Evergreen shrub)

Summary of main points

1) Including a variety of abiotic factors increased number of species predicted & amount of variation explained

- Using all climatologic factors generally increased # spp predicted
- Using all factors increased avg. r^2 values for ALL traits

2) The ability of a abiotic factor to predict a species' traits relates to its ecological behavior

- Repro. effort predicted using previous year's factors
- Ability of a factor to predict a trait related to leaf & flowering phenology

Which factor to use?

Check using this year's air temps. above 2 °C for predicting my height!

Check last fall's soil temps if you wanna know how much I'll be reproducing!

Implications & Future work

- If modeling arctic plant responses to climate change use several abiotic factors
- Plant predictability is tied to ecological behavior
- Knowing which behaviors to base predictions on will improve our ability to predict how climate change will affect the Arctic

Sources

ACIA 2004. Impacts of a Warming Arctic: Arctic Climate Impact Assessment. Cambridge University Press.

Arft, A.M., M.D. Walker, J. Gurevitch, J.M. Alatalo, M.S. Bret-Harte, M. Dale, M. Diemer, F. Gugerli, G.H.R. Henry, M.H. Jones, R.D. Hollister, I.S. Jónsdóttir, K. Laine, E. Lévesque, G.M. Marion, U. Molau, P. Mølgaard, U. Nordenhäll, V. Raszhivin, C.H. Robinson, G. Starr, A. Stenström, M. Stenström, ø. Totland, P.L. Turner, L.J. Walker, P.J. Webber, J.M. Welker, and P.A. Wookey. 1999. Response patterns of tundra plant species to experimental warming: a meta-analysis of the International Tundra Experiment. Ecological Monographs 69(4): 491-511.

Hollister RD, P.J. Webber, and C. Bay. 2005. Plant response to temperature in northern Alaska: Implications for predicting vegetation change. Ecology 86(6): 1562-1570.

IPCC (2007) Climate Change 2007: The Scientific Basis. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. Cambridge, United Kingdom. 230 pp.

Post E, Forchhammer MC (2008) Climate change reduced reproductive success of Arctic herbivore through trophic mismatch. Philosophical Transactions of the Royal Society. 363, 2369-2375.

R Development Core Team (2008) R: A language and environment for statistical computing.

SPSS Inc (2009) PASW. SPSS Incorporated, Chicago, Illinois.

Starr G, Neuman DS, Oberbauer SF (2004) Ecophysiological analysis of two arctic sedges under reduced root temperatures. *Physiologia Plantarum,* **120,** 458-464.

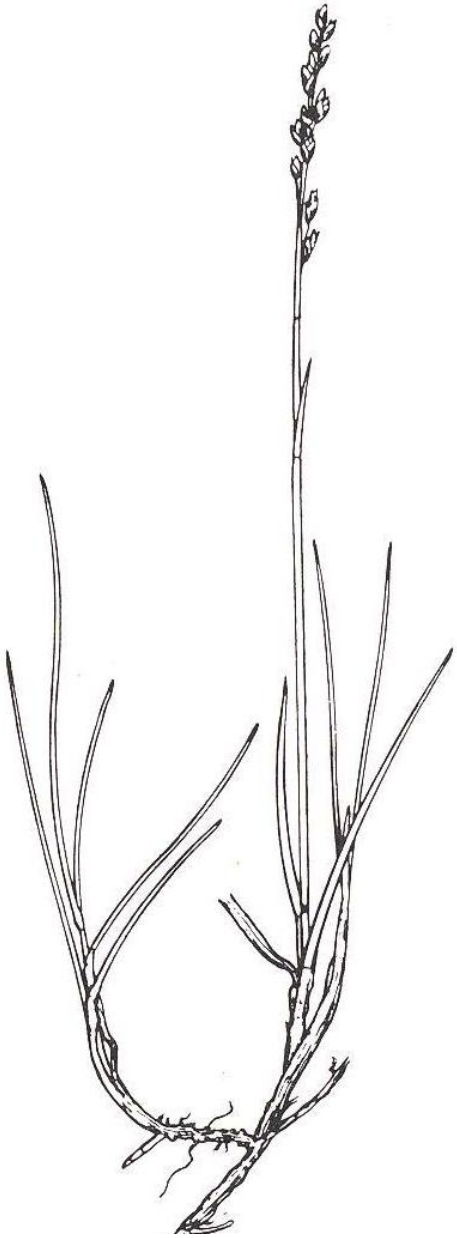
Thorhallsdottir TE (1998) Flowering phenology in the central highland of Iceland and implications for climatic warming in the Arctic. *Oecologia,* **114,** 43-49.

Acknowledgements

GVSU Arctic Ecology Program

- Jeremy May, Jenny Liebig, , Kelsey Kremers, Jean Galang, Michael Lothschutz, Amanda Snyder


Any questions?

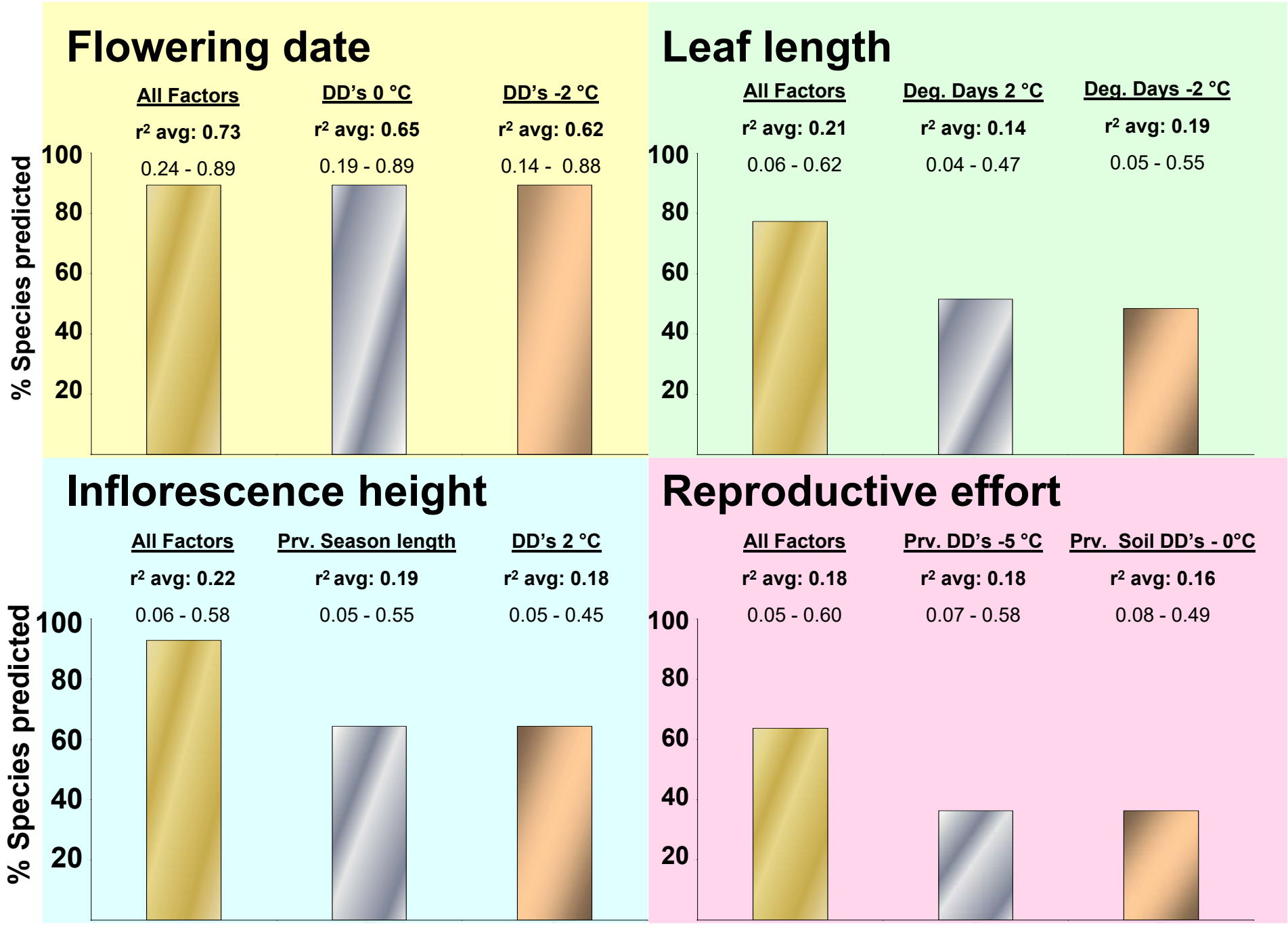


The ability of a climatologic factor to predict a species' traits relates to its ecological behavior

Example: Sexual reproduction is "expensive"!

Warmer temperatures may make it more affordable

Senecio atropurpureus


Flowering date
All Factors
r² avg: 0.73
0.24 - 0.89
DD's 0 °C
r² avg: 0.65
0.19 - 0.89
DD's -2 °C
r² avg: 0.62
0.14 - 0.88
Leaf length
All Factors
r² avg: 0.21
0.06 - 0.62
Deg. Days 2 °C
r² avg: 0.14
0.04 - 0.47
Deg. Days -2 °C
r² avg: 0.19
0.05 - 0.55
Inflorescence height
All Factors
r² avg: 0.22
0.06 - 0.58
Prv. Season length
r² avg: 0.19
0.05 - 0.55
DD's 2 °C
r² avg: 0.18
0.05 - 0.45
Reproductive effort
All Factors
r² avg: 0.18
0.05 - 0.60
Prv. DD's -5 °C
r² avg: 0.18
0.07 - 0.58
Prv. Soil DD's - 0°C
r² avg: 0.16
0.08 - 0.49
% Species predicted
100
80
60
40
20

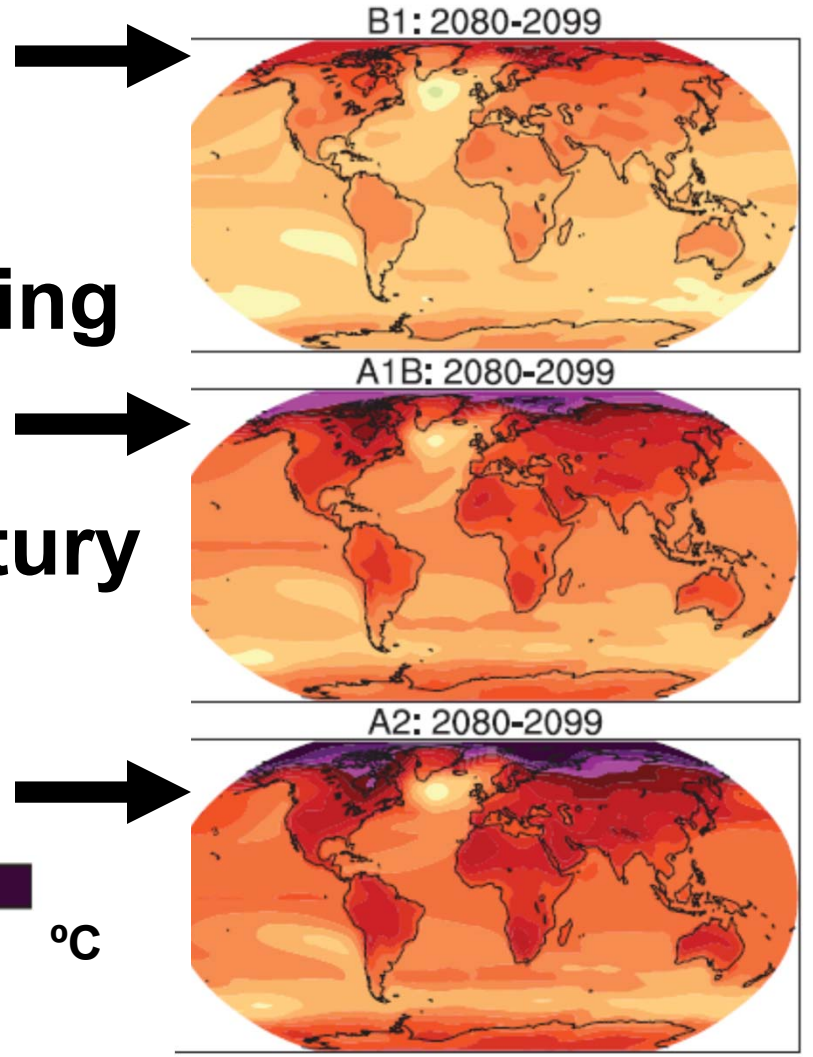
The Arctic is warming and is predicted to continue warming

Rapid & dramatic warming

(4 - 8ºC)

predicted over next century

(IPCC 2007)



Summary of results

(with proposed explanations)

1) Across plant traits, more species were predicted by degree days than seasonal event dates (e.g. snowmelt date)

- Degree days incorporate time & temperature

2) The number of species predicted & amount of variability explained by degree days depended on base temperature

- Temp. requirements for growth & reproduction vary by species & trait

3) Some traits were better predicted using the previous year's climatic factors rather than the current year's

- Previous year's conditions affect resources availability in current year

4) Species' responses to climatic factors could be explained by timing of resource acquisition & utilization

- Ecological behavior should determine which

2) The number of species predicted & amount of variability explained by degree days depended on base temperature

- Just show current year's degree days for inLn, flower date, and leaf length with r2 values
- Point out lower DD's predict more spp for leaf-out while higher do for repro traits (repro effort not included)

3) Some traits were better predicted using the previous year's climatic factors rather than the current year's

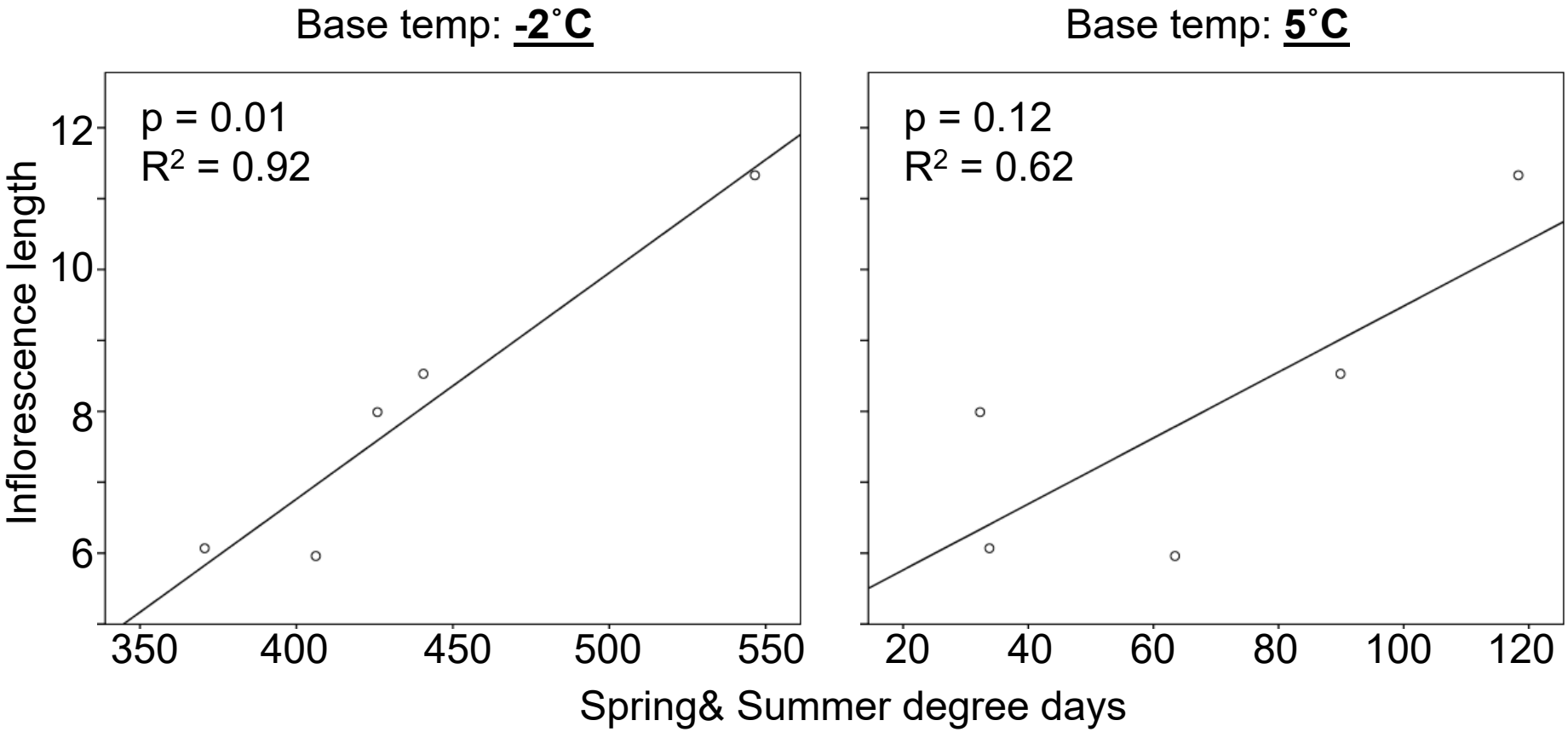
- Show regression of CTET BD
  - Previous year's soil tdd
  - Current year's soil tdd

4) Species' responses to climatic factors could be explained by timing of resource acquisition & utilization

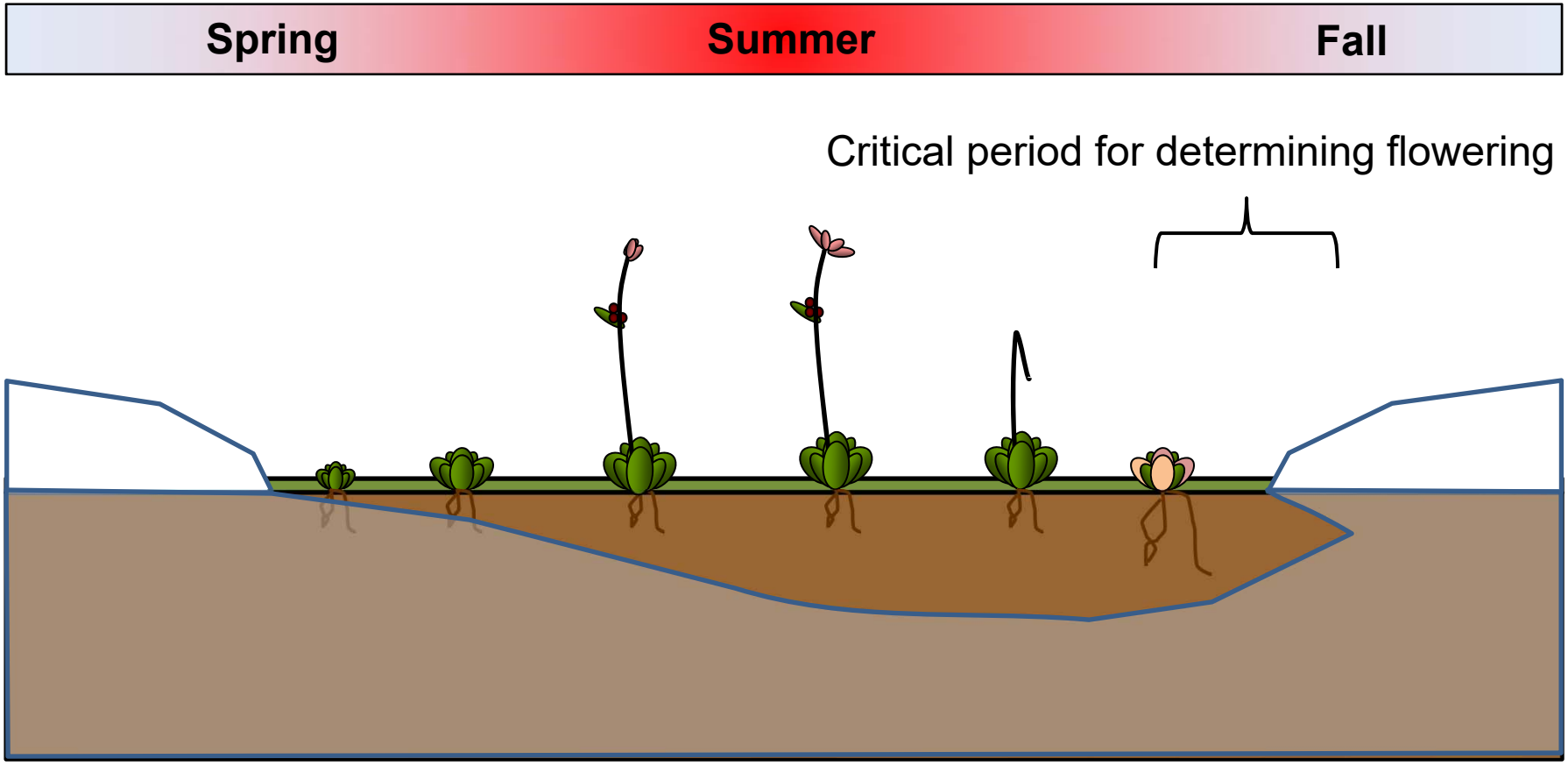
- Refer to previous thing w/CTET
- Case study with DFIS
  - Leaves by current & previous
  - Inf's by current mostly

Findings in context:
degree day base temp. matters

Potentilla hyparctica

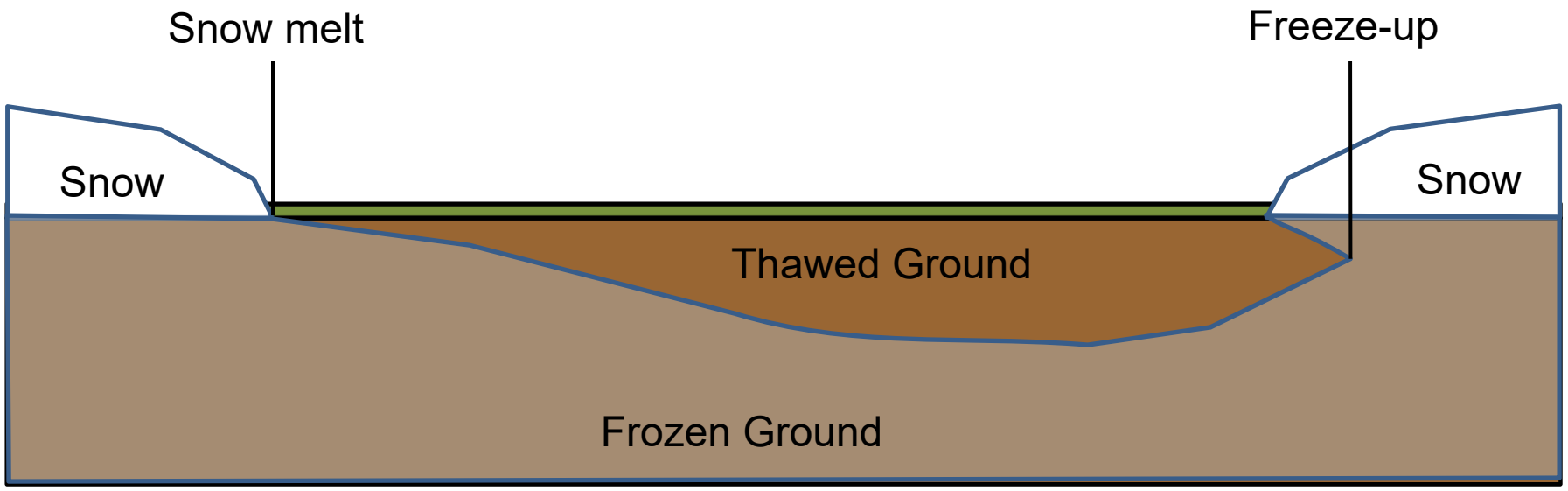


Findings in context: repro. effort better predicted using previous year's temps.

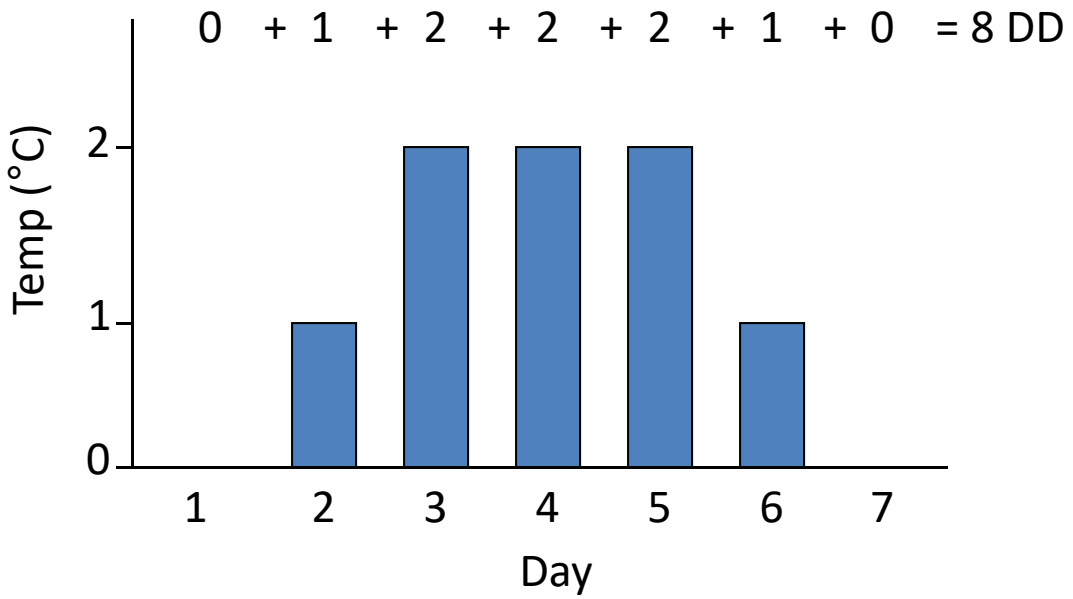


Arctic growing season

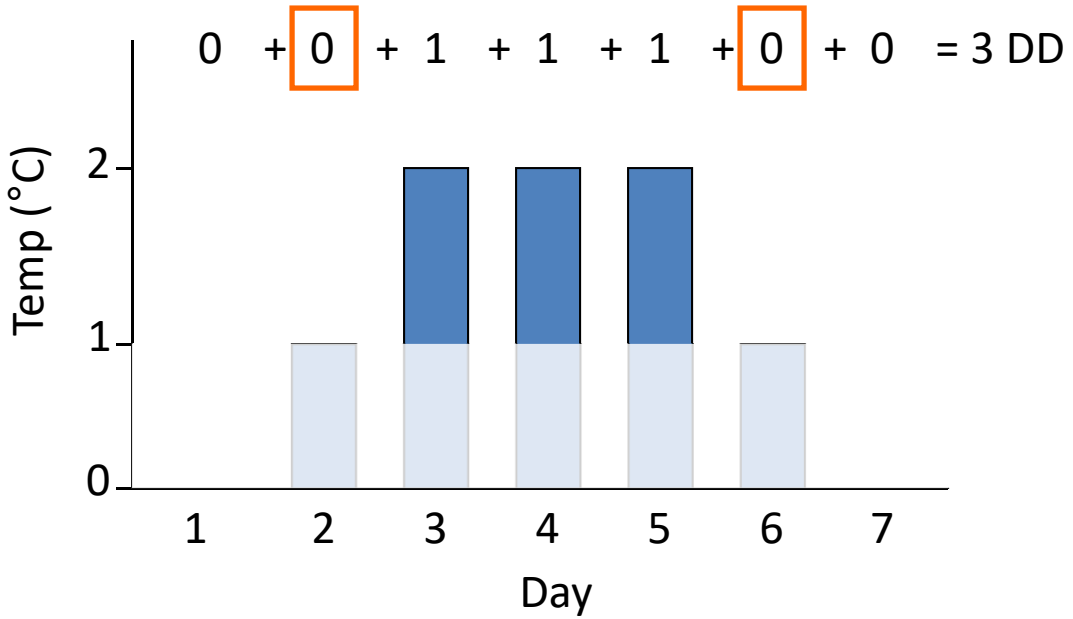
Spring	Summer	Fall
(Mid-June to Late June)	*(July to Mid-August)*	*(Mid-August to Late Sept.)*



Base Temp: 0 °C



Base Temp: 1 °C



- Repro effort: 9 (27.27%) species predicted using previous season’s abiotic factors