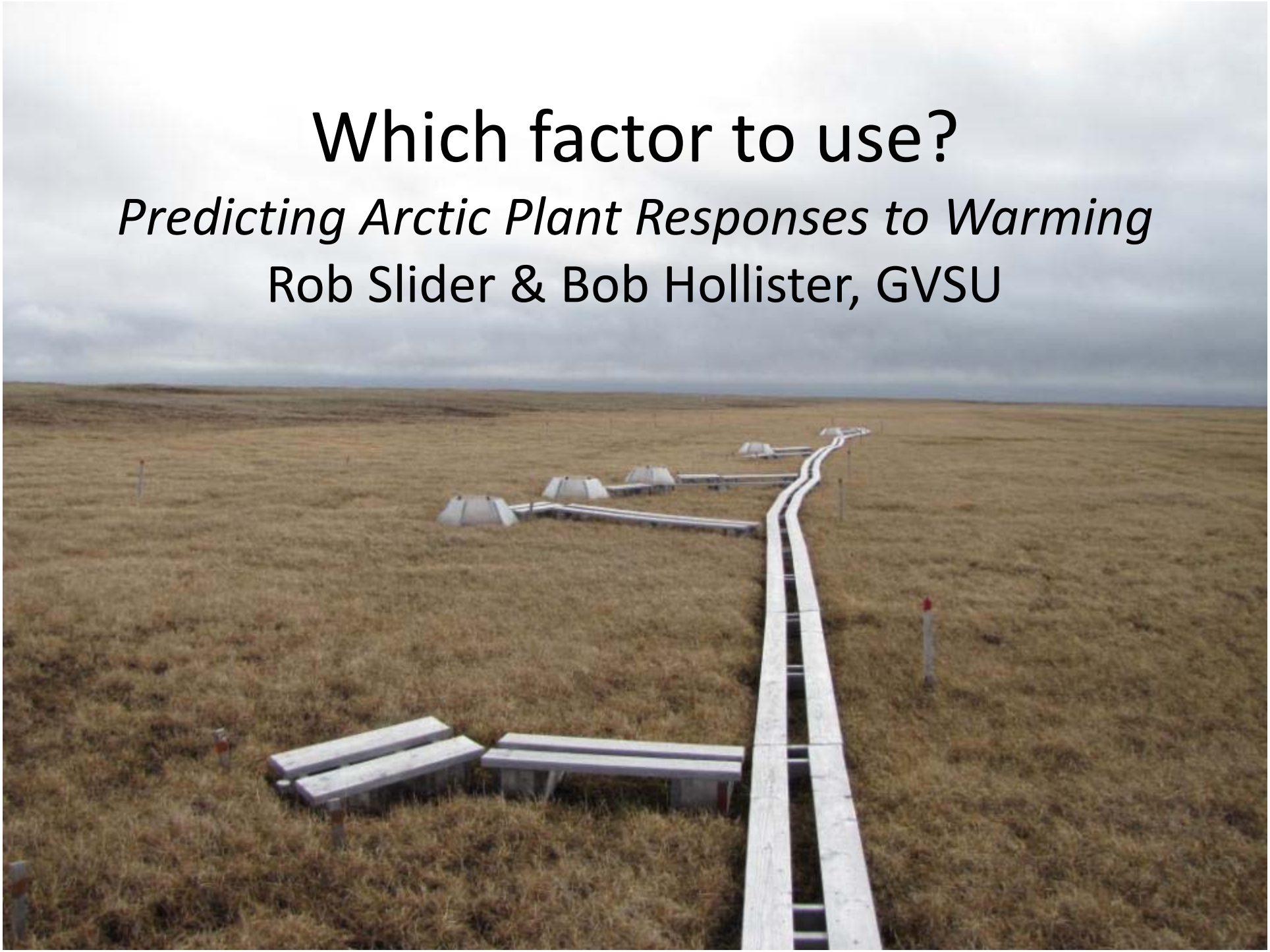
Which factor to use?

Predicting Arctic Plant Responses to Warming

Rob Slider & Bob Hollister, GVSU



Predicting plant responses to warming is important

- Arctic plants play critical roles in local and global systems

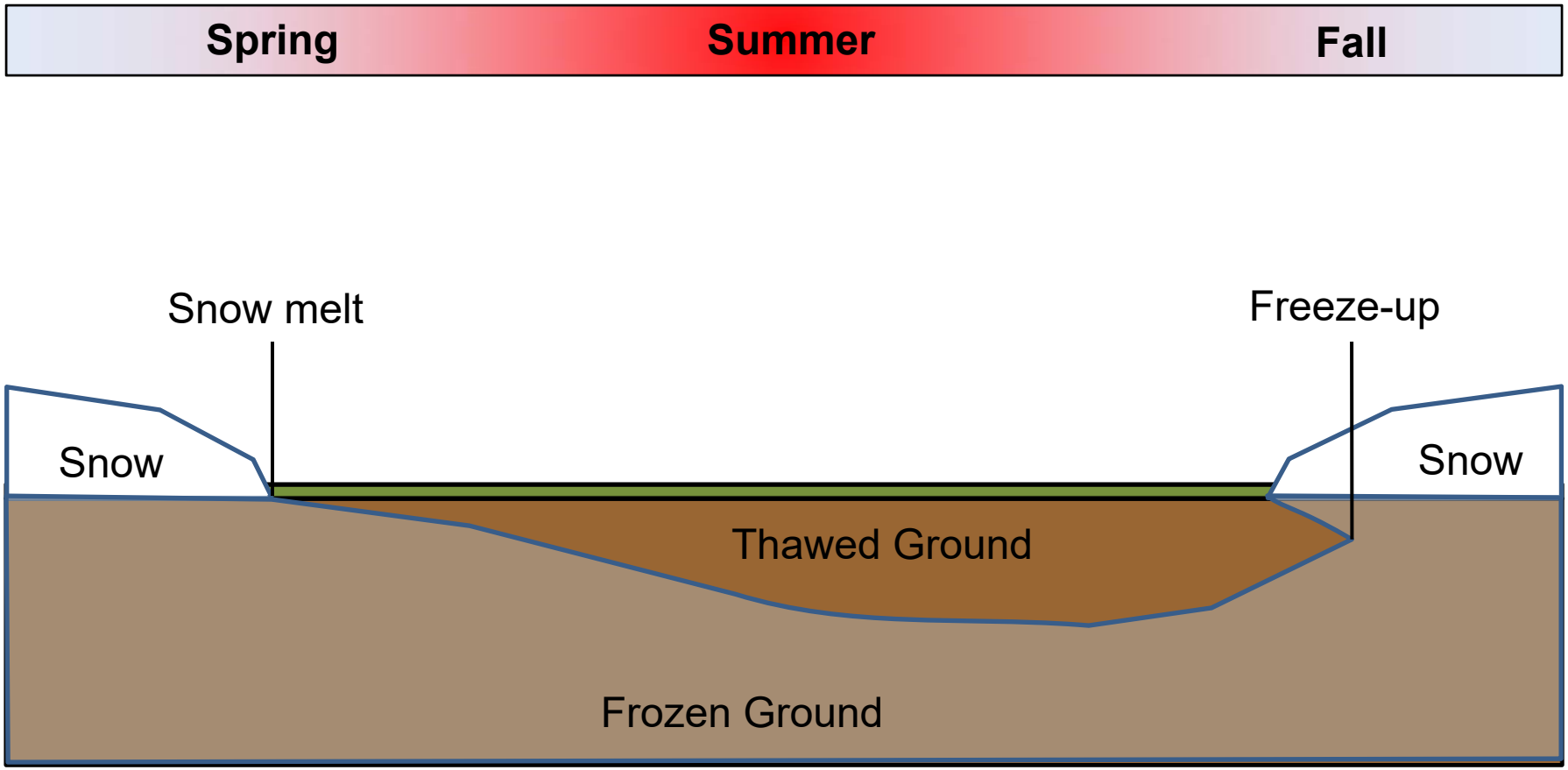
- Predicting plant responses to abiotic factors can improve models of these systems

<u>Study Question:</u>

Since predicting plant responses to warming is important

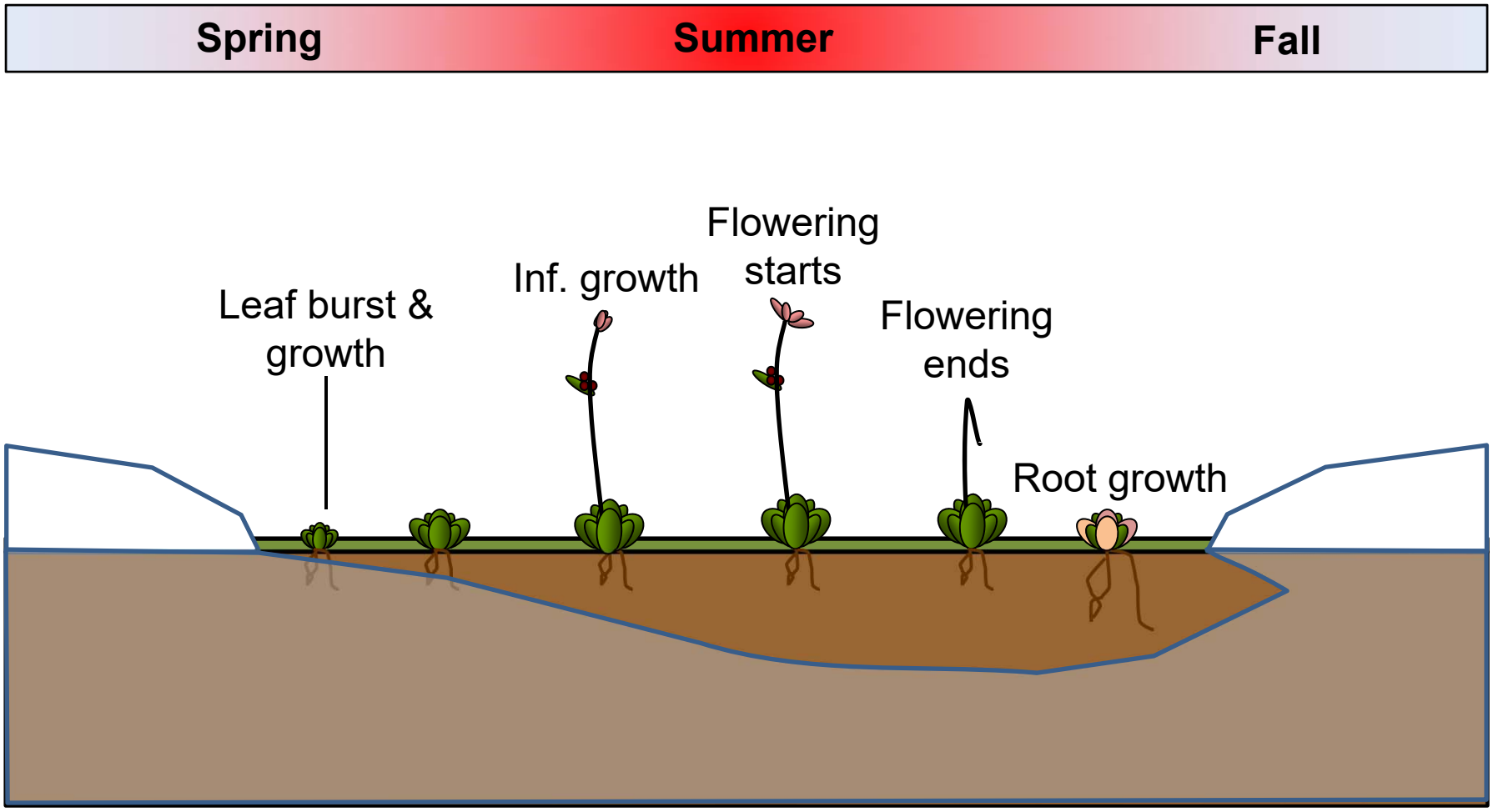
how can we best predict them?

Arctic growing season

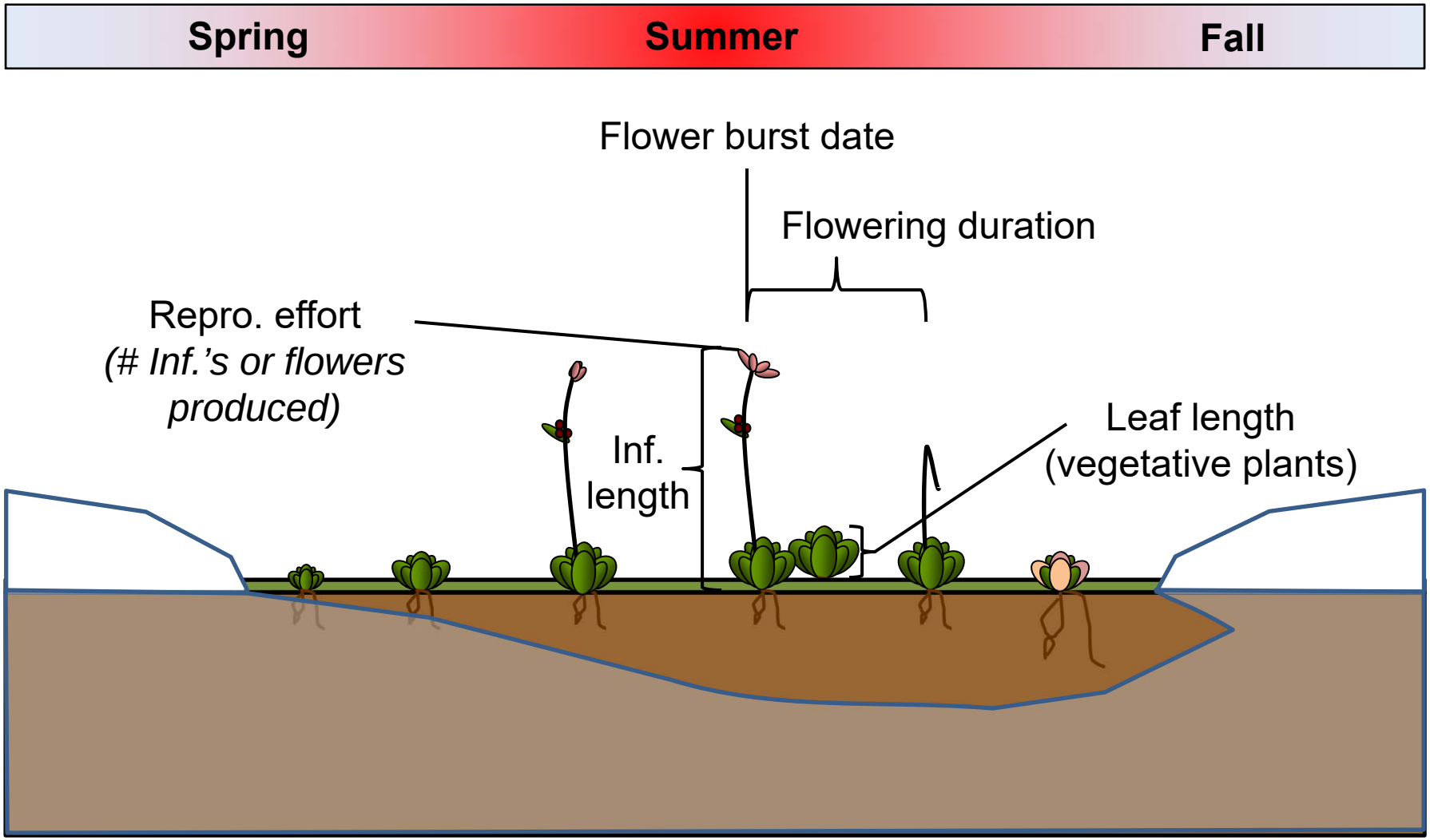


Arctic growing season

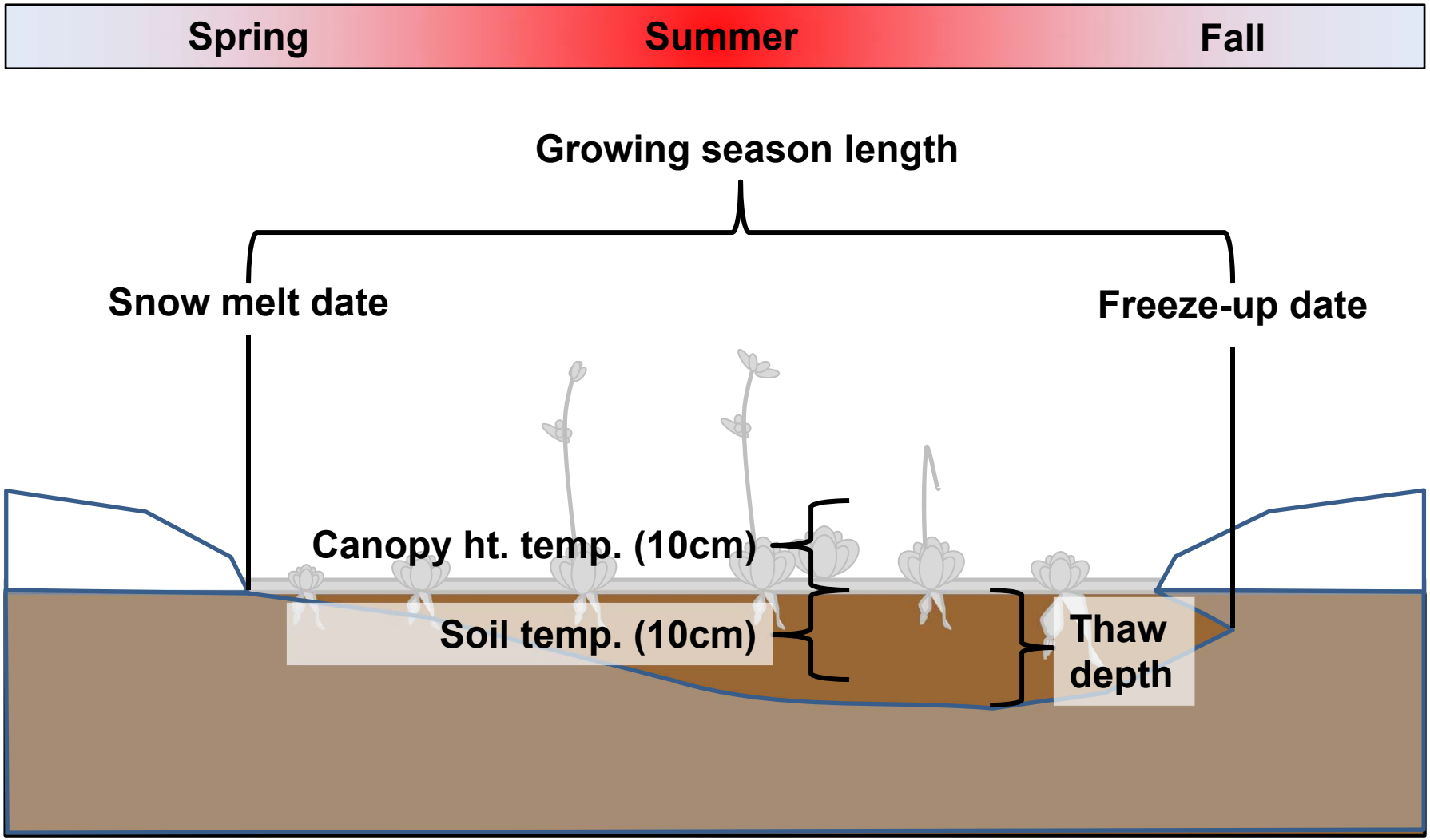
from a plant's perspective



Plant traits examined



Abiotic factors examined



Specific trait predictions

Prediction 1: Plant traits will be better predicted using degree days than season dates (e.g. snow melt date).

- Season dates only account for time while degree days incorporate temperature

Prediction 2: Using different degree day base temps. will alter the number of species predicted.

- Species have different minimal growing requirements and this will determine how effectively degree days predict their traits

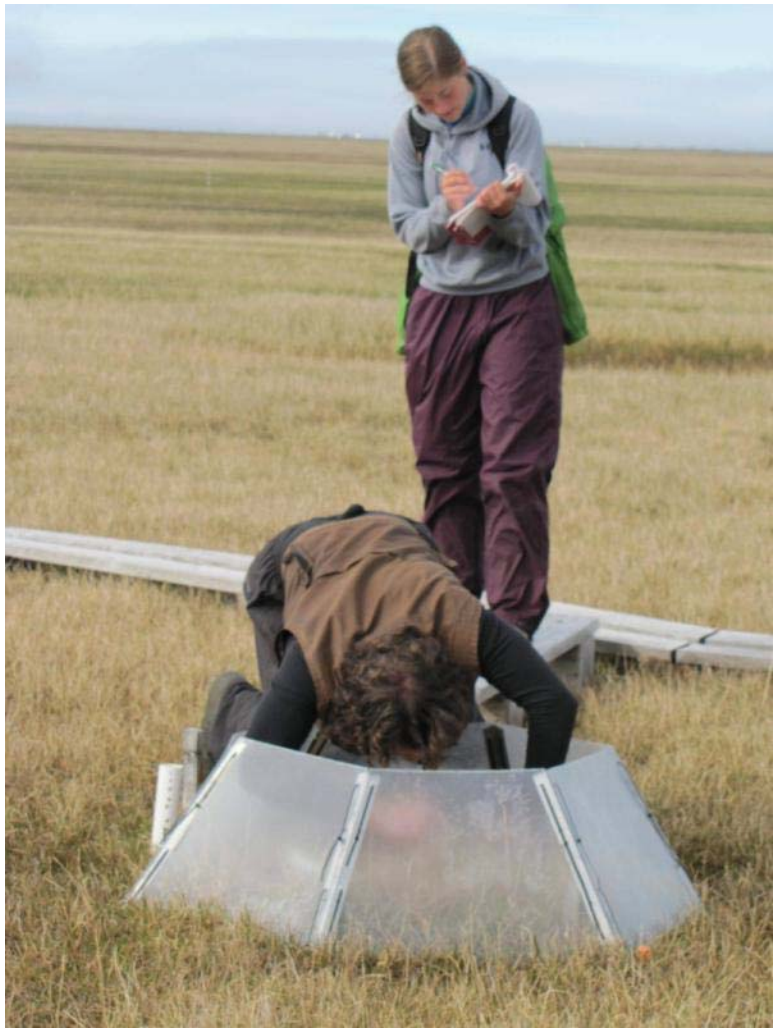
Prediction 3: Reproductive effort will be better predicted using temp. measures from previous years than those during the current year.

- Previous season's temps. critical in determining flower "finalization"

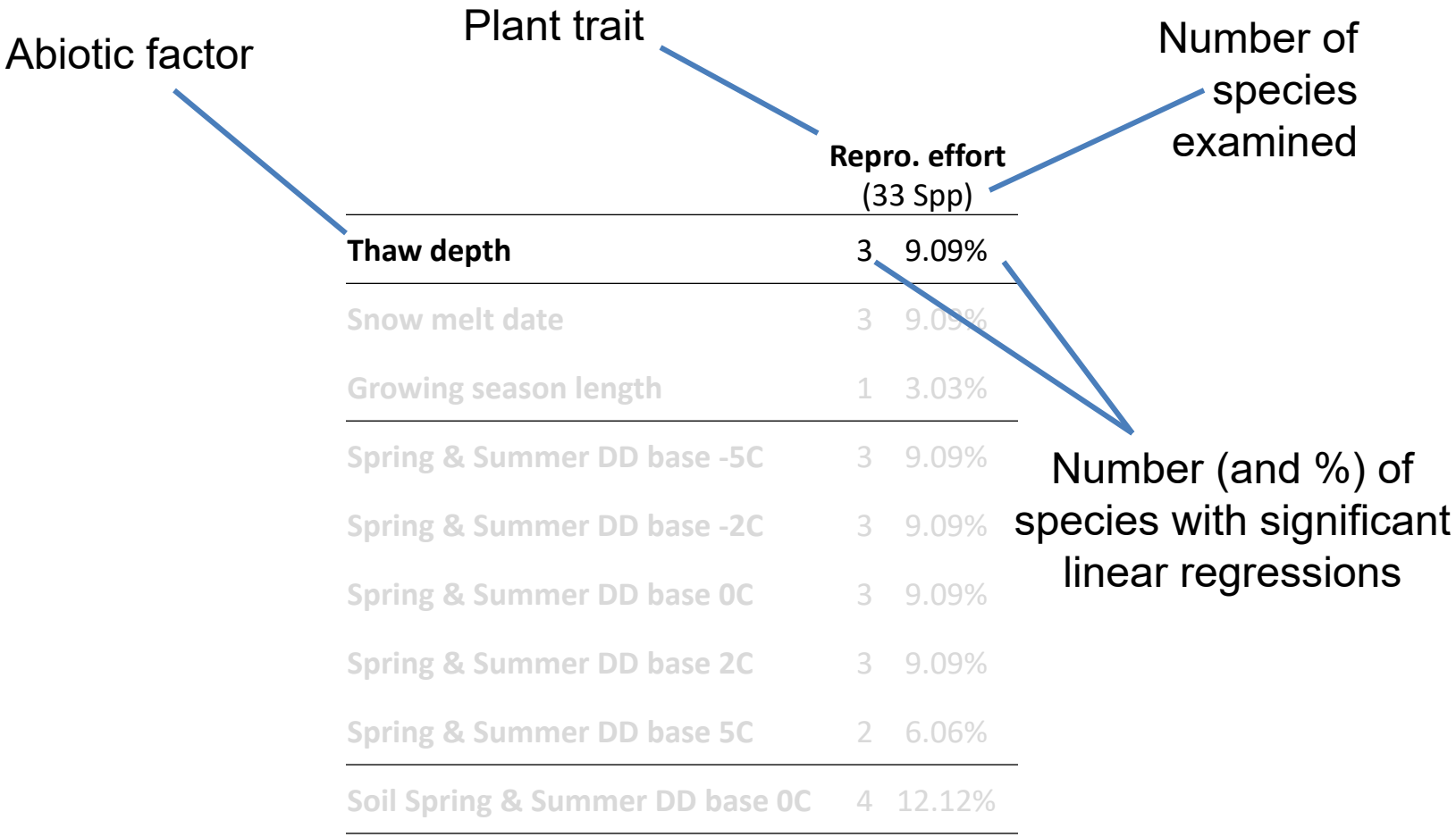
Methods

- Control plot data from 5 years between 1999-2008

  (Years <u>all</u> abiotic factors were collected)
- Plant traits averaged each year
- Abiotic factors averaged each year
- Calculating degree days:
  - Various base temp (-5˚C to 5˚C)
  - Two periods:
    - Snow-melt through Aug 15 *(spring & summer)*
    - Aug 15 – Freeze-up *(fall)*
- Linear regressions in R ($\alpha = 0.05$)



Interpreting results



Prediction 1: Plant traits will be better predicted using degree days than season dates (e.g. snow melt date)

Repro. effort: # sig. predictions fairly similar regardless of factor used

	Repro. effort (33 Spp)	
Thaw depth	3	9.09%
Snow melt date	3	9.09%
Growing season length	1	3.03%
Spring & Summer DD base -5C	3	9.09%
Spring & Summer DD base -2C	3	9.09%
Spring & Summer DD base 0C	3	9.09%
Spring & Summer DD base 2C	3	9.09%
Spring & Summer DD base 5C	2	6.06%
Soil Spring & Summer DD base 0C	4	12.12%

Prediction 1: Plant traits will be better predicted using degree days than season dates (e.g. snow-melt date)

Inf. length: # sig. predictions higher using degree days or thaw than season dates

	Repro. effort (33 Spp)		**Inf. length** (24 Spp)	
Thaw depth	3	9.09%	5	20.83%
Snow melt date	3	9.09%	.	.
Growing season length	1	3.03%	1	4.17%
Spring & Summer DD base -5C	3	9.09%	6	25.00%
Spring & Summer DD base -2C	3	9.09%	5	20.83%
Spring & Summer DD base 0C	3	9.09%	3	12.50%
Spring & Summer DD base 2C	3	9.09%	2	8.33%
Spring & Summer DD base 5C	2	6.06%	.	.
Soil Spring & Summer DD base 0C	4	12.12%	7	29.17%

Prediction 1: Plant traits will be better predicted using degree days than season dates (e.g. snow-melt date)

Leaf length: # sig. predictions somewhat higher using degree days

	Repro. effort (33 Spp)		Inf. length (24 Spp)		**Leaf length** (27 Spp)	
Thaw depth	3	9.09%	5	20.83%	1	3.70%
Snow melt date	3	9.09%	.	.	2	7.41%
Growing season length	1	3.03%	1	4.17%	2	7.41%
Spring & Summer DD base -5C	3	9.09%	6	25.00%	4	14.81%
Spring & Summer DD base -2C	3	9.09%	5	20.83%	3	11.11%
Spring & Summer DD base 0C	3	9.09%	3	12.50%	3	11.11%
Spring & Summer DD base 2C	3	9.09%	2	8.33%	2	7.41%
Spring & Summer DD base 5C	2	6.06%	.	.	2	7.41%
Soil Spring & Summer DD base 0C	4	12.12%	7	29.17%	2	7.41%

Prediction 1: Plant traits will be better predicted using degree days than season dates (e.g. snow-melt date)

Flowering date: # sig. predictions higher using season date or soil degree days

	Repro. effort (33 Spp)		Inf. length (24 Spp)		Leaf length (27 Spp)		**Flowering date** (19 Spp)	
Thaw depth	3	9.09%	5	20.83%	1	3.70%	1	5.26%
Snow melt date	3	9.09%	.	.	2	7.41%	2	10.53%
Growing season length	1	3.03%	1	4.17%	2	7.41%	2	10.53%
Spring & Summer DD base -5C	3	9.09%	6	25.00%	4	14.81%	1	5.26%
Spring & Summer DD base -2C	3	9.09%	5	20.83%	3	11.11%	1	5.26%
Spring & Summer DD base 0C	3	9.09%	3	12.50%	3	11.11%	.	.
Spring & Summer DD base 2C	3	9.09%	2	8.33%	2	7.41%	.	.
Spring & Summer DD base 5C	2	6.06%	.	.	2	7.41%	.	.
Soil Spring & Summer DD base 0C	4	12.12%	7	29.17%	2	7.41%	3	15.79%

Prediction 1: Plant traits will be better predicted using degree days than season dates (e.g. snow-melt date)

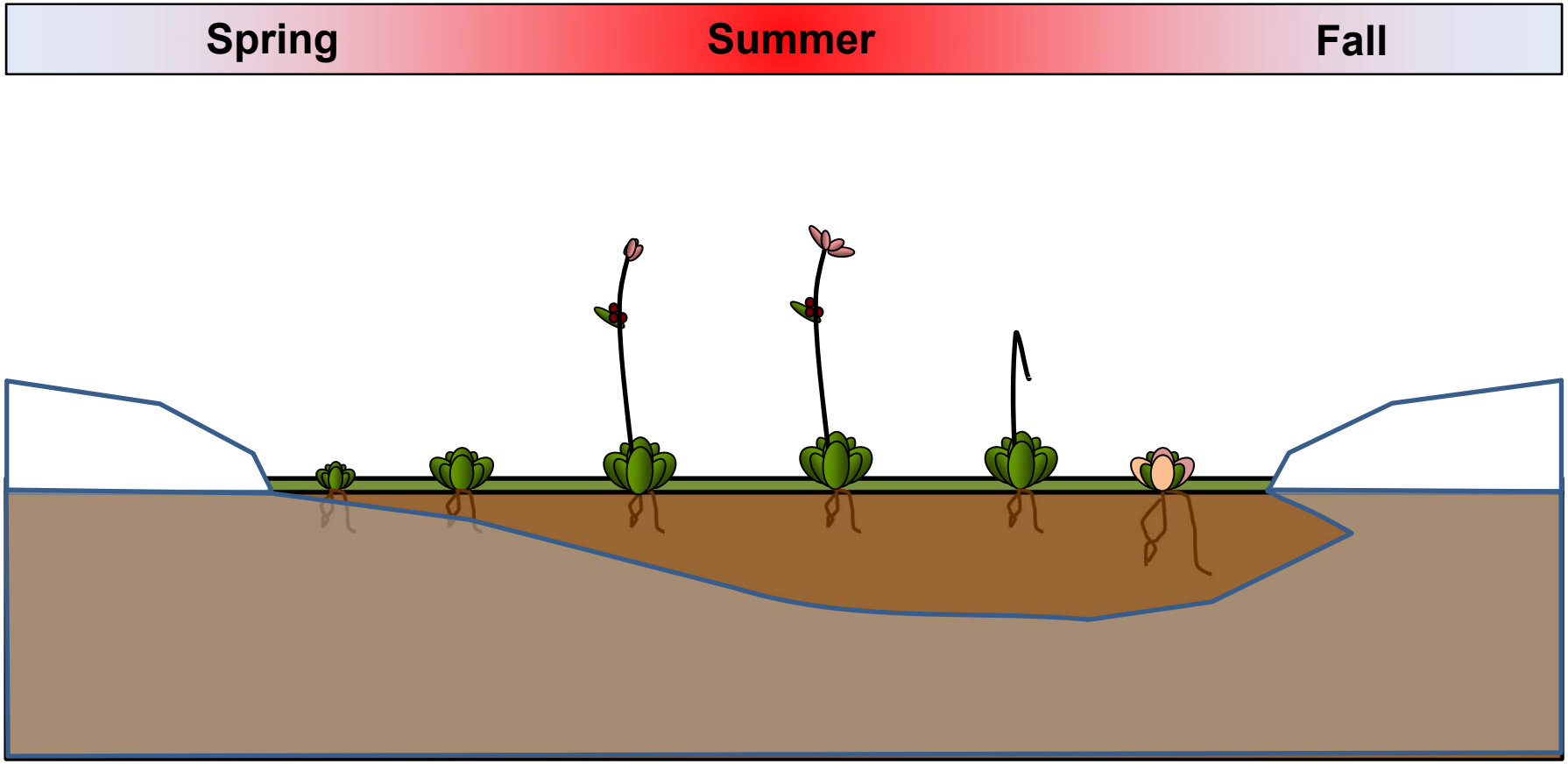
Flower duration: # sig. predictions higher using soil degree days, but poor overall

	Repro. effort (33 Spp)		Inf. length (24 Spp)		Leaf length (27 Spp)		Flowering date (19 Spp)		**Flower duration** (19 Spp)	
Thaw depth	3	9.09%	5	20.83%	1	3.70%	1	5.26%	1	5.26%
Snow melt date	3	9.09%	.	.	2	7.41%	2	10.53%	.	.
Growing season length	1	3.03%	1	4.17%	2	7.41%	2	10.53%	1	5.26%
Spring & Summer DD base -5C	3	9.09%	6	25.00%	4	14.81%	1	5.26%	.	.
Spring & Summer DD base -2C	3	9.09%	5	20.83%	3	11.11%	1	5.26%	.	.
Spring & Summer DD base 0C	3	9.09%	3	12.50%	3	11.11%	.	.	.	.
Spring & Summer DD base 2C	3	9.09%	2	8.33%	2	7.41%	.	.	.	.
Spring & Summer DD base 5C	2	6.06%	.	.	2	7.41%	.	.	.	.
Soil Spring & Summer DD base 0C	4	12.12%	7	29.17%	2	7.41%	3	15.79%	2	10.53%

Prediction 1: Plant traits will be better predicted using degree days than season dates (e.g. snow-melt date)

	Repro. effort (33 Spp)		Inf. length (24 Spp)		Leaf length (27 Spp)		Flowering date (19 Spp)		Flower duration (19 Spp)	
Thaw depth	3	9.09%	5	20.83%	1	3.70%	1	5.26%	1	5.26%
Snow melt date	3	9.09%	.	.	2	7.41%	2	10.53%	.	.
Growing season length	1	3.03%	1	4.17%	2	7.41%	2	10.53%	1	5.26%
Spring & Summer DD base -5C	3	9.09%	6	25.00%	4	14.81%	1	5.26%	.	.
Spring & Summer DD base -2C	3	9.09%	5	20.83%	3	11.11%	1	5.26%	.	.
Spring & Summer DD base 0C	3	9.09%	3	12.50%	3	11.11%	.	.	.	.
Spring & Summer DD base 2C	3	9.09%	2	8.33%	2	7.41%	.	.	.	.
Spring & Summer DD base 5C	2	6.06%	.	.	2	7.41%	.	.	.	.
Soil Spring & Summer DD base 0C	4	12.12%	7	29.17%	2	7.41%	3	15.79%	2	10.53%

Findings in context: degree days yielded more significant models than season dates



Prediction 2: Using different degree day base temps. will alter the number of species predicted.

Trend: as base temperature increases, the number of significant models decreases

	Repro. effort (33 Spp)		Inf. length (24 Spp)		Leaf length (27 Spp)		Flowering date (19 Spp)		Flower duration (19 Spp)	
Spring & Summer DD base -5C	3	9.09%	6	25.00%	4	14.81%	1	5.26%	.	.
Spring & Summer DD base -2C	3	9.09%	5	20.83%	3	11.11%	1	5.26%	.	.
Spring & Summer DD base 0C	3	9.09%	3	12.50%	3	11.11%	.	.	.	.
Spring & Summer DD base 2C	3	9.09%	2	8.33%	2	7.41%	.	.	.	.
Spring & Summer DD base 5C	2	6.06%	.	.	2	7.41%	.	.	.	.

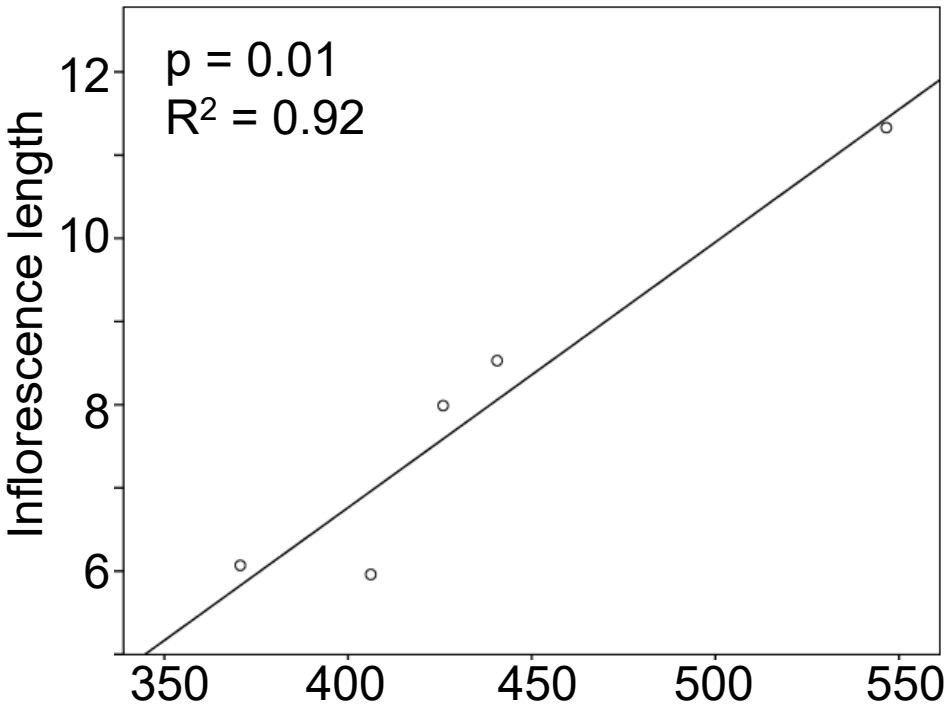
Prediction 2: Using different degree day base temps. will alter the number of species predicted.

Trend: as base temperature increases, the number of significant models decreases

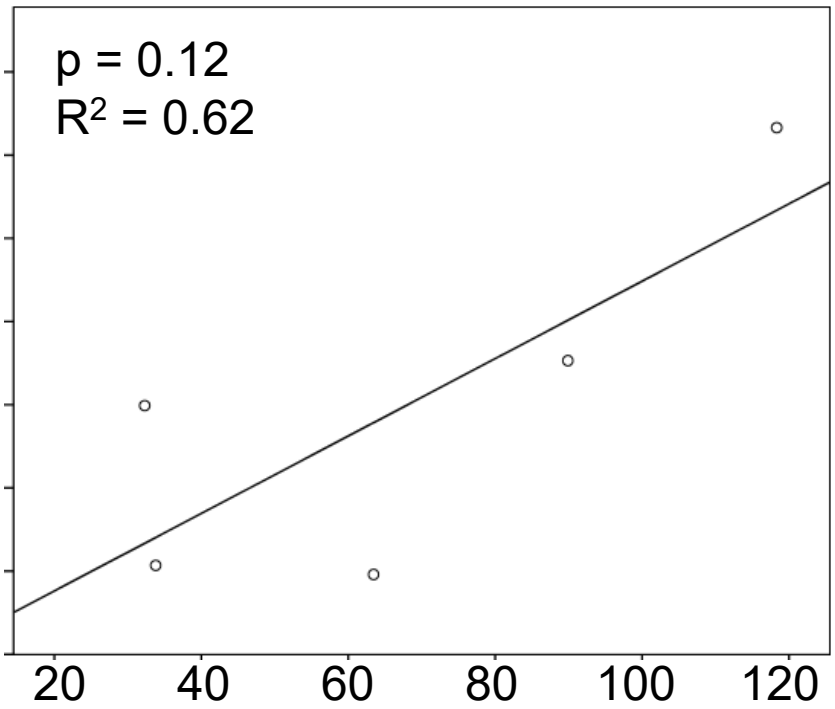
	Repro. effort (33 Spp)		Inf. length (24 Spp)		Leaf length (27 Spp)		Flowering date (19 Spp)		Flower duration (19 Spp)	
Spring & Summer DD base -5C	3	9.09%	6	25.00%	4	14.81%	1	5.26%	.	.
Spring & Summer DD base -2C	3	9.09%	5	20.83%	3	11.11%	1	5.26%	.	.
Spring & Summer DD base 0C	3	9.09%	3	12.50%	3	11.11%	.	.	.	.
Spring & Summer DD base 2C	3	9.09%	2	8.33%	2	7.41%	.	.	.	.
Spring & Summer DD base 5C	2	6.06%	.	.	2	7.41%	.	.	.	.

Findings in context:
degree day base temp. matters

Base temp: **-2˚C**



Base temp: **5˚C**



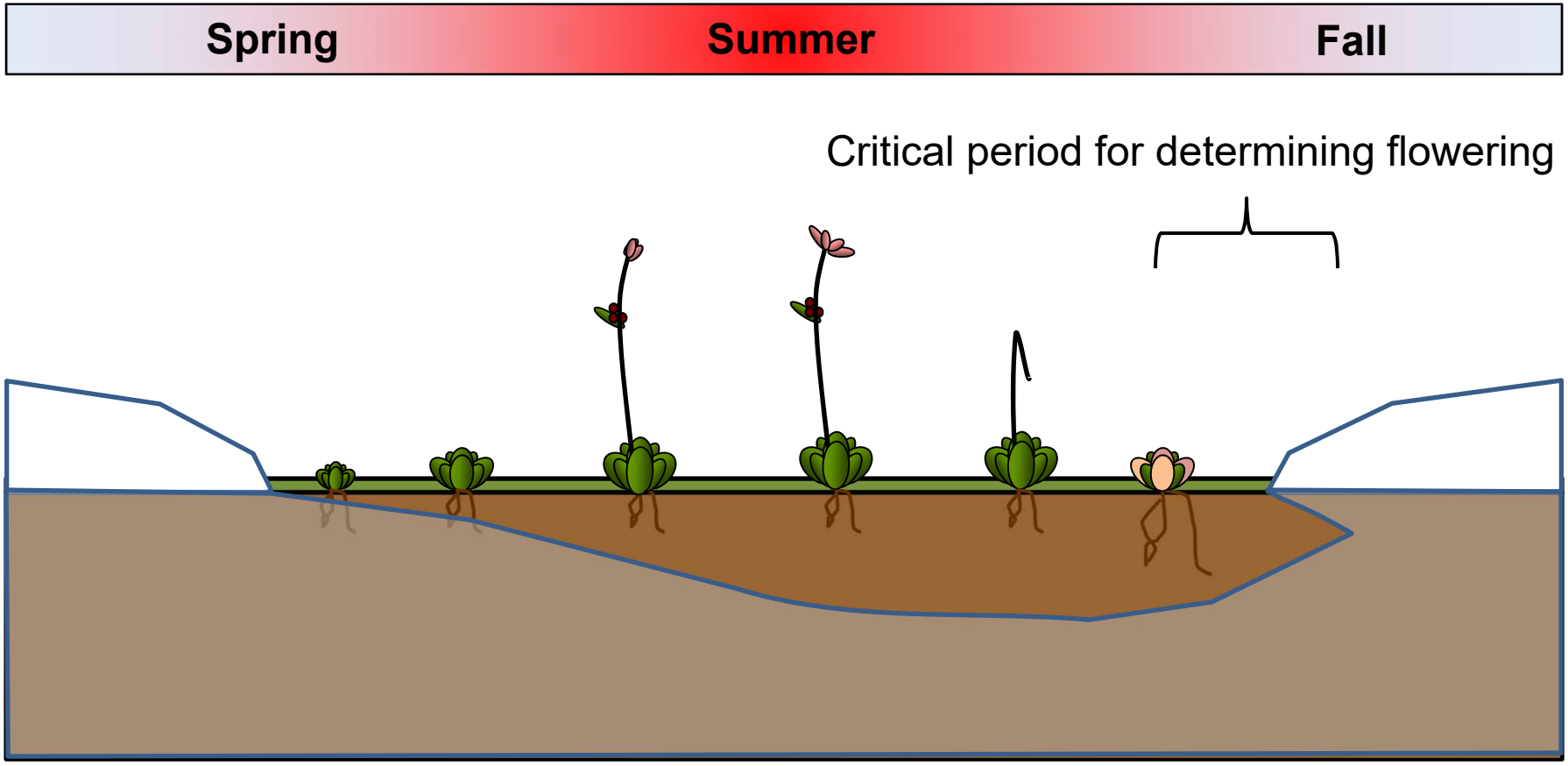
Spring& Summer degree days

Prediction 3: Reproductive effort will be better predicted using temp. measures from previous years than those during the current year.

Trend: Using previous year's canopy temps slightly increased # sig. models AND using previous fall soil degree days showed greatest number of sig. models.

	Repro. Effort (33 Spp.)			
	Using **current year's** temps		Using **previous year's** temps	
Spring & Summer DD base -5C	3	9.09%	4	12.12%
Spring & Summer DD base -2C	3	9.09%	4	12.12%
Spring & Summer DD base 0C	3	9.09%	4	12.12%
Spring & Summer DD base 2C	3	9.09%	4	12.12%
Spring & Summer DD base 5C	2	6.06%	.	.
Soil Spring & Summer DD base 0C	4	12.12%	2	6.06%
Soil Fall DD base 0C			6	18.18%

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



Other trends

Soil degree days had the greatest number of sig. models for all plant traits but leaf length

	Repro. effort (33 Spp)		**Inf. length** (24 Spp)		**Leaf length** (27 Spp)		**Flowering date** (19 Spp)		**Flower duration** (19 Spp)	
Thaw depth	3	9.09%	5	20.83%	1	3.70%	1	5.26%	1	5.26%
Snow melt date	3	9.09%	.	.	2	7.41%	2	10.53%	.	.
Growing season length	1	3.03%	1	4.17%	2	7.41%	2	10.53%	1	5.26%
Spring & Summer DD base -5C	3	9.09%	6	25.00%	4	14.81%	1	5.26%	.	.
Spring & Summer DD base -2C	3	9.09%	5	20.83%	3	11.11%	1	5.26%	.	.
Spring & Summer DD base 0C	3	9.09%	3	12.50%	3	11.11%	.	.	.	.
Spring & Summer DD base 2C	3	9.09%	2	8.33%	2	7.41%	.	.	.	.
Spring & Summer DD base 5C	2	6.06%	.	.	2	7.41%	.	.	.	.
Soil Spring & Summer DD base 0C	4	12.12%	7	29.17%	2	7.41%	3	15.79%	2	10.53%

Other trends

Combined ability of abiotic factors to predict plant traits

	Repro. effort (33 Spp)		**Inf. length** (24 Spp)		**Leaf length** (27 Spp)		**Flowering date** (19 Spp)		**Flower duration** (19 Spp)	
Thaw depth	3	9.09%	5	20.83%	1	3.70%	1	5.26%	1	5.26%
Snow melt date	3	9.09%	.	.	2	7.41%	2	10.53%	.	.
Growing season length	1	3.03%	1	4.17%	2	7.41%	2	10.53%	1	5.26%
Spring & Summer DD base -5C	3	9.09%	6	25.00%	4	14.81%	1	5.26%	.	.
Spring & Summer DD base -2C	3	9.09%	5	20.83%	3	11.11%	1	5.26%	.	.
Spring & Summer DD base 0C	3	9.09%	3	12.50%	3	11.11%	.	.	.	.
Spring & Summer DD base 2C	3	9.09%	2	8.33%	2	7.41%	.	.	.	.
Spring & Summer DD base 5C	2	6.06%	.	.	2	7.41%	.	.	.	.
Soil Spring & Summer DD base 0C	4	12.12%	7	29.17%	2	7.41%	3	15.79%	2	10.53%
TOTAL Spp Predicted	**11**	**33.00%**	**12**	**50.00%**	**7**	**25.92%**	**8**	**42.11%**	**4**	**21.05%**

Summary

- Degree days tend to be better at predicting plant traits than season dates
- Changing base temperature for calculating degree days changes number of species predicted
- Reproductive effort can be better predicted using temp. data from previous years
- Using soil temps. can increase the number of species whose traits are predicted
- Using multiple abiotic factors improves predictions

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

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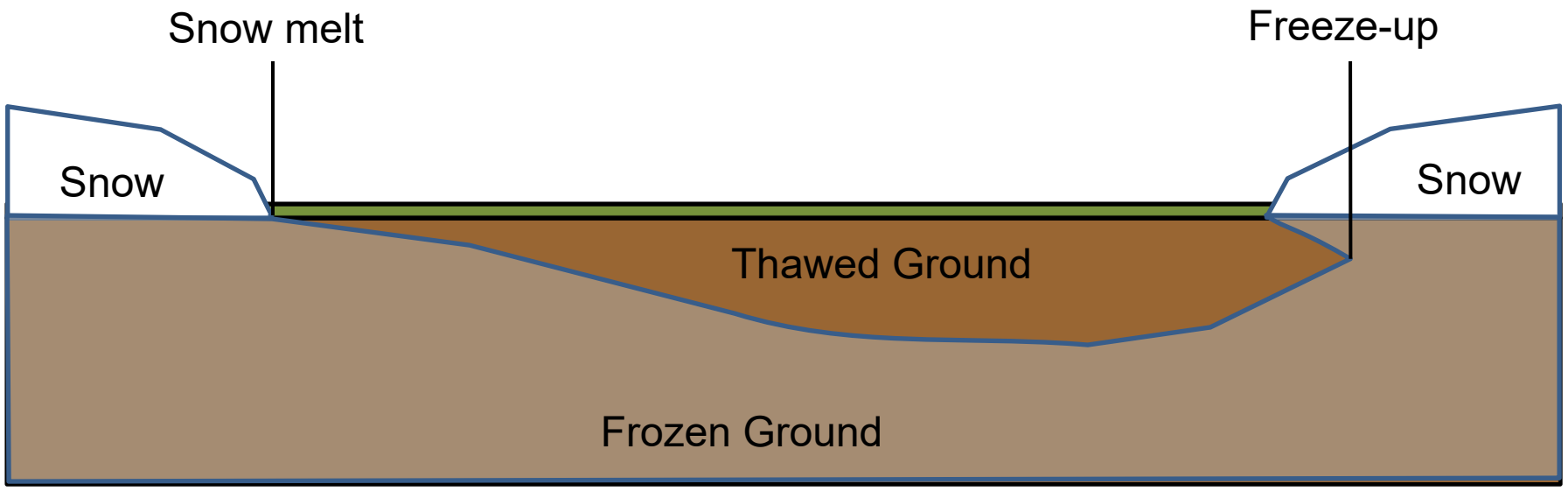
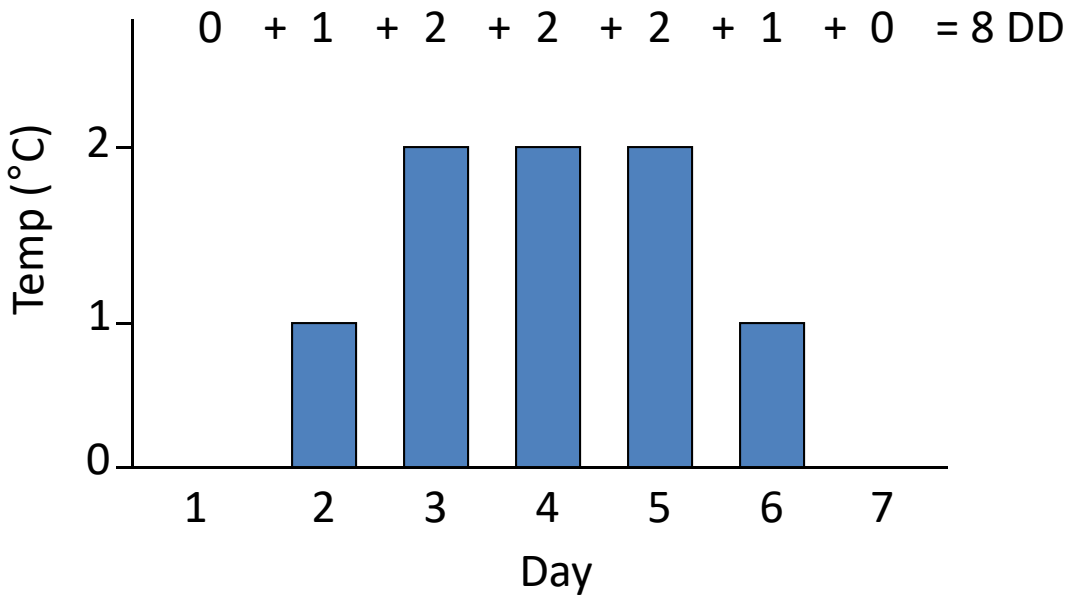
Questions?

Arctic growing season

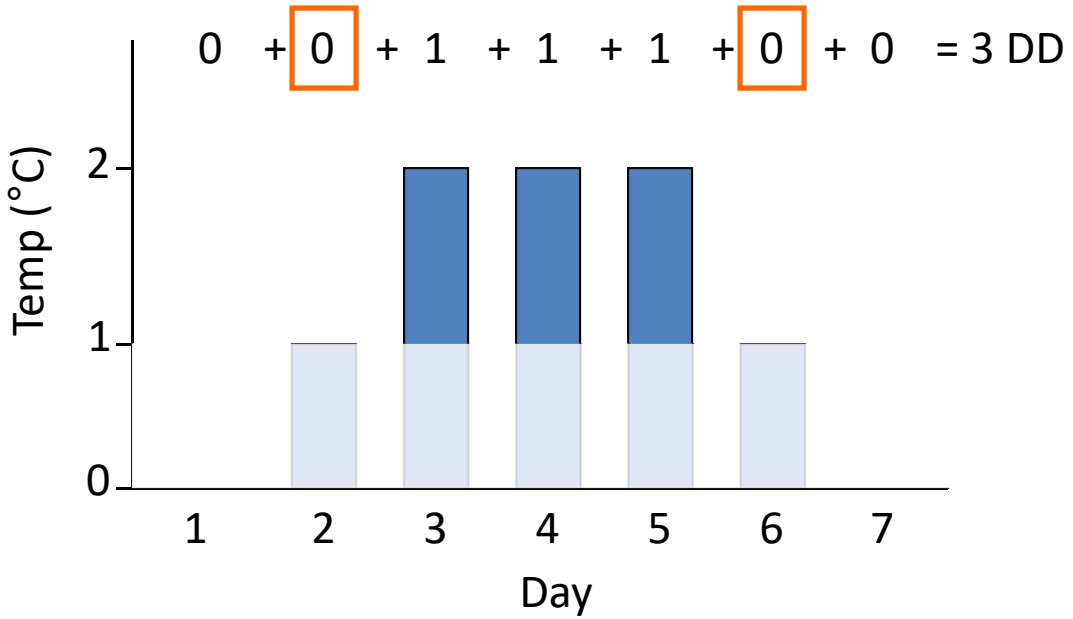
Spring	Summer	Fall
(Mid-June to Late June)	*(July to Mid-August)*	*(Mid-August to Late Sept.)*



Base Temp: 0 °C



Base Temp: 1 °C



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