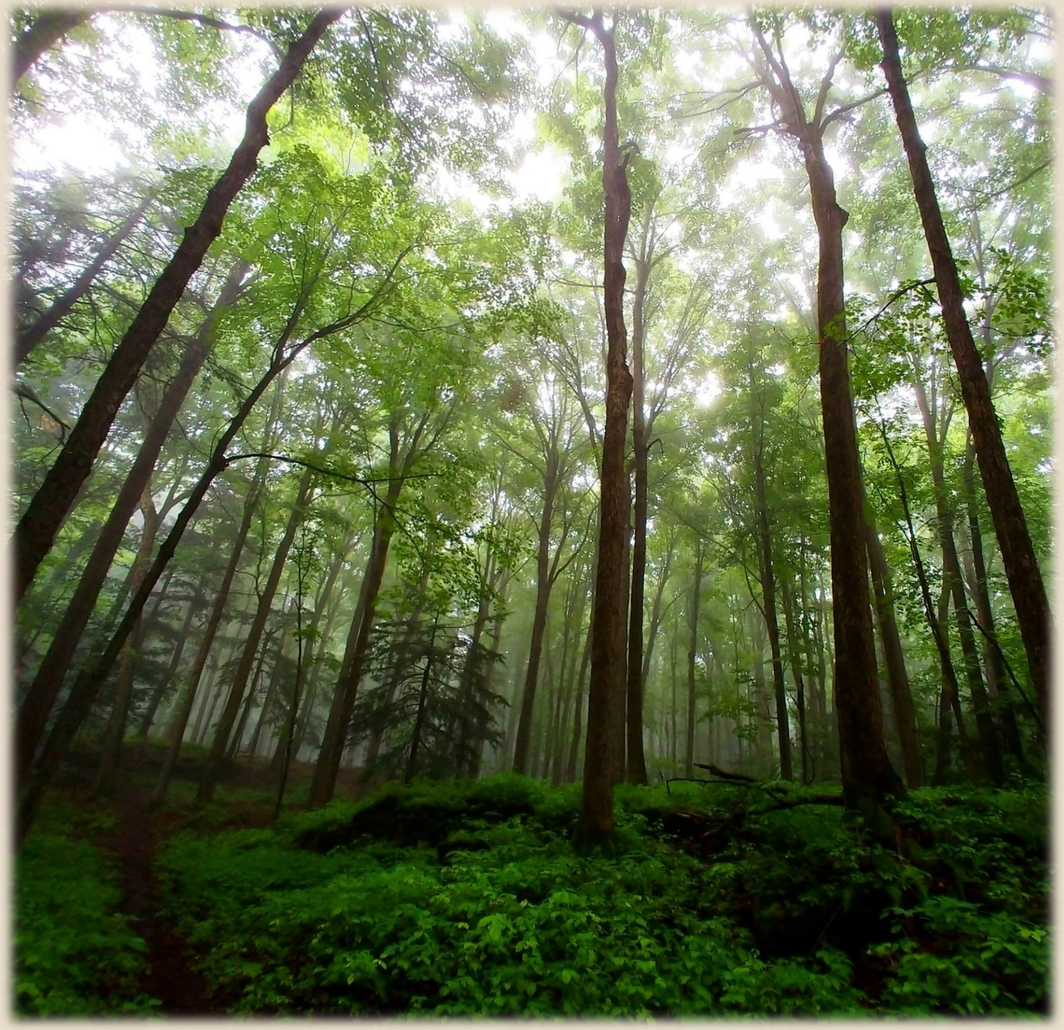
Tracking spring wildflower temporal niche across the microclimatic gradients of northeastern temperate deciduous forests

Dr. Morgan Southgate &
Dr. Jordon Tourville

11.20.2025



Thompson Lake State Park, NY

Temperate deciduous forests

- Light is a limiting resource; springtime plant **phenology** balances avoiding frost and maximizing time for growth
- Strategy varies across forest layers
  - Canopy trees**:** not limited by light
  - Understory plants**:** lose access to >90% of light after canopy closure
    - Shade tolerance and shade avoidance
- Many understory plants emerge before canopy closure to access brief window of high light availability
  - **Phenological escape**
  - Equivalent to a **temporal niche**

Spring ephemerals

Dutchman’s breeches

trout lily

wild leek

Summer-green wildflowers

red trillium

early blue cohosh

Jack-in-the-pulpit

(Semi-) evergreen wildflowers

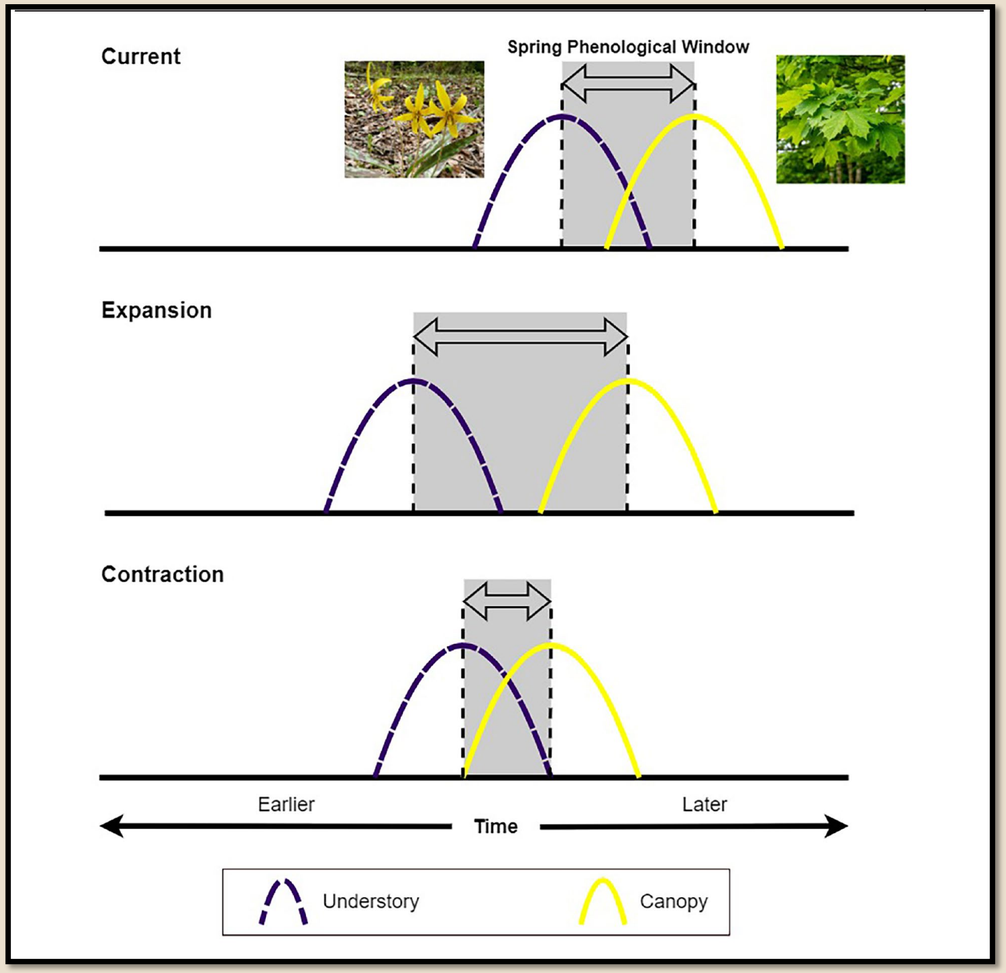
sharp-lobed hepatica

foamflower

trout lily flowering in early spring, southern Vermont

Spring wildflowers & climate change

- Temperate tree species are advancing onset of spring growth with warming spring temperatures
- Spring-active wildflowers are potentially vulnerable to **phenological mismatch**
  - Differential responses to climate change leading to asynchrony in timing of biotic interactions



Tourville et al. 2024 Figure 1

Climate change & phenological escape

- Three possible outcomes for dynamics of phenological window
- Recent studies:
  - Evidence for both expansion and contraction
  - Variation in phenological temperature sensitivity by region
- Mostly at macroclimate scale
  - Community science + climatic raster data
- Environmental factors driving plant phenology vary across spatial scales

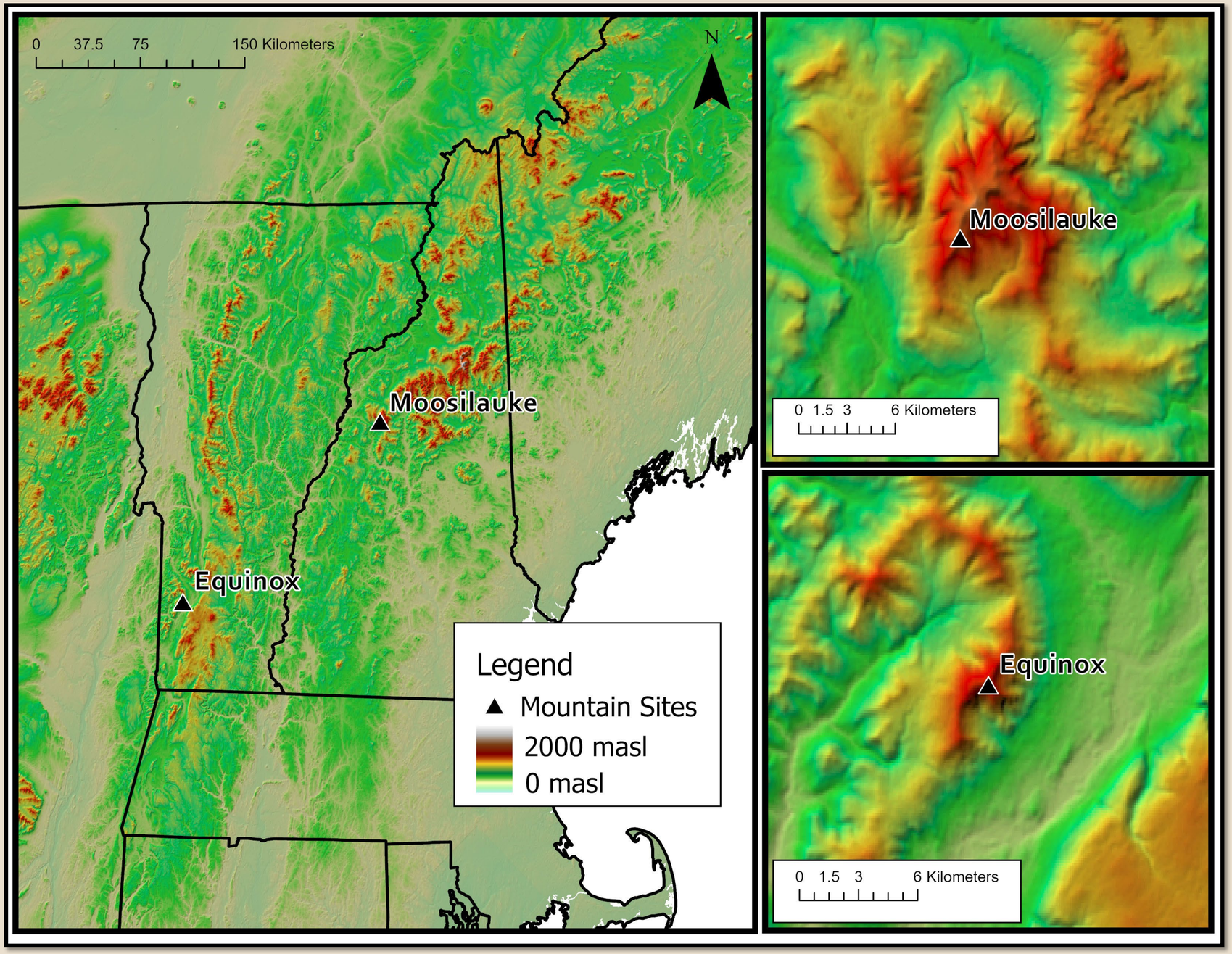
Study focus

Does spring-active wildflower phenology vary across microclimatic gradients?

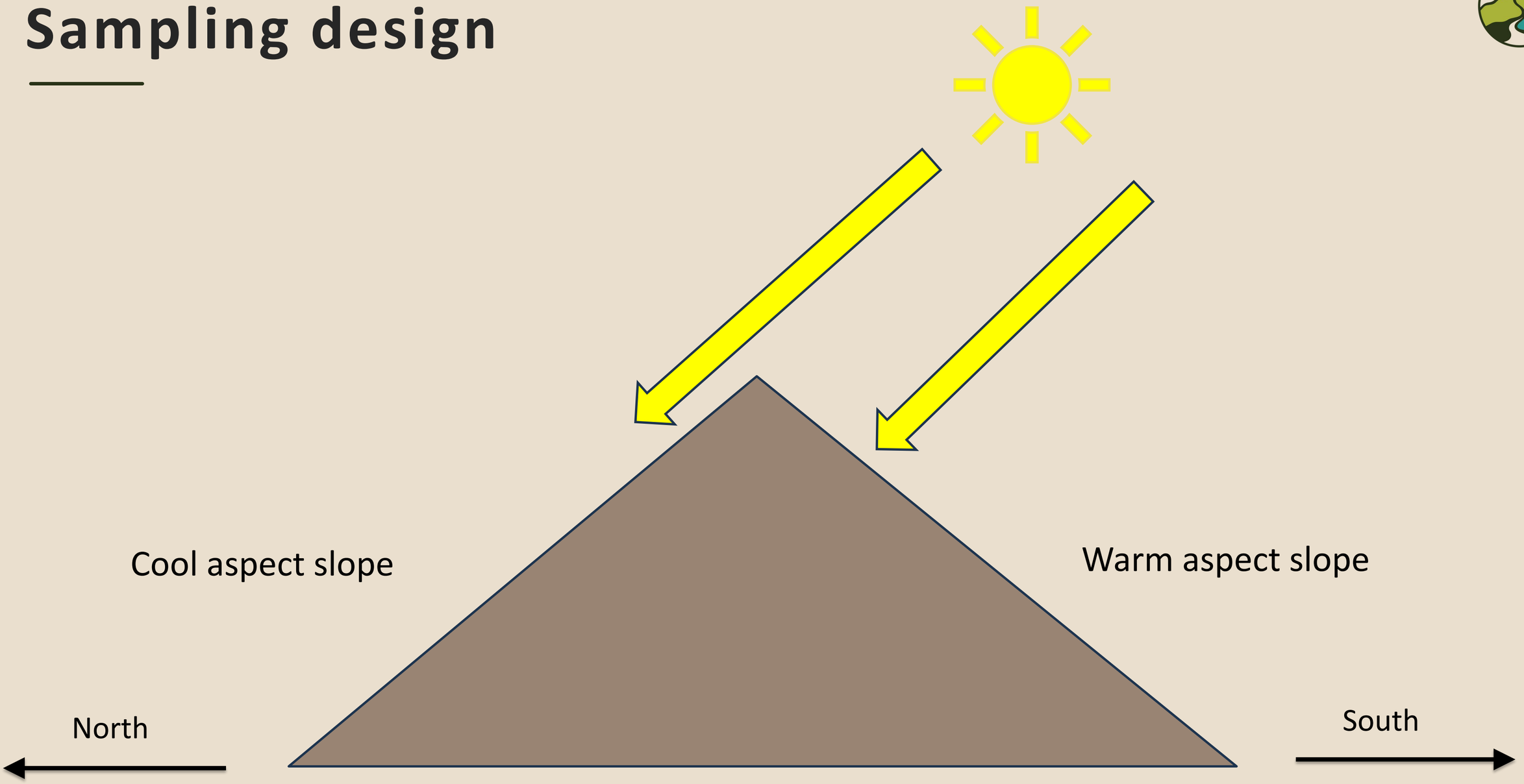
Site selection

- Goal: to sample across greatest possible elevational gradient in temperate deciduous forests

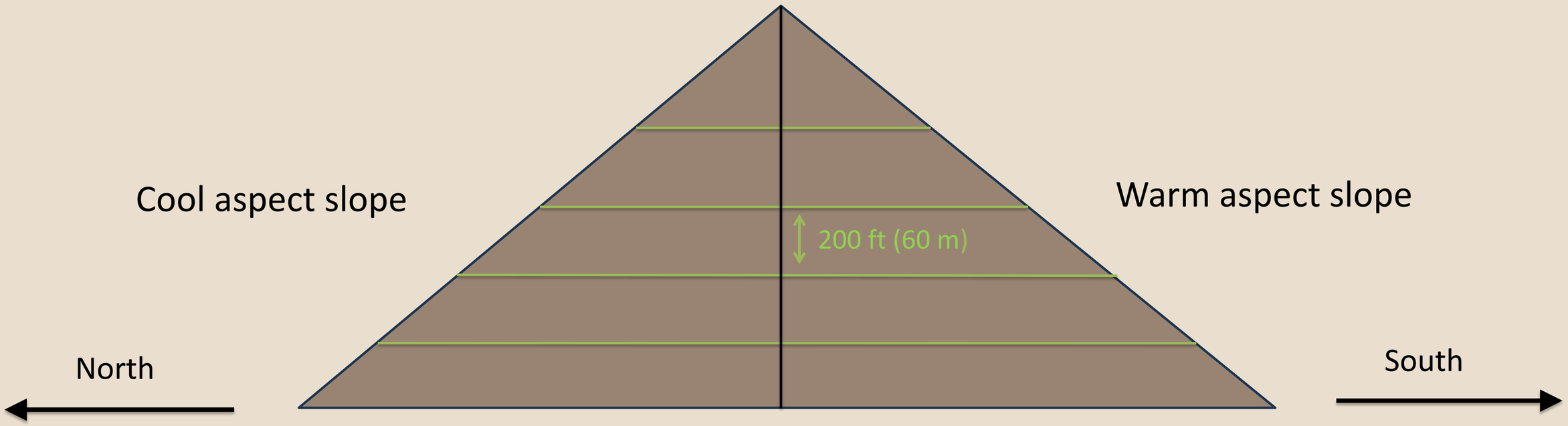
- Site criteria:
  - Prominence > 2900 ft
  - Conserved
  - Sedimentary bedrock



Sampling design



Sampling design

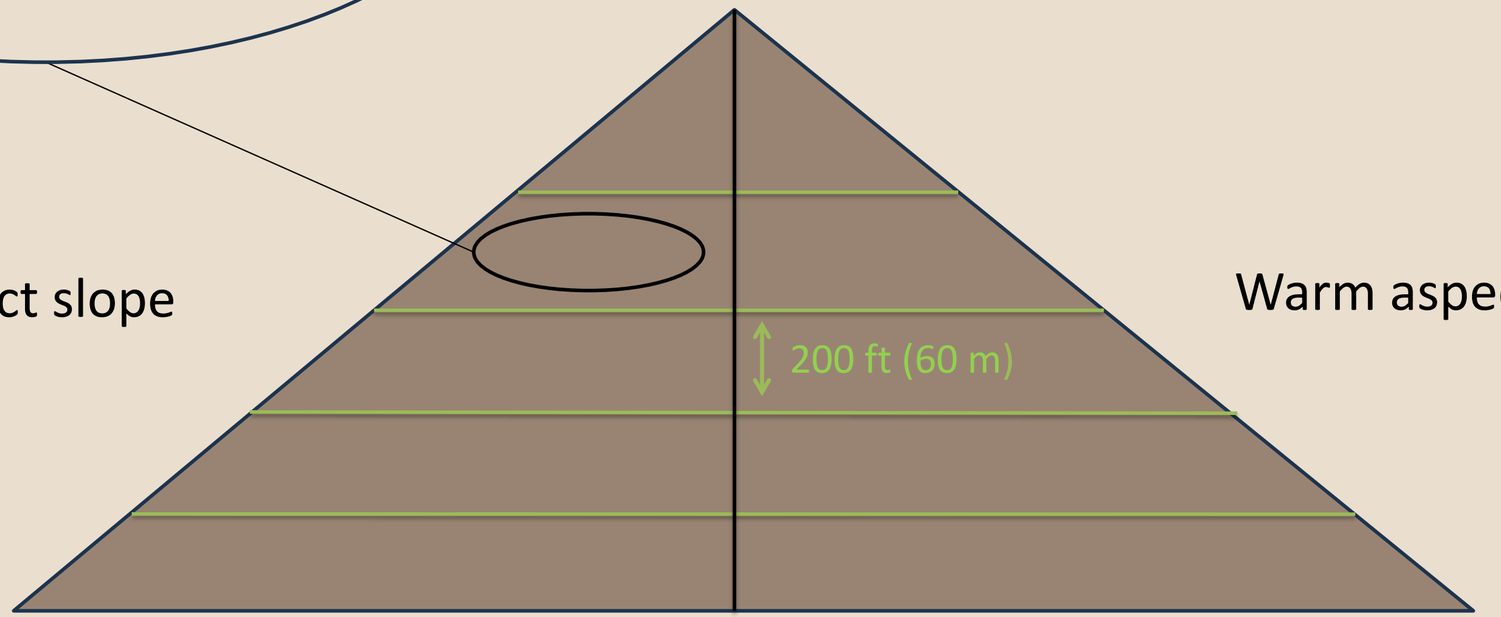


Sampling design

Hollow

Shoulder

* Geomorphon Landforms Tool (ArcPro)



Cool aspect slope

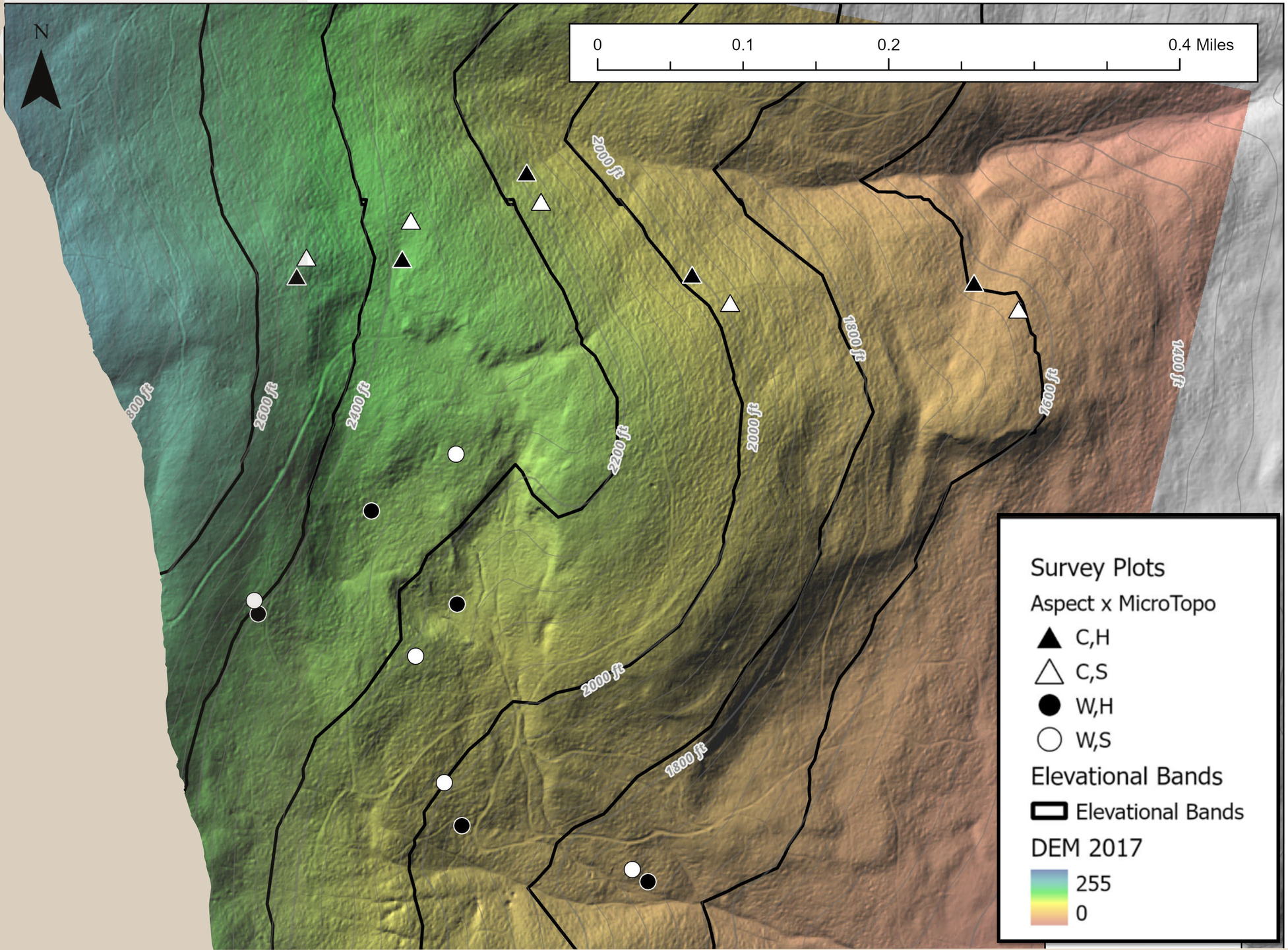
Warm aspect slope

North

South

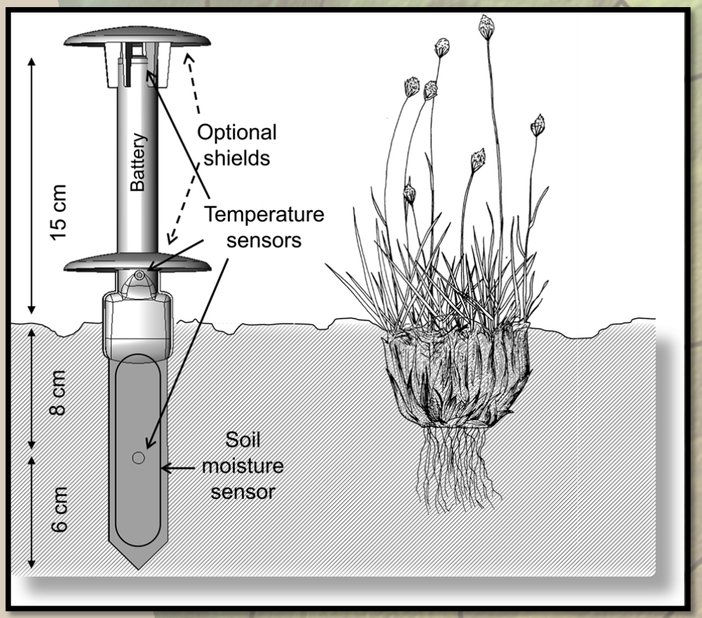
Mt. Equinox

- 20 plots across 1000 ft



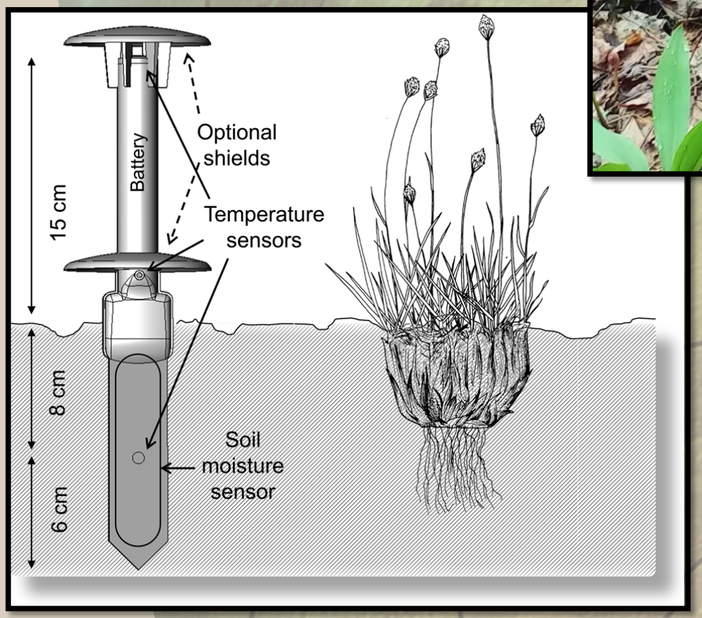
Mt. Equinox

- 20 plots across 1000 ft
- TMS-4 datalogger in center of plot
  - Record air temp, soil temp, and soil moisture every 15 minutes



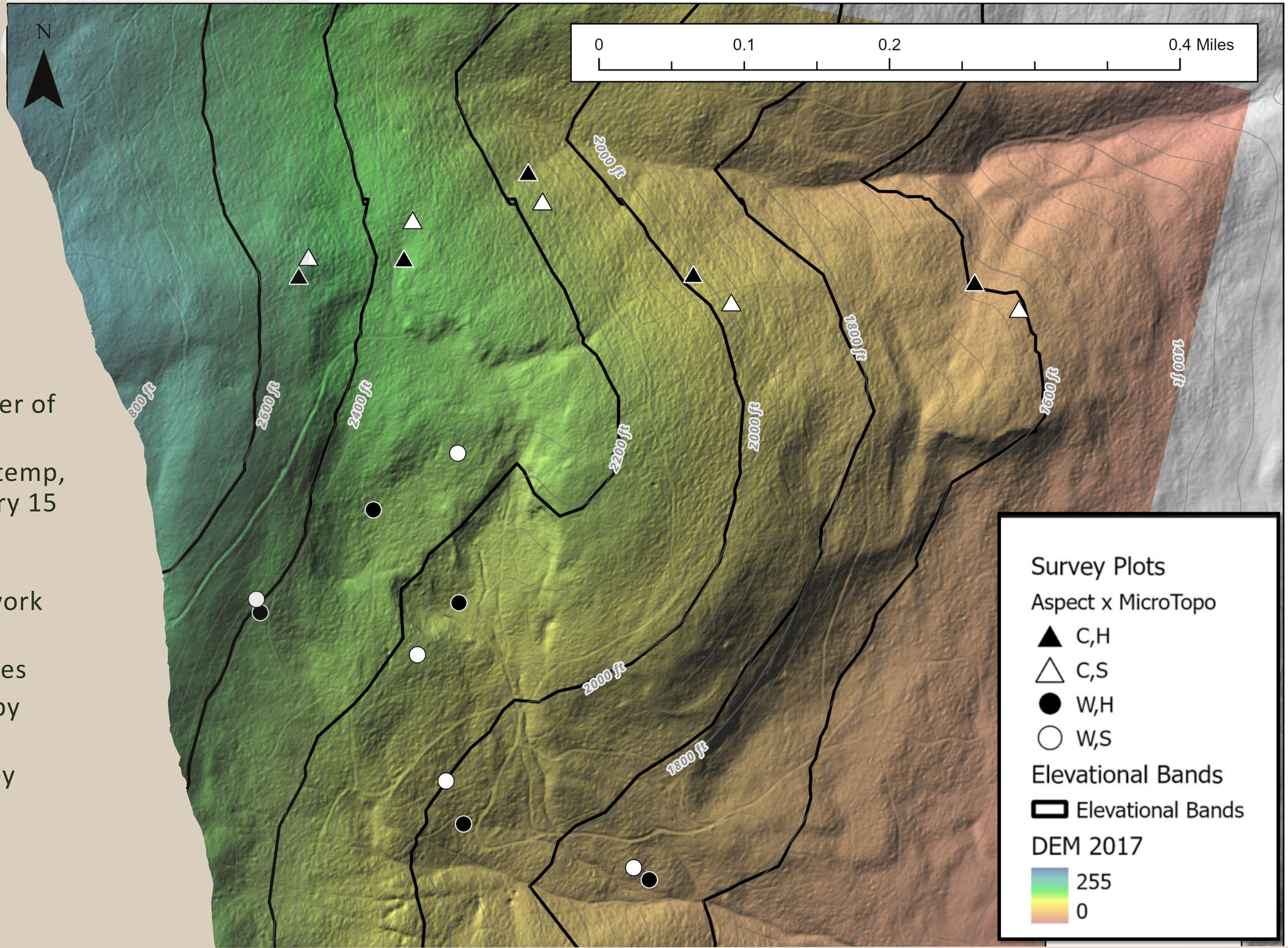
Mt. Equinox

- 20 plots across 1000 ft
- TMS-4 datalogger in center of plot
  - Record air temp, soil temp, and soil moisture every 15 minutes



Mt. Equinox

- 20 plots across 1000 ft
- TMS-4 datalogger in center of plot
  - Record air temp, soil temp, and soil moisture every 15 minutes
- 15 x 15 ft plots following National Phenology Network protocols
- Resampled all plots 9 times
  - 1x/week before canopy closure
  - 1x/month after canopy closure



May 1, 2025

May 13, 2025

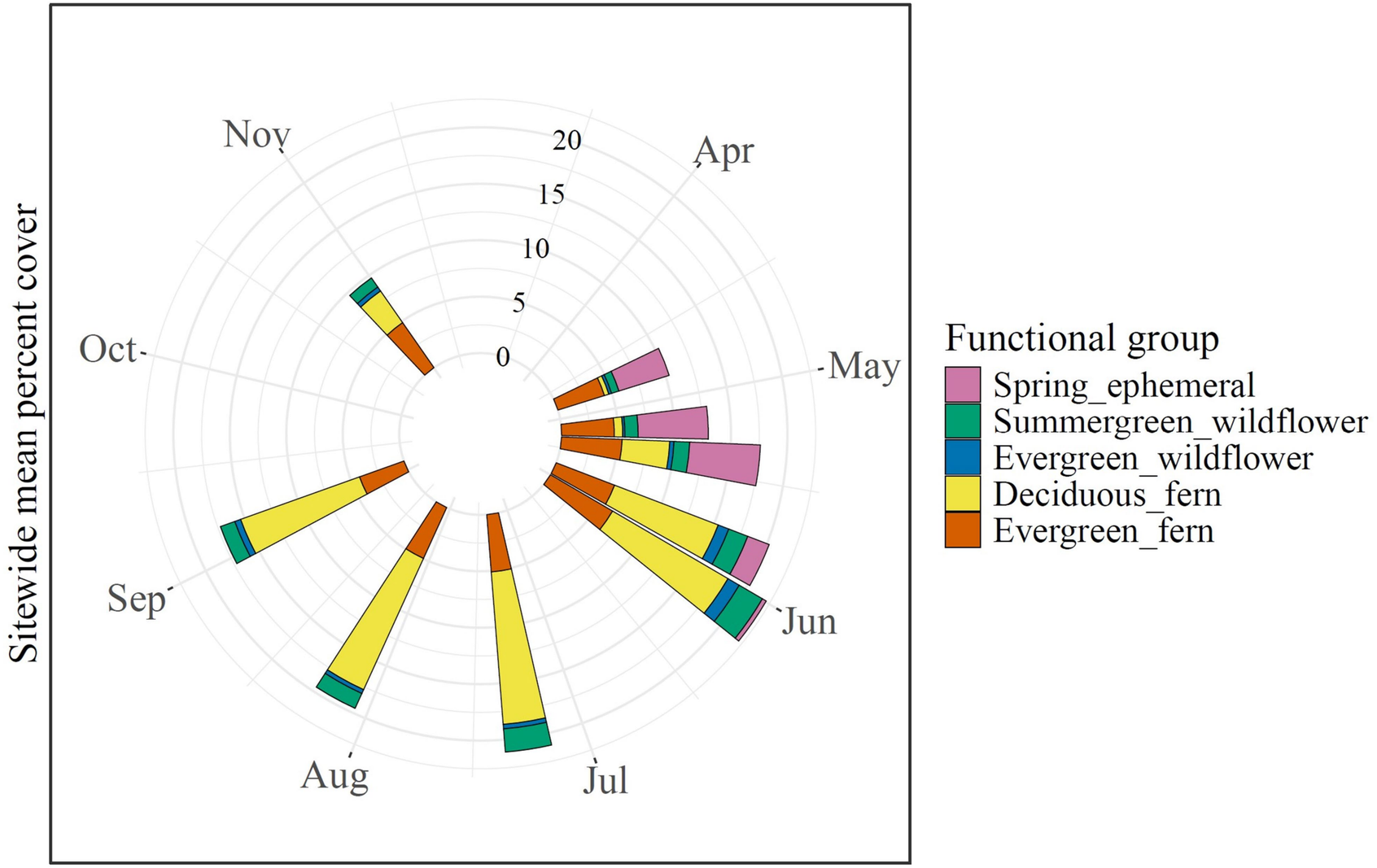
May 21, 2025

May 1, 2025

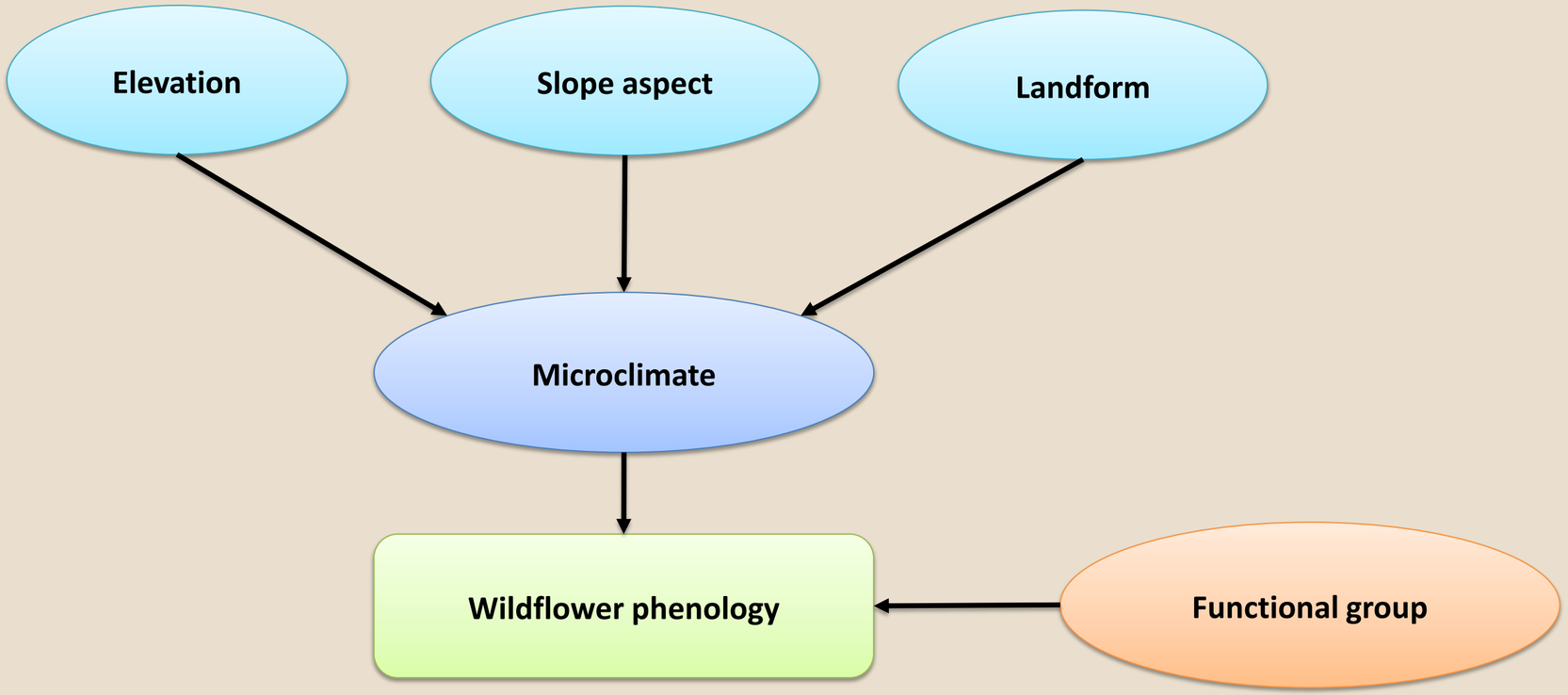
May 13, 2025

June 3, 2025

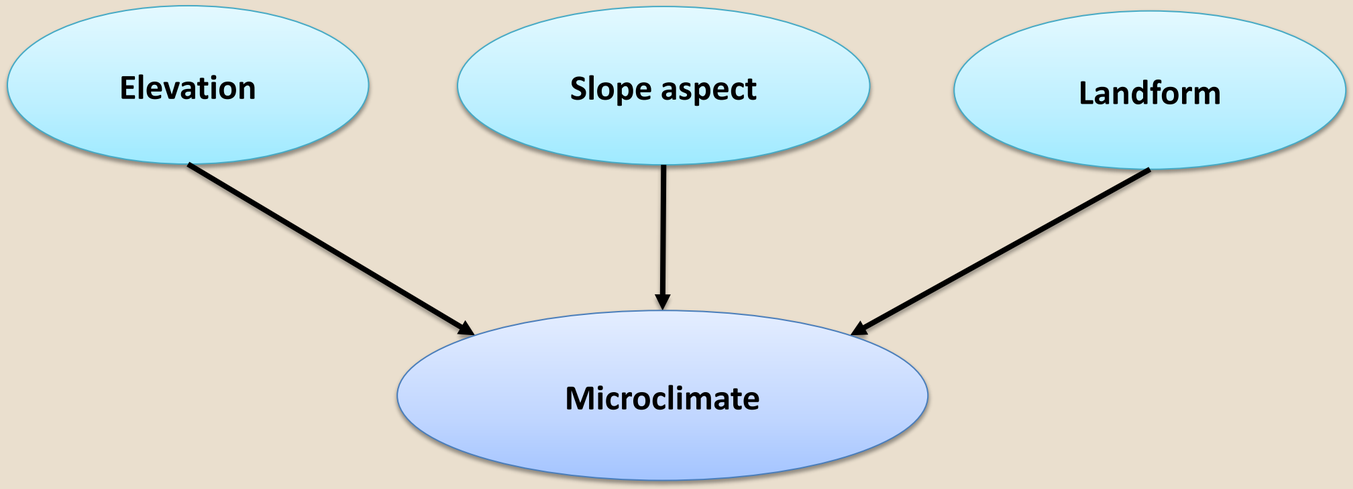
Seasonal context for herbaceous phenology



Analytical Framework

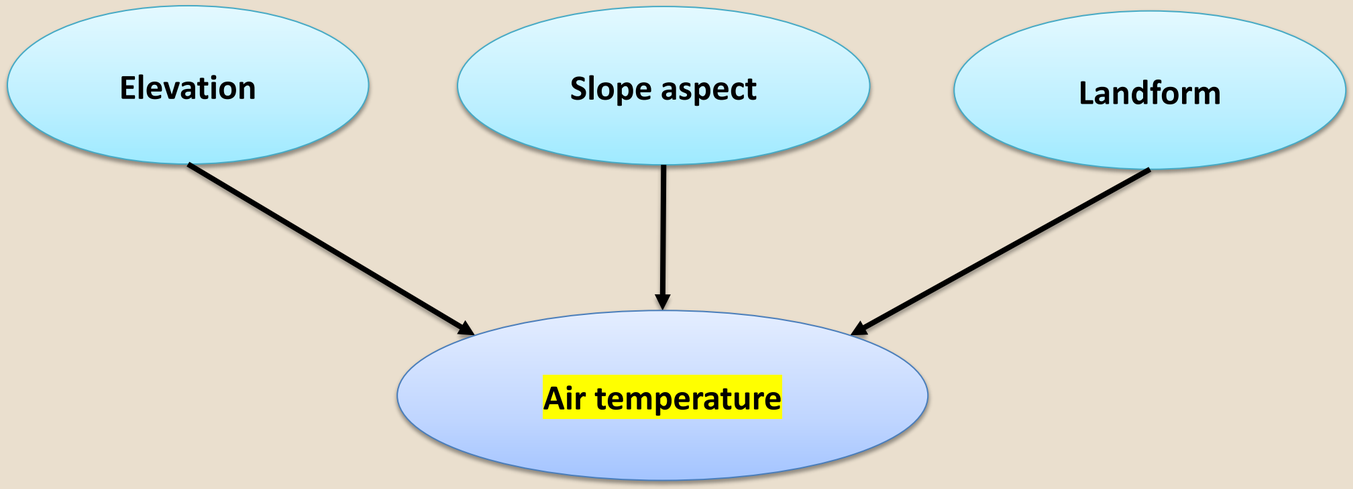


Analytical Framework: Model 1



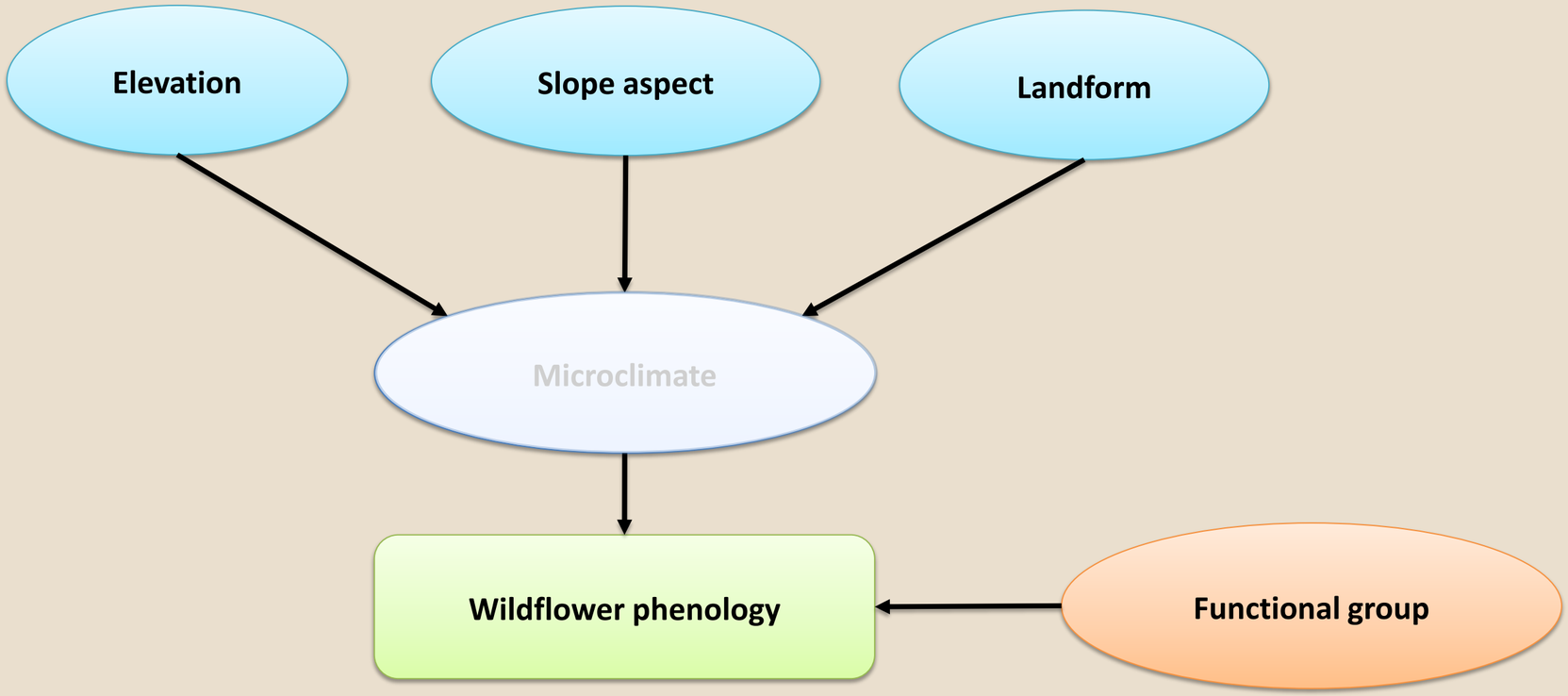
Bayesian generalized additive models with mvgam in R

Analytical Framework: Model 1



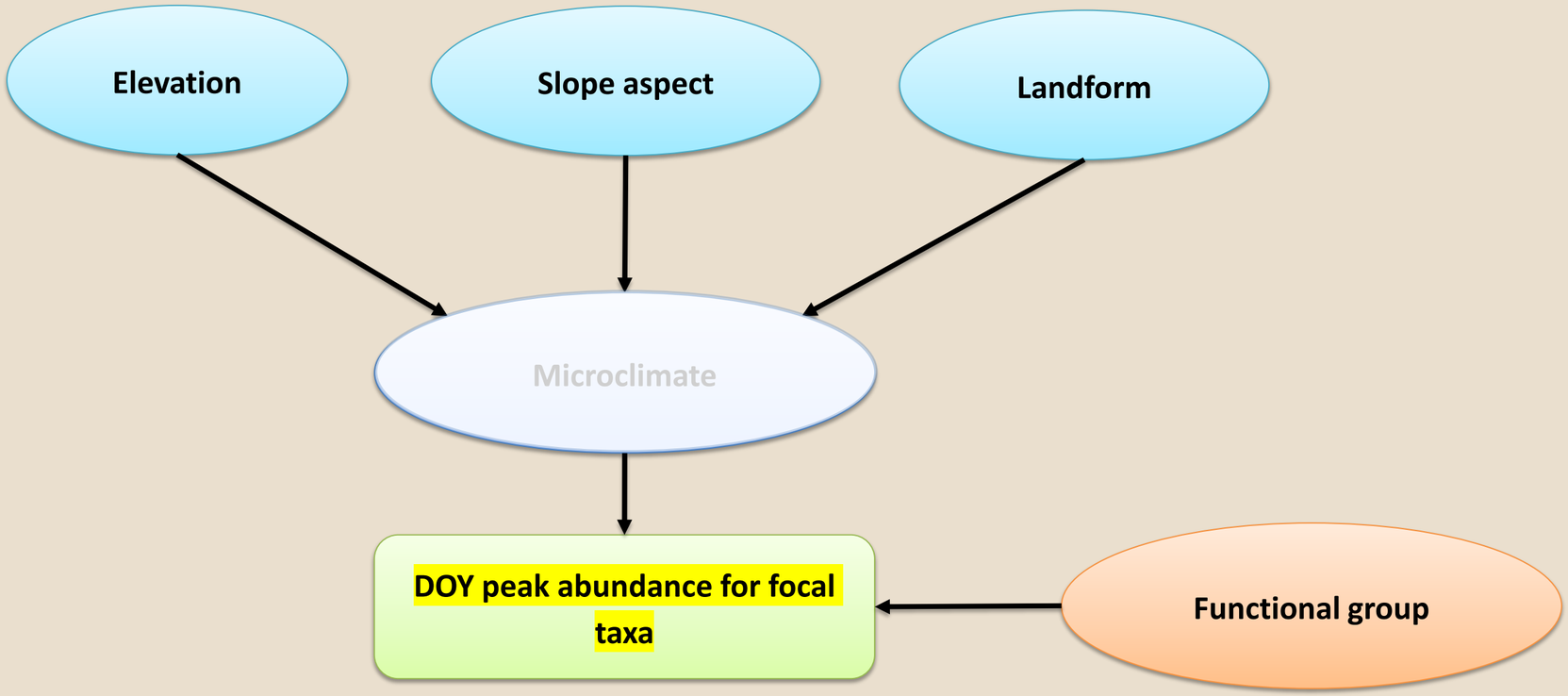
Bayesian generalized additive models with mvgam in R

Analytical Framework: Model 2



Bayesian mixed-effects linear regression models with brms in R

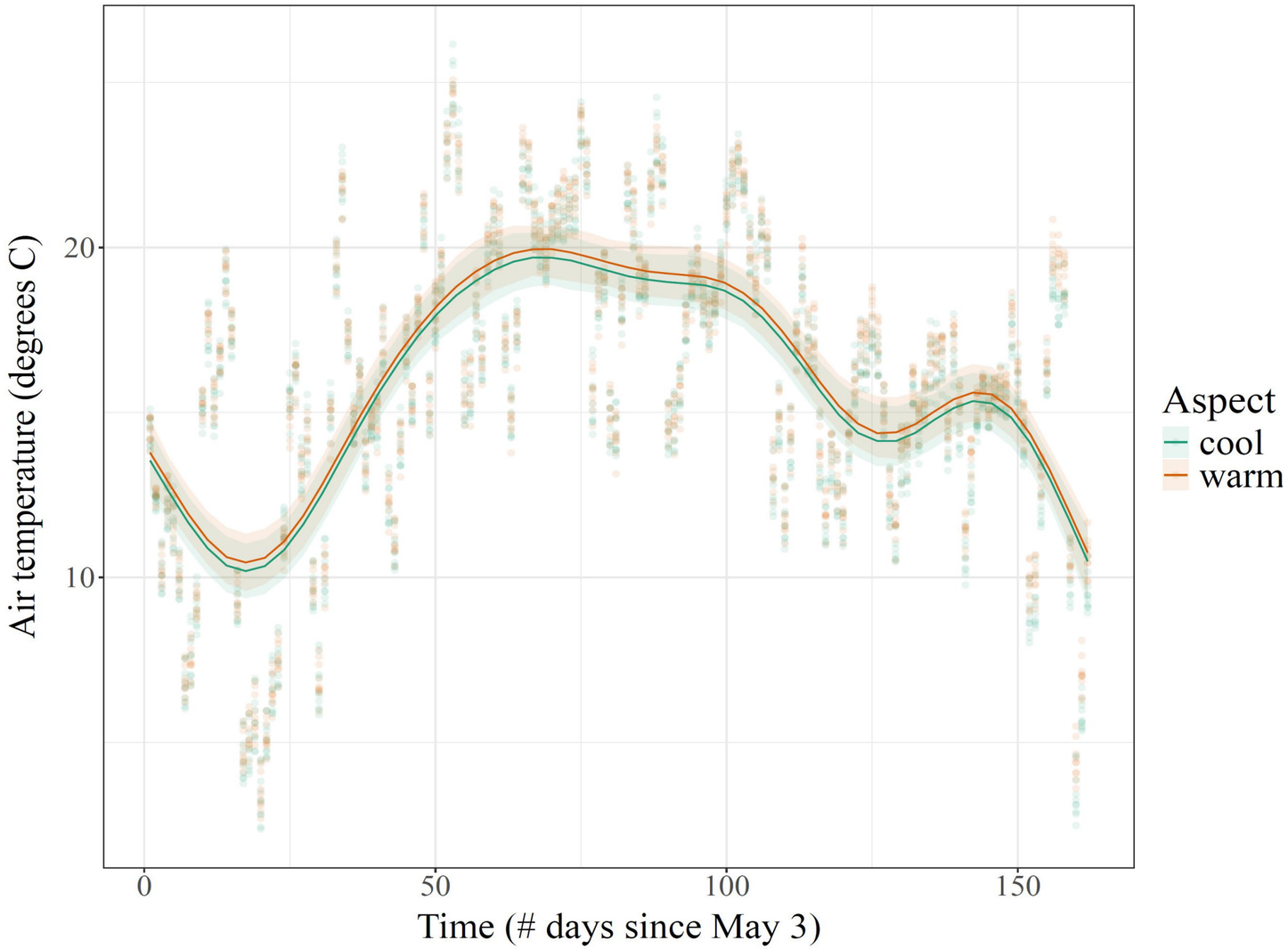
Analytical Framework: Model 2



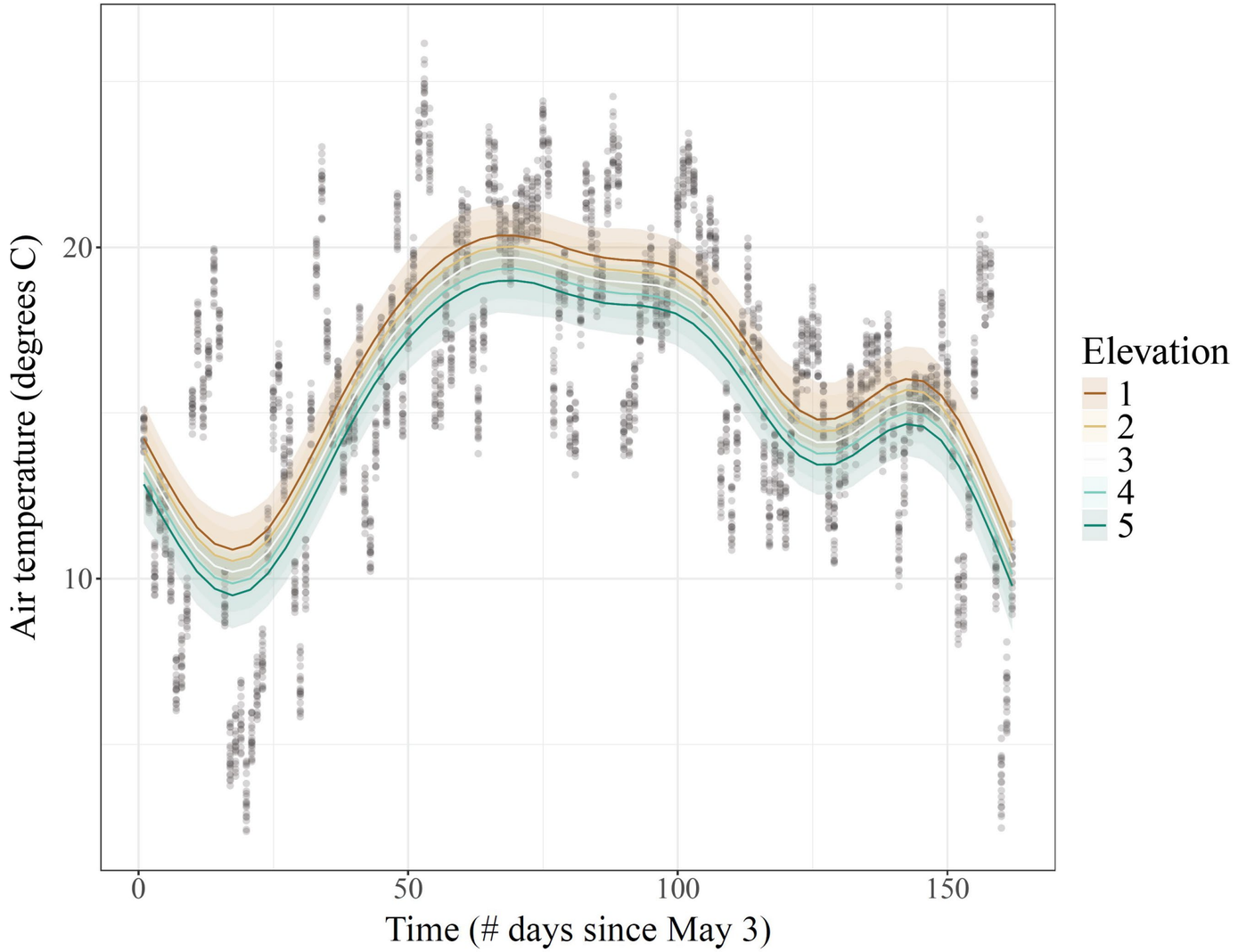
Bayesian mixed-effects linear regression models with brms in R

* 4 spring ephemerals, 6 summer-active

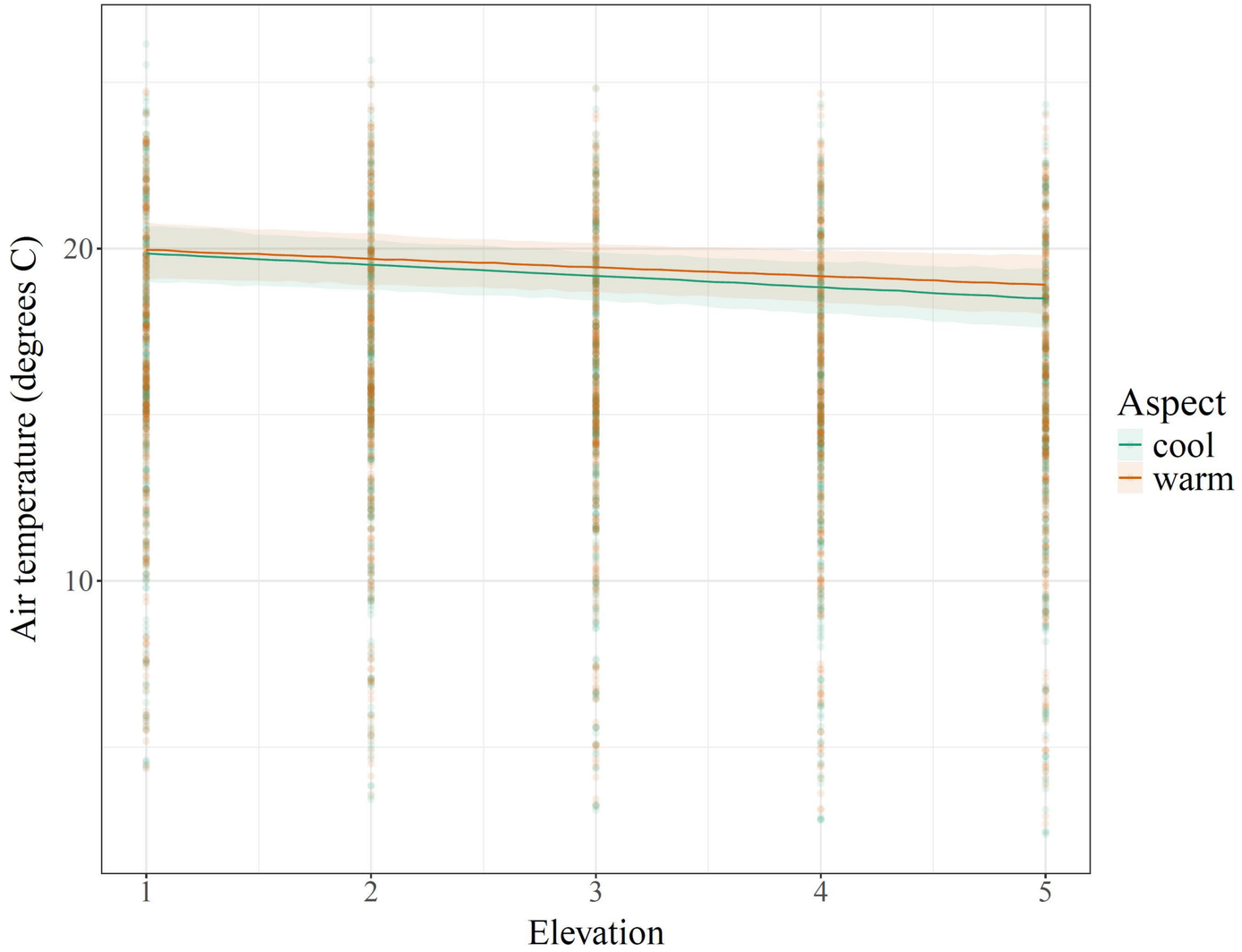
Model 1: Air temp ~ slope aspect



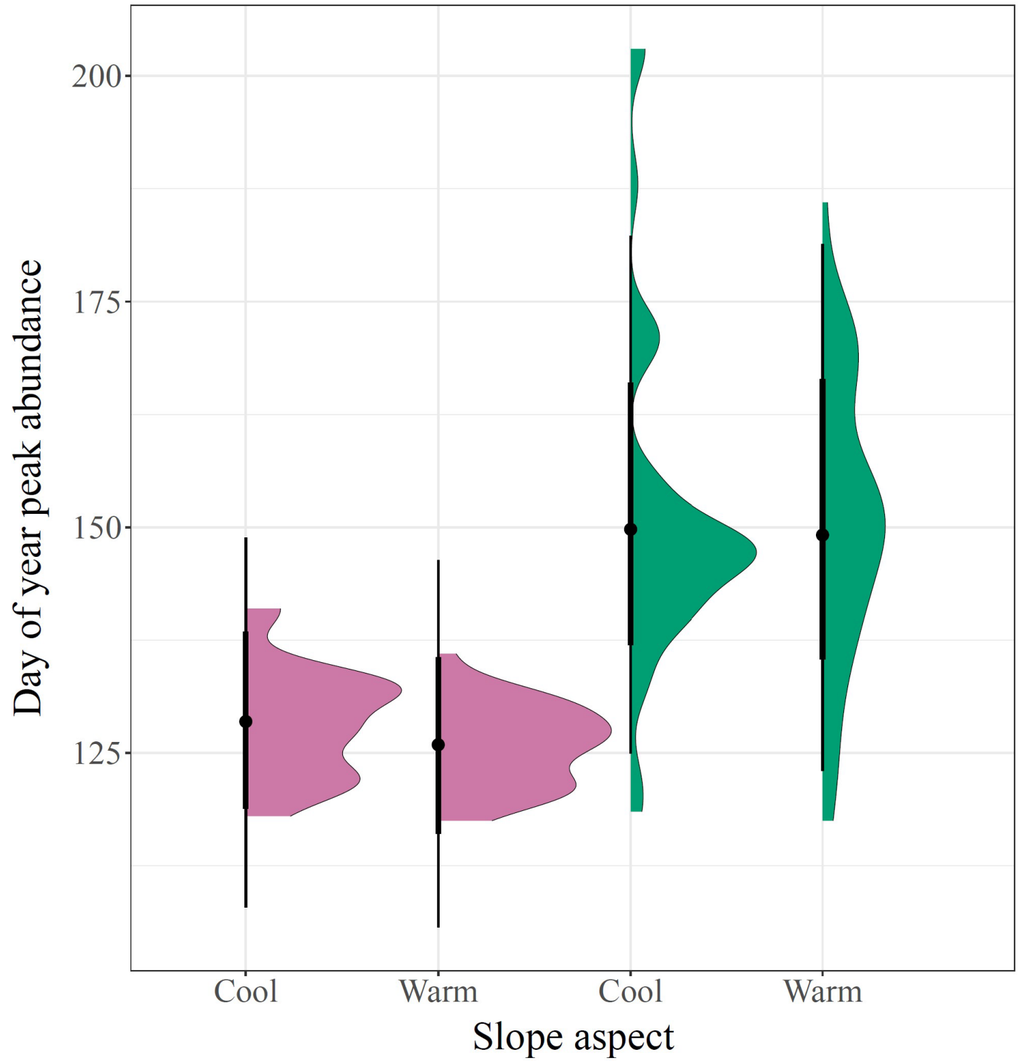
Model 1: Air temp ~ elevation



Model 1: Aspect * elevation



Model 2: Phenology ~ aspect

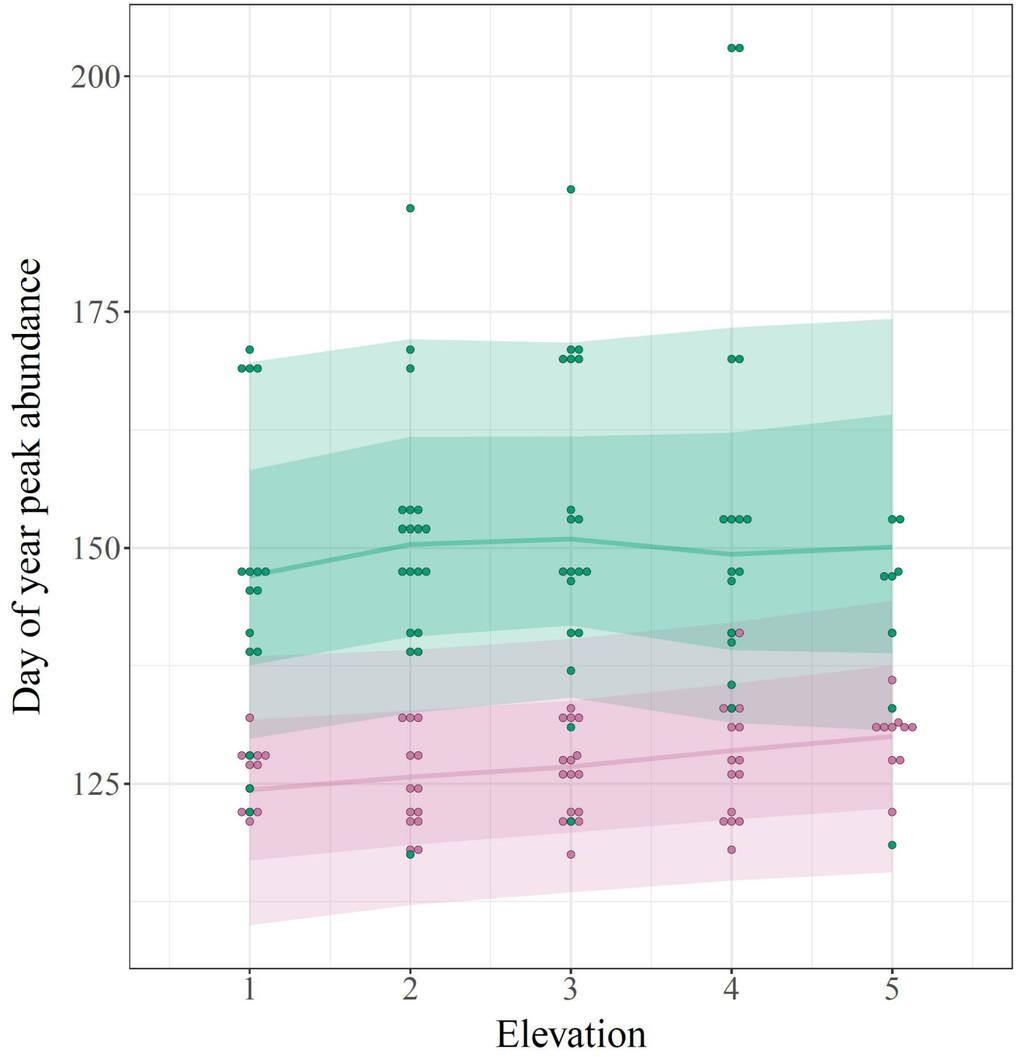


Model estimates:

Cool aspect: + 2.2 days (vs. warm)

Summer-active: + 23.5 days (vs. spring ephems)

Model 2: Phenology ~ elevation



Model Estimates

Summer-active: 0.71 days/200 ft elev

Spring ephemeral: 1.15 days/200 ft elev

Functional_group

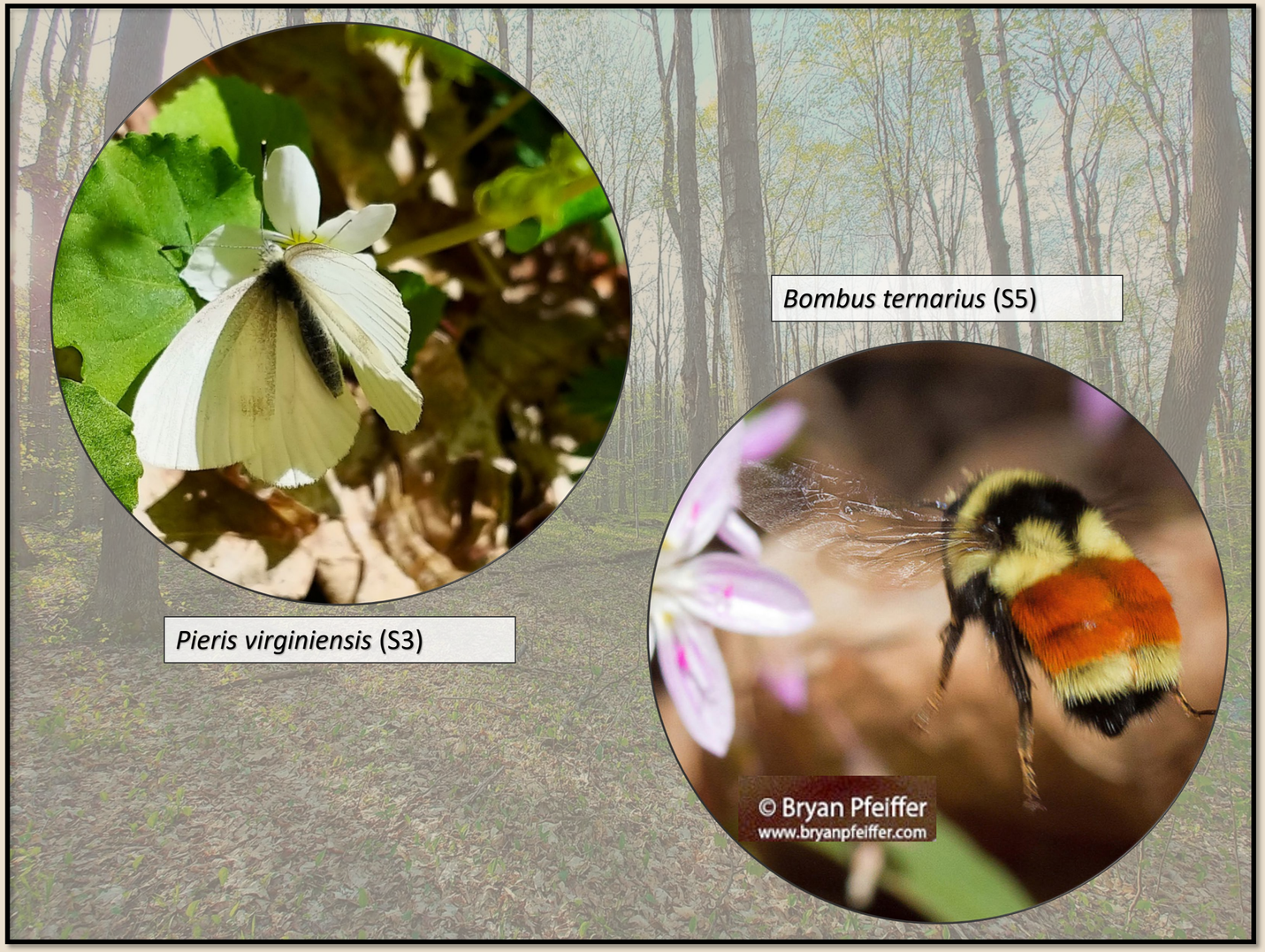
Spring_ephemeral

Summer_active

Looking north from the lower elevations of Mount Equinox in mid-spring

Research Importance

- Results indicate spring wildflower phenology is sensitive to microclimatic variation
- Do landscape-scale effects buffer forest microclimates from the extremes of macroclimatic warming?
- Potential of **microrefugia** for spring wildflower biodiversity



Research Importance

- Results indicate spring wildflower phenology is sensitive to microclimatic variation
- Do landscape-scale effects buffer some forest microclimates from the extremes of macroclimatic warming?
- Potential of **microrefugia** for spring wildflower biodiversity
- Broad implications for ecological integrity

Acknowledgements

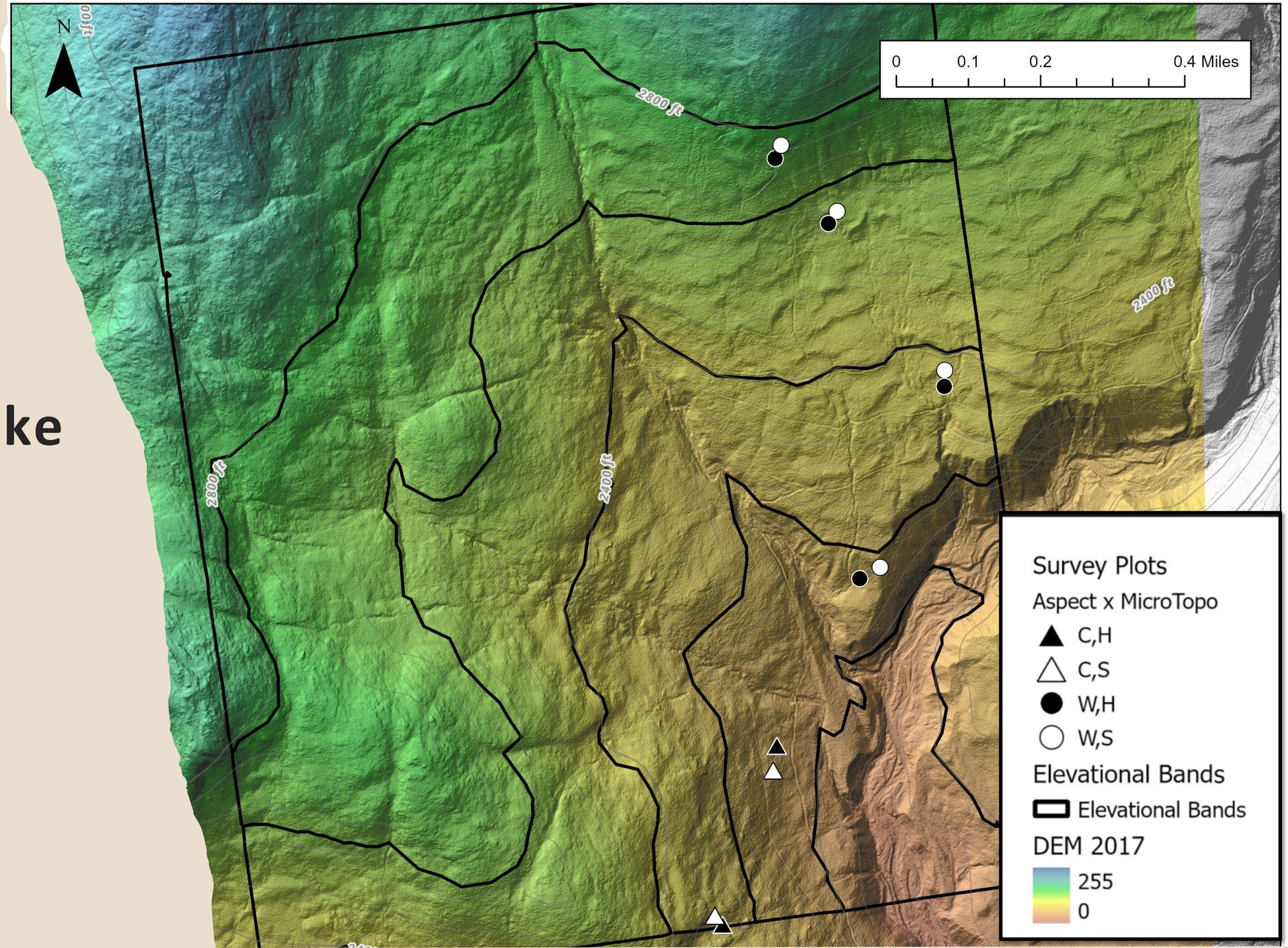
This research is funded by the Natixis Foundation

- AMC Research Team
- Fieldwork assistance: Braedon Lineman, Madelyn Wood, Abby Budliger & Thomas Anderson
- Sampling design consultation: Dan Farrell

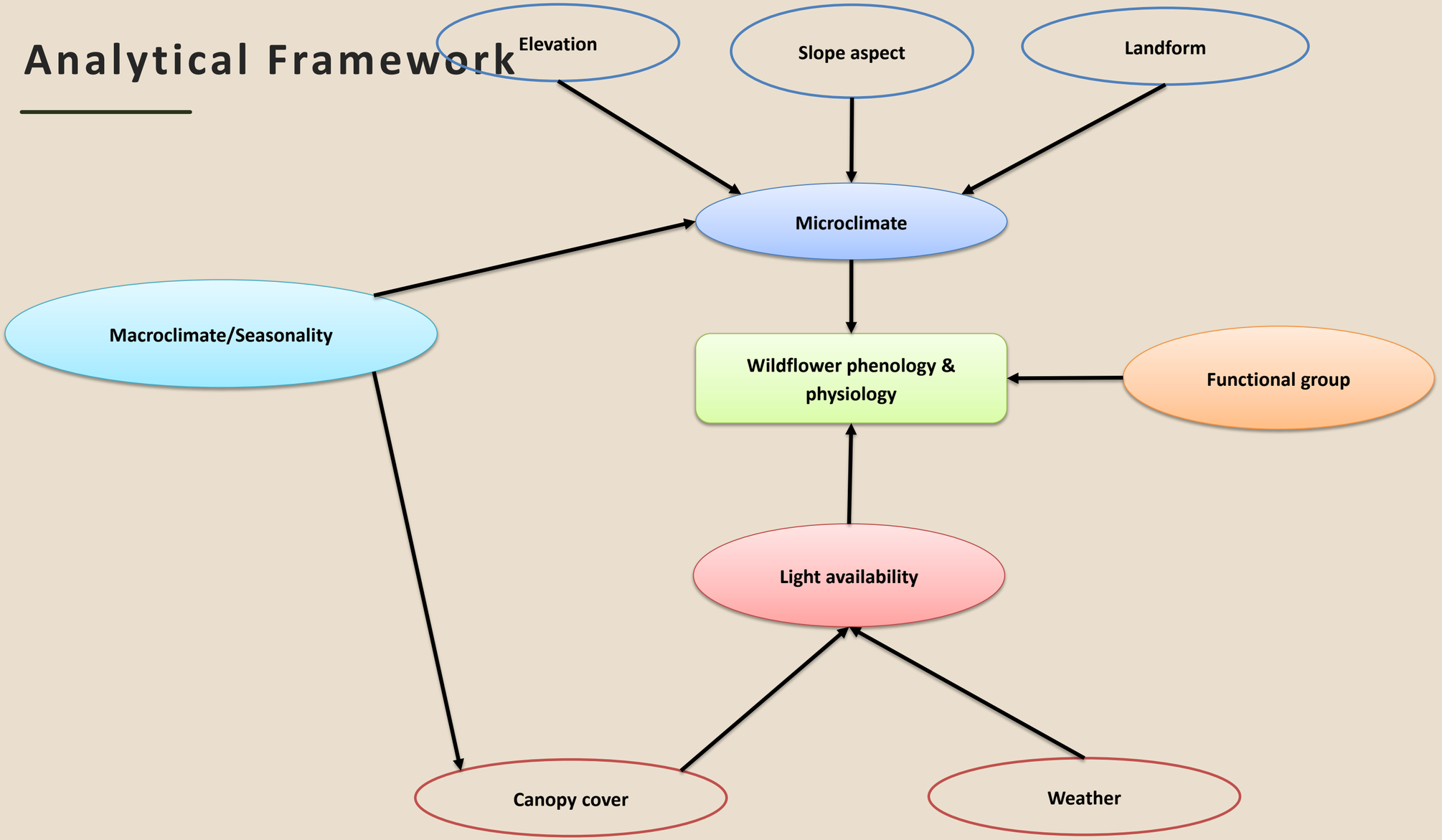
- Bürkner P (2018). “Advanced Bayesian Multilevel Modeling with the R Package brms.” *The R Journal*, 10(1), 395–411. doi:10.32614/RJ-2018-017
- Clark N, Wells K (2023). “Dynamic Generalized Additive Models (DGAMs) for forecasting discrete ecological time series.” *Methods in Ecology and Evolution*, 14, 771-784. doi:10.18637/jss.v100.i05.
- Jasiewicz, Juroslav, and Tomasz F. Stepinski. "Geomorphons - a pattern recognition approach to classification and mapping of landforms." *Geomorphology* 182 (2013): 147–56.B
- Tourville, J. C., Murray, G. L., & Nelson, S. J. (2024). Distinct latitudinal patterns of shifting spring phenology across the Appalachian Trail Corridor. *Ecology*, *105*(10), e4403.
- Wild, J., Kopecký, M., Macek, M., Šanda, M., Jankovec, J., & Haase, T. (2019). Climate at ecologically relevant scales: A new temperature and soil moisture logger for long-term microclimate measurement. *Agricultural and Forest Meteorology*, *268*, 40-47.

Mt. Moosilauke

- 12 plots
- 800 ft (240 m) elevation gain



Analytical Framework



Data analysis

- **Phenology:** Hierarchical Bayesian linear regression of DOY peak abundance (brms)
  - $DOY_{peak} \sim elev * aspect * landform * Functional.group + 1|Species$
  - Focal species (present in at least 40% of plots)
    - Spring ephemerals: *Allium tricoccum, Erythronium americanum, Claytonia caroliniana, Dicentra* spp.
    - Summer-active: *Trillium erectum, Arisaema triphyllum, Caulophyllum giganteum, Polygonatum pubescens, Actaea* spp., *Thalictrum dioicum*
- **Microclimate:** Bayesian generalized additive model of TMS-4 variables (mvgam)
  - $Temp \sim s_1(x_1, x_2, x_3) + s_2(x_1, x_2, x_3) + \ldots + s_j(x_1, x_2, x_3) + 1|Series + AR(1)$

June 3, 2025

July 7, 2025

August 5, 2025

September 2

November 6

Next steps

- Model soil temperature as a function of topography
- Model phenology as a function of microclimate
- Model wildflower physiology by functional group and topography
- Resample all plots beginning in April 2026