



# Understanding plant phenology in a warming world

Examining urban effects

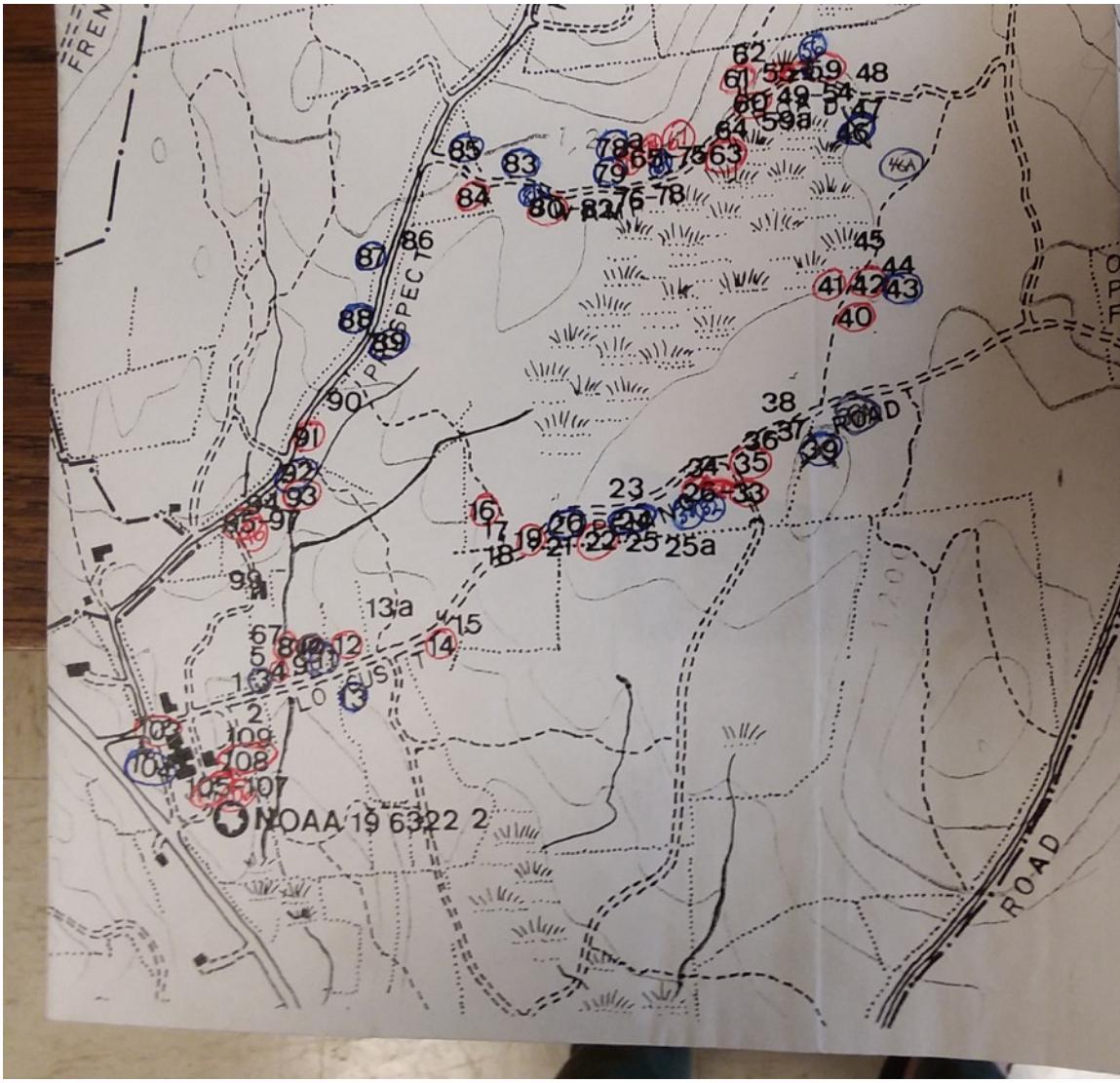


# Growing Degree Days (GDDs)

- If temperature is greater than 0°C, then you add up the temperatures

$$X = \begin{cases} T - 0 & \text{if } T > 0 \\ 0 & \text{if } T \leq 0 \end{cases}$$

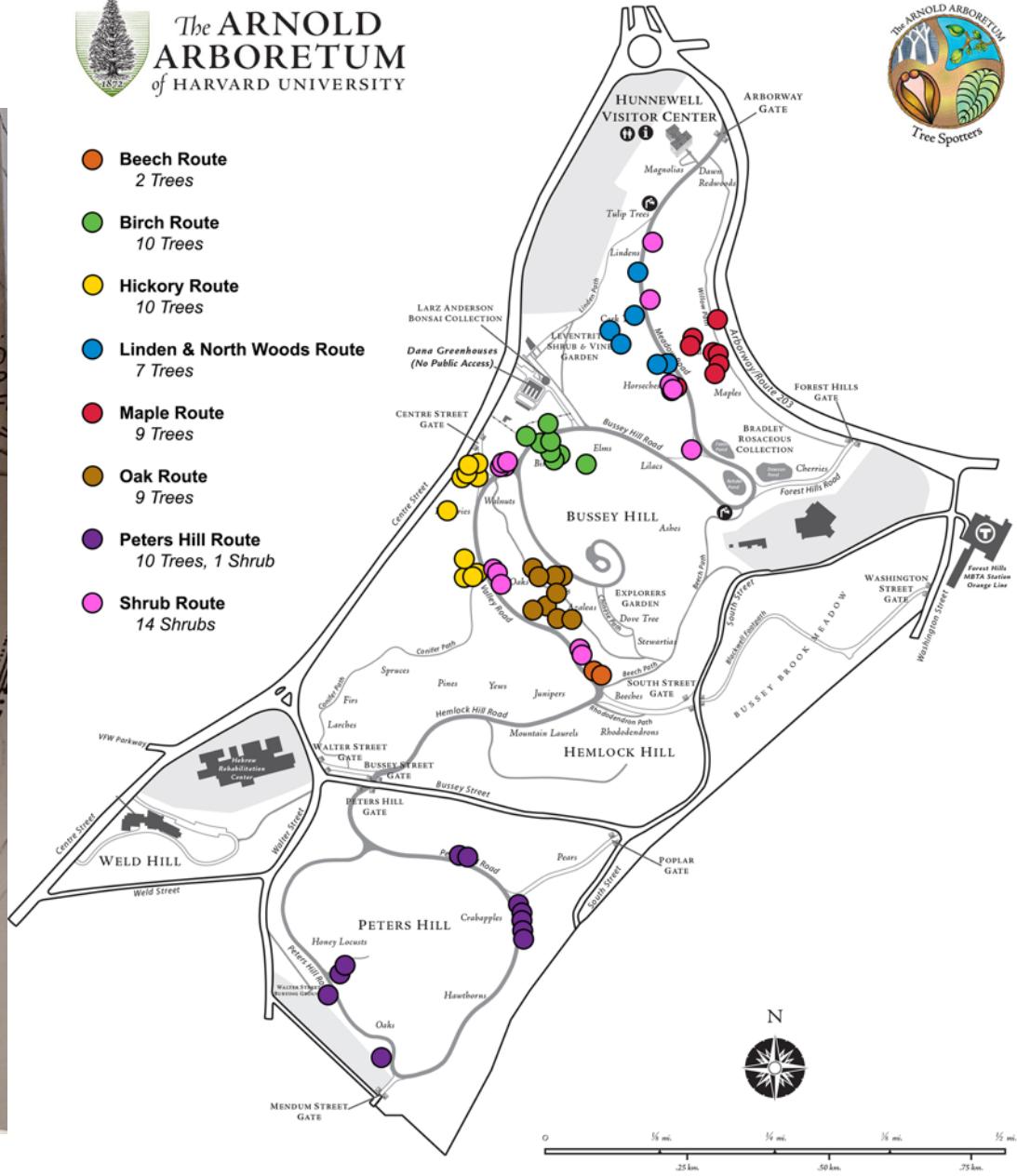
- E.g., Temperature is...
  - Day 1:  $5 - 0 = 5$
  - Day 2:  $7 - 0 = 7$
  - Day 3:  $-2 \leq 0$  so is 0
  - So by Day 3, 12 GDDs (5+7) have been accumulated.



The ARNOLD  
ARBORETUM  
of HARVARD UNIVERSITY



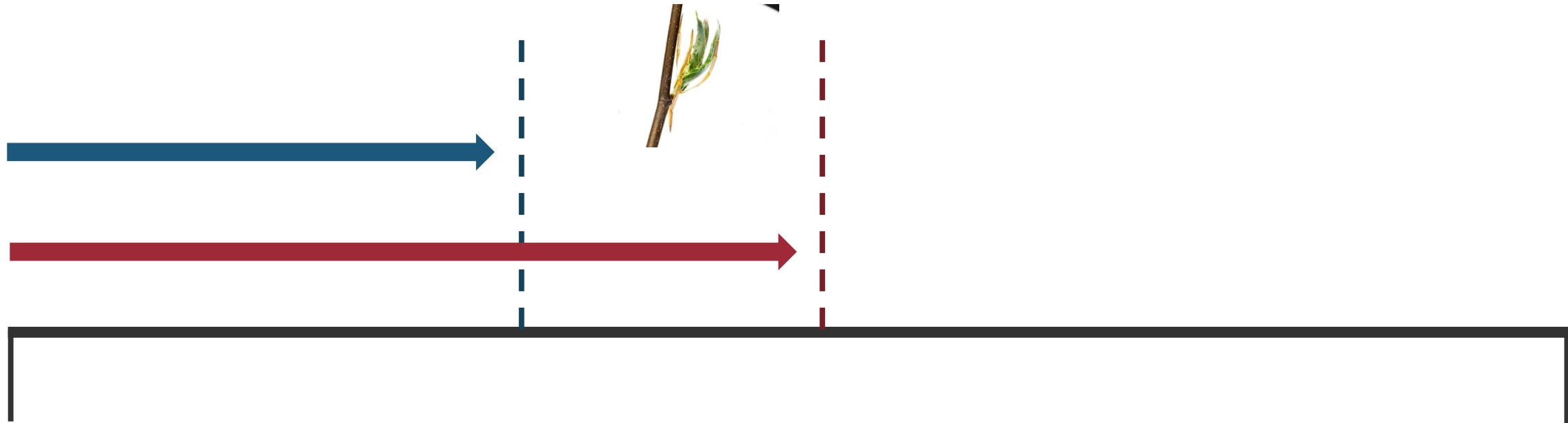
- Beech Route  
2 Trees
- Birch Route  
10 Trees
- Hickory Route  
10 Trees
- Linden & North Woods Route  
7 Trees
- Maple Route  
9 Trees
- Oak Route  
9 Trees
- Peters Hill Route  
10 Trees, 1 Shrub
- Shrub Route  
14 Shrubs



# SITE EFFECT

*Fagus grandifolia*

- Arboretum
- Harvard Forest



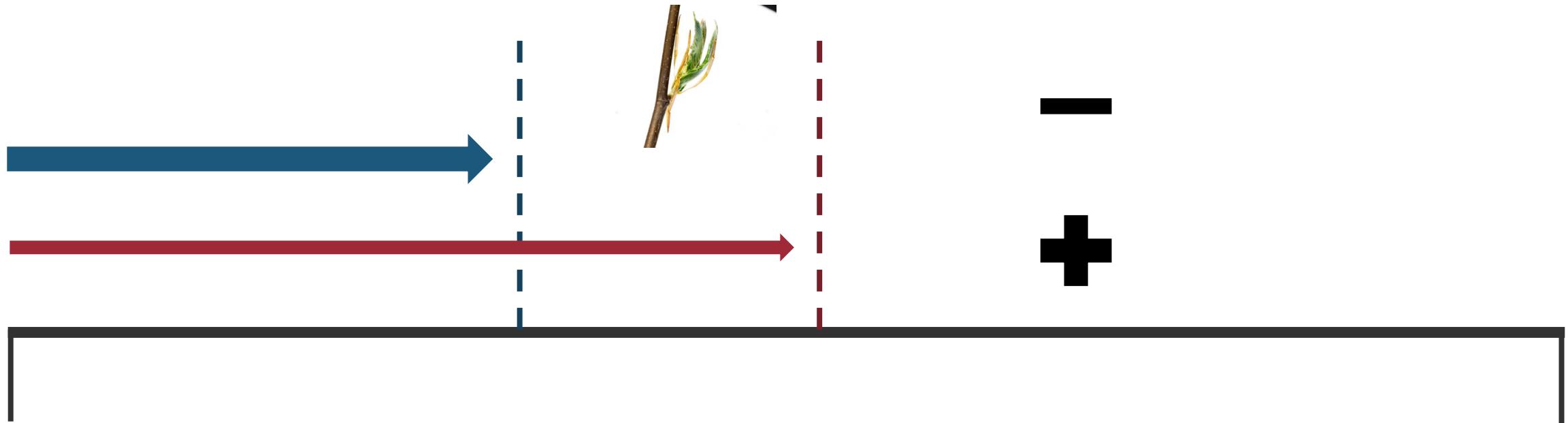
Jan 1

Dec 31

# SITE EFFECT

*Fagus grandifolia*

- Arboretum
- Harvard Forest



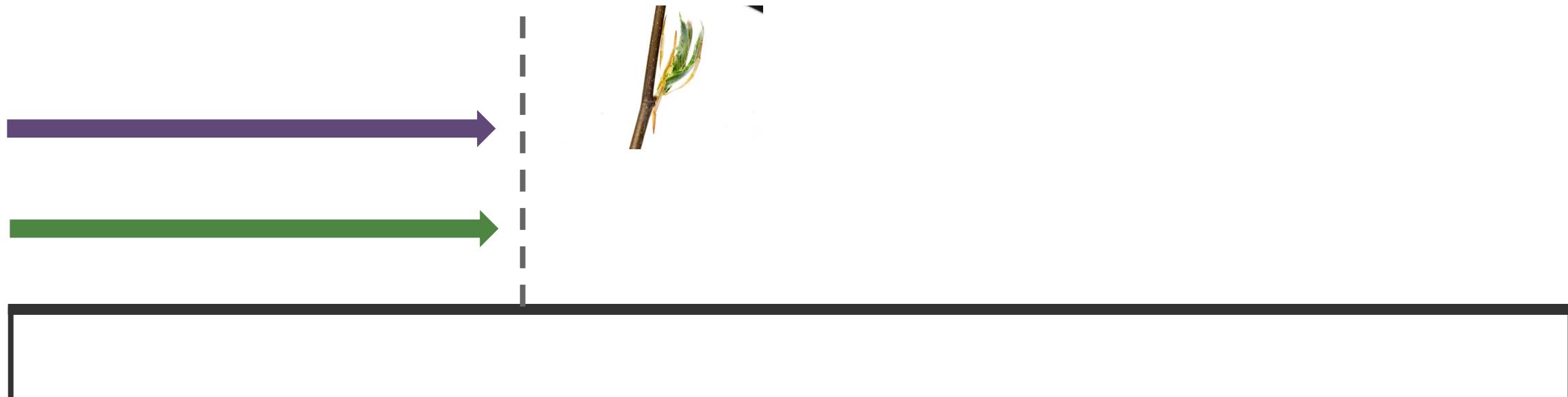
Jan 1

Dec 31

# METHOD EFFECT

*Fagus grandifolia*

- Hobo Logger
- Weather Station



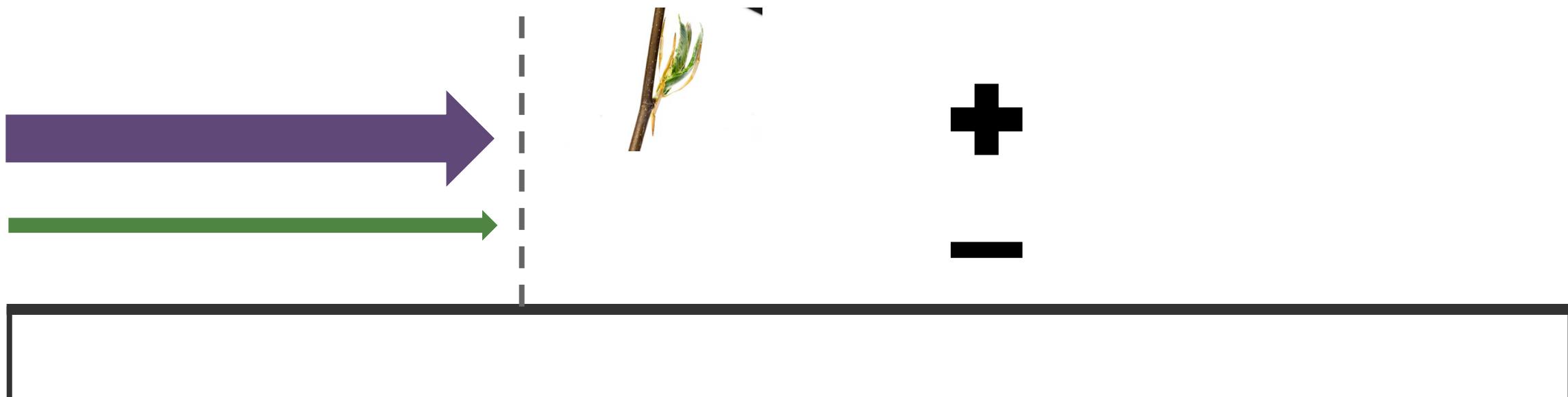
Jan 1

Dec 31

# METHOD EFFECT

- Hobo Logger
- Weather Station

*Fagus grandifolia*



Jan 1

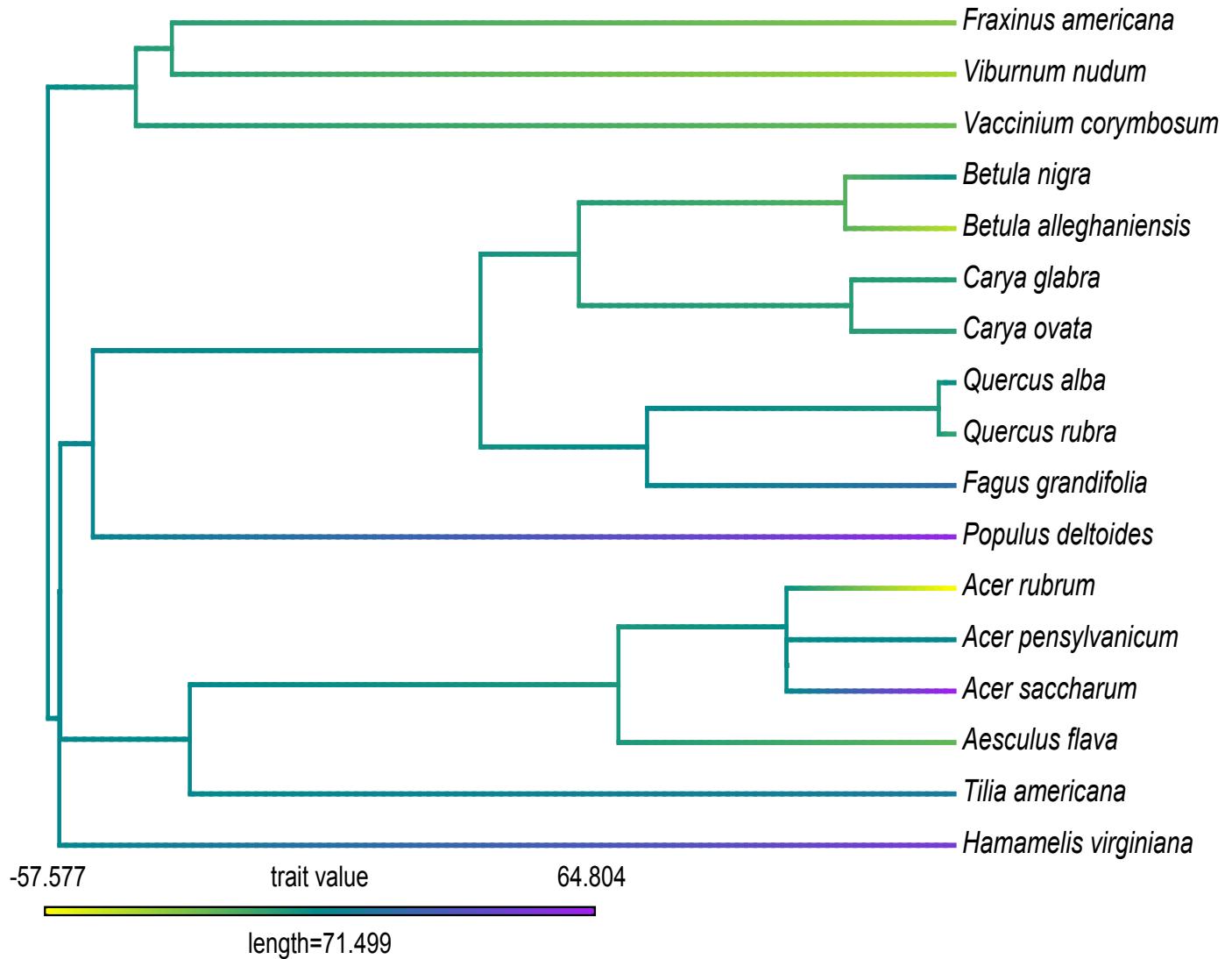
Dec 31

# Let's think more about accuracy...

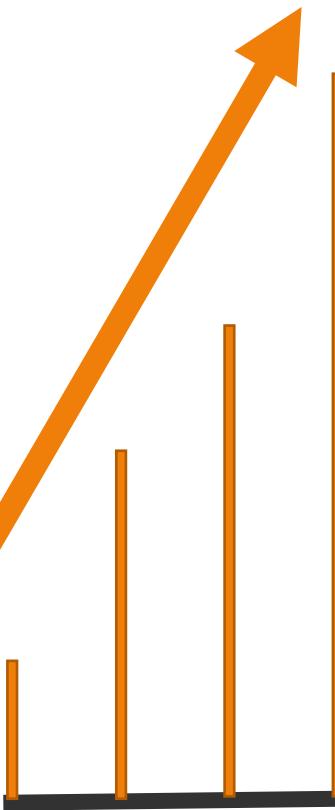
Interspecific variation in GDD threshold

We want to know how to estimate that threshold as accurately as possible

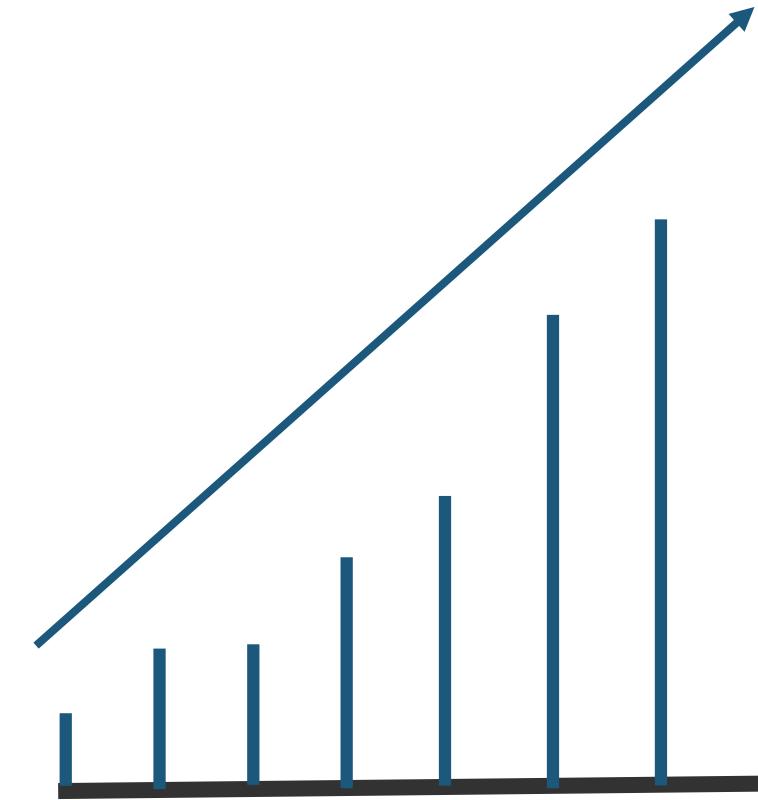
Question: how do we determine accuracy from model output?



# Let's think more about accuracy....



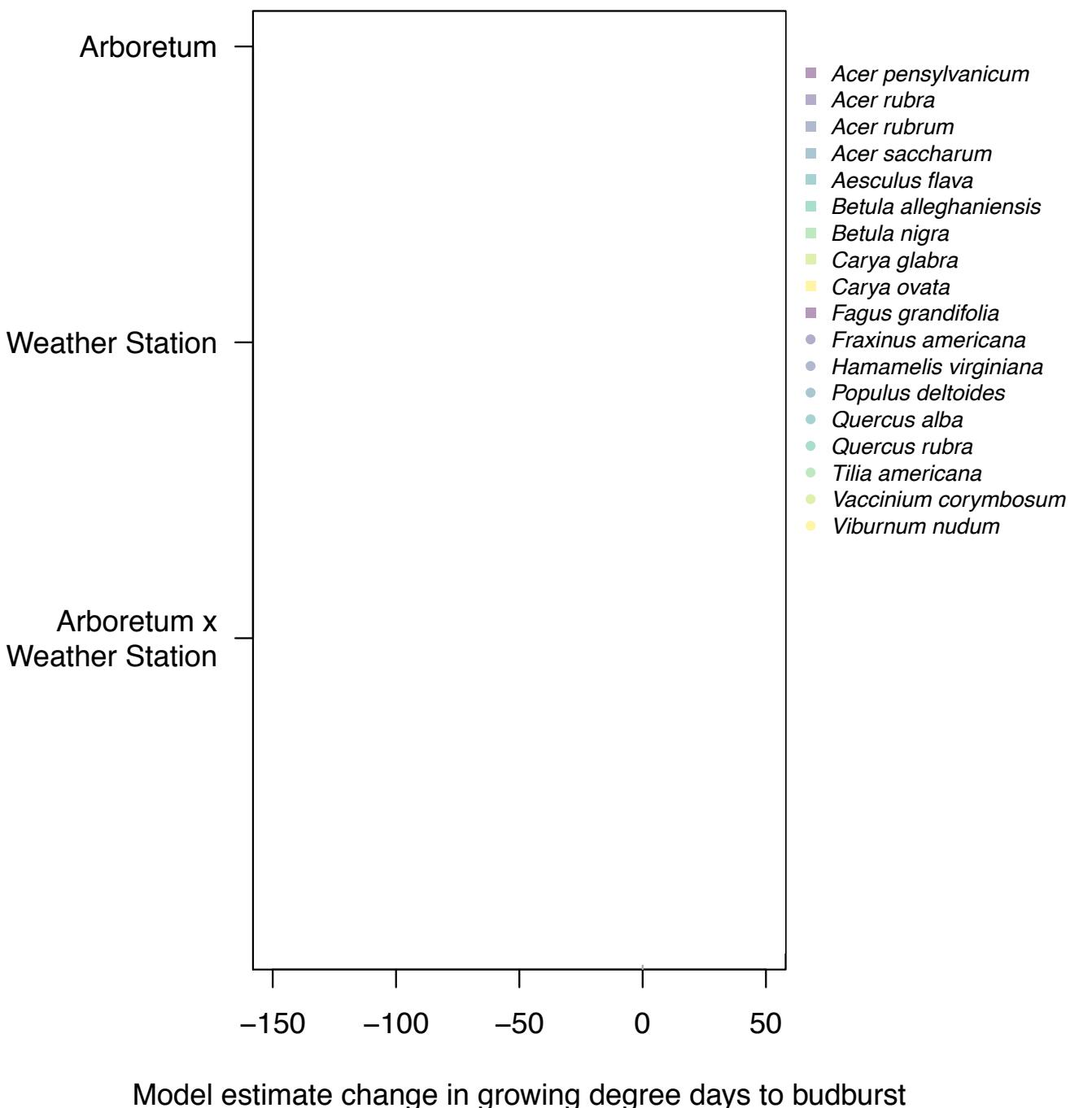
Hobo Logger



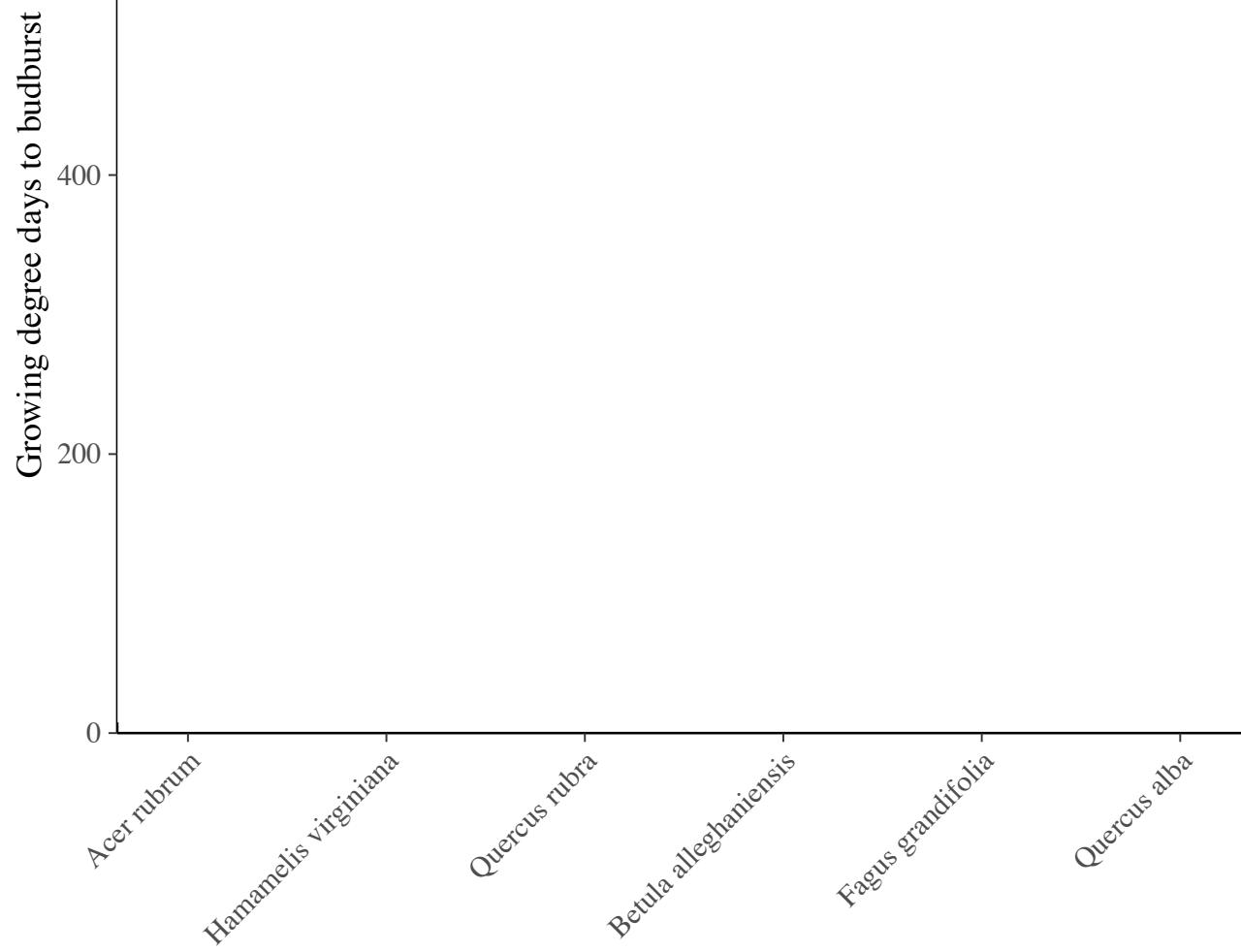
Weather Station



# Site and Method Effects



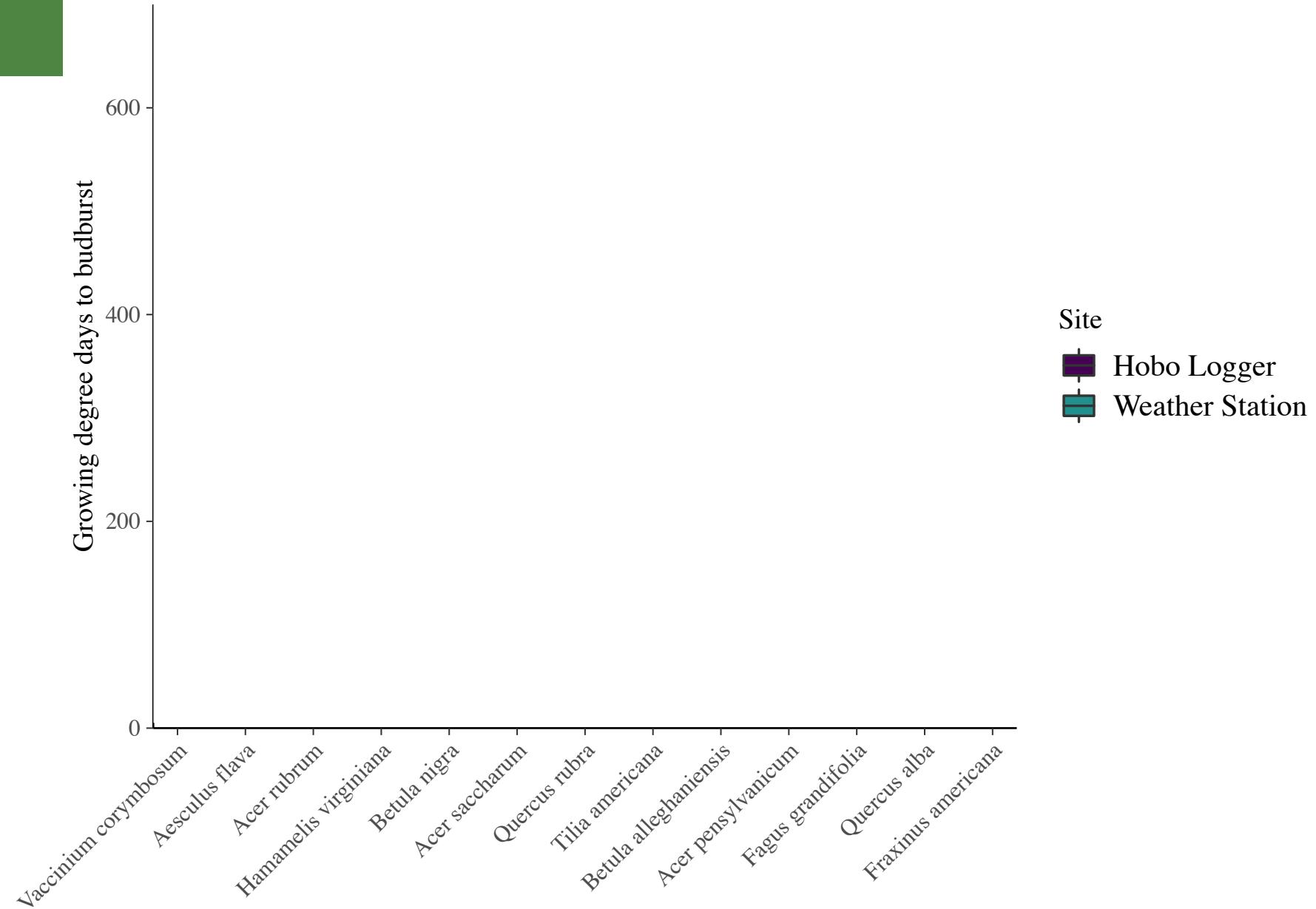
# SITE EFFECTS



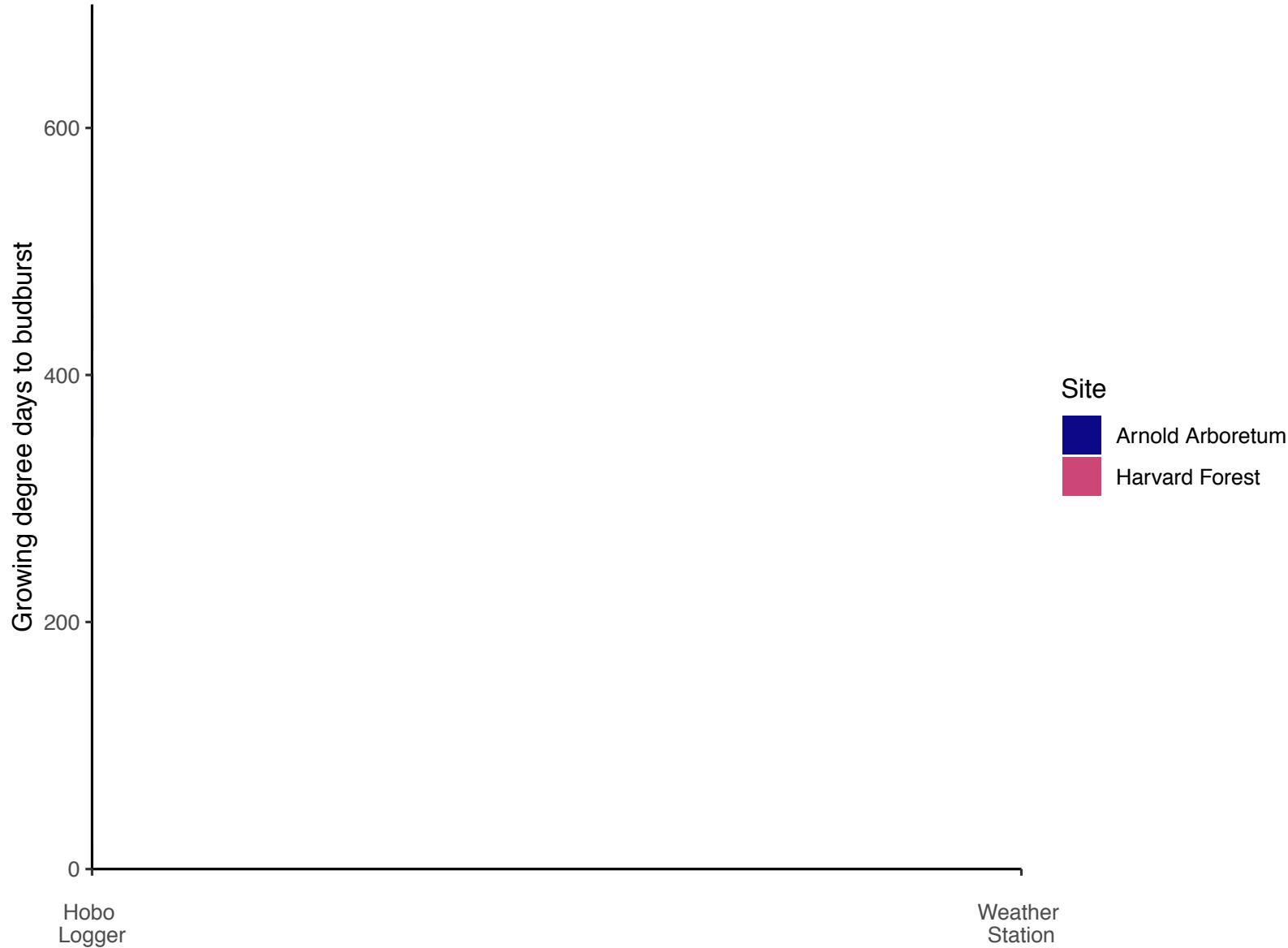
Site

- Arnold Arboretum
- Harvard Forest

# METHOD EFFECTS



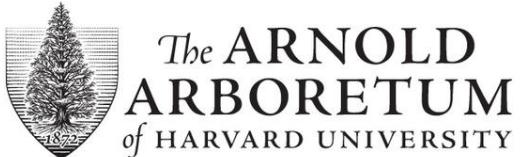
# INTERACTION



# QUICK CONCLUSIONS

- GDDs VARY ACROSS SITES
  - Harvard Forest has more GDDs
- GDDs DIFFER BETWEEN METHODS
  - Hobo loggers record higher GDDs
- BUT! We have an interaction
  - More variation in GDDs at the Arboretum
- PHENOLOGY IS FINICKY. More work to be done!





THE UNIVERSITY OF  
BRITISH COLUMBIA

## THE TEMPORAL ECOLOGY LAB

Lizzie Wolkovich, PhD

Dan Buonaiuto

Ignacio Morales-Castilla, PhD

Aileen Ettinger, PhD

Deirdre Loughnan

Darwin Sodhi



Harvard University | Department of

Organismic and Evolutionary Biology

## THE HOLBROOK LAB

Noel Michele Holbrook, PhD

Fulton Rockwell, PhD

Jess Gersony

Anju Manandhar

Meghan Blumstein

Morgan Furze, PhD

Zhe He

Erin Wright



## COMMITTEE MEMBERS

Paul Moorcroft, PhD

Neil Pederson, PhD



## ARNOLD ARBORETUM - TREE SPOTTERS

Suz Mrozak

Danny Schissler

Kate Stonefoot

Pam Thompson

Our Citizen Scientists!!

## COLLABORATORS AND SPECIAL THANKS

Iñaki Garcia de Cortazar-Atauri, PhD

Ben Cook, PhD

Kea Woodruff

Faye Rosin

Alice Linder

Dan Flynn

Alissandra Ayala

John O'Keefe, PhD

Audrey Barker Plotkin

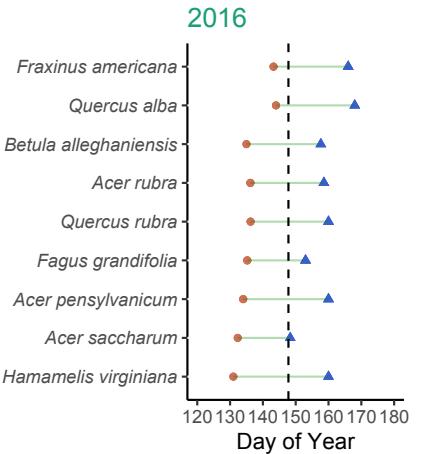


NASA Goddard Institute for Space Studies

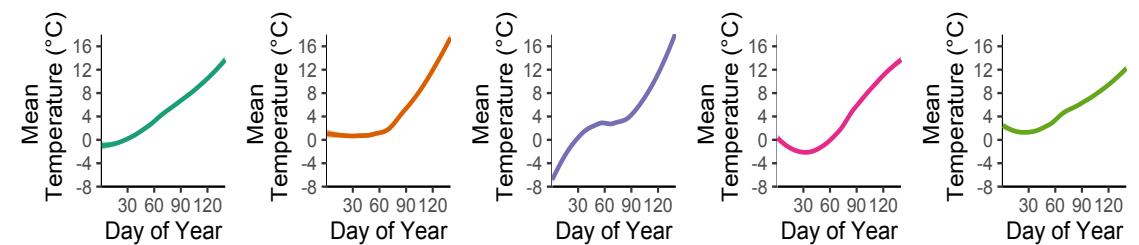
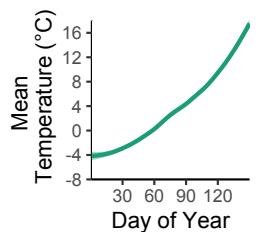
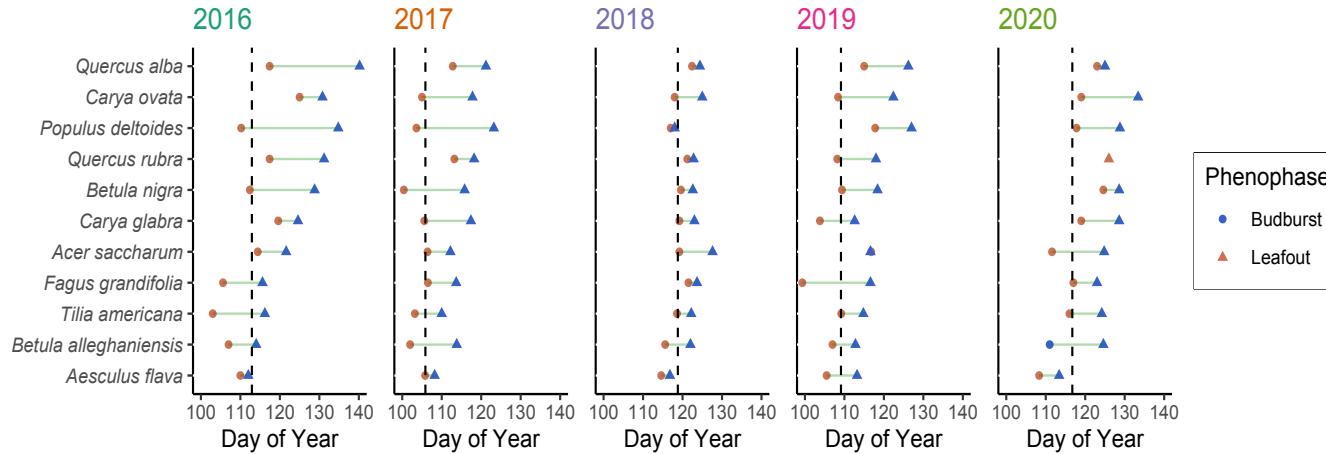


# Budburst to leafout

Harvard Forest



Arnold Arboretum



# WHY IS PLANT PHENOLOGY SO IMPORTANT?



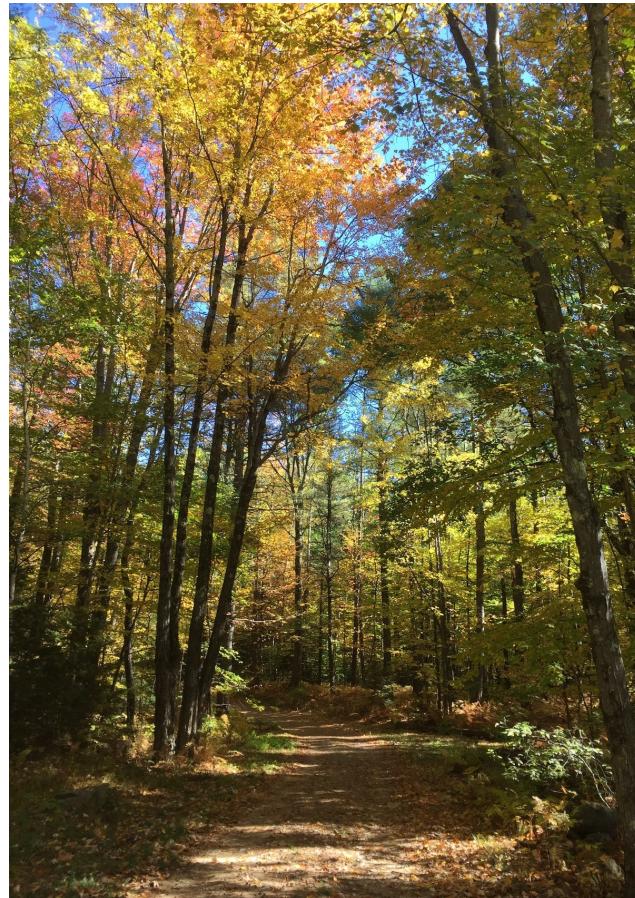
Spring Freeze Risk



Drought Risk

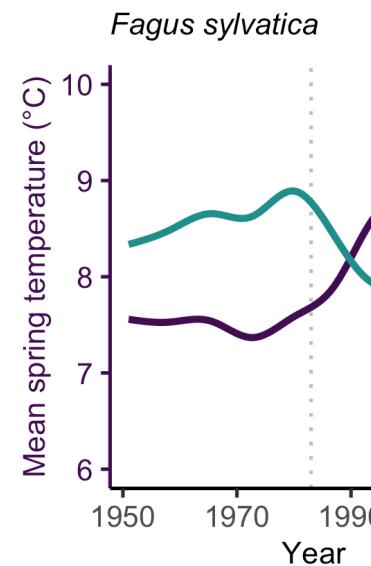
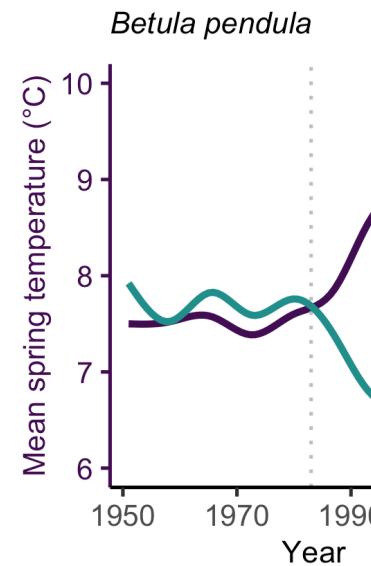


Growth Rate

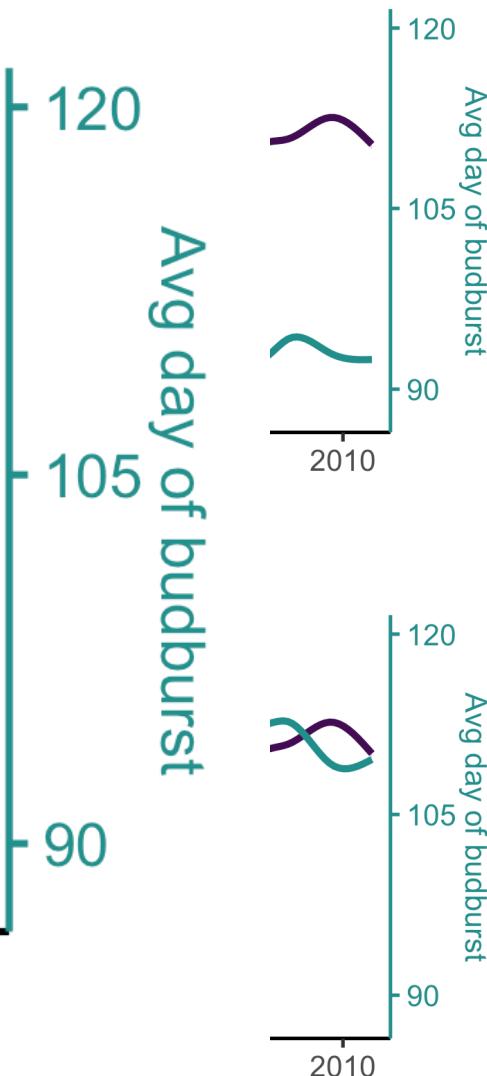
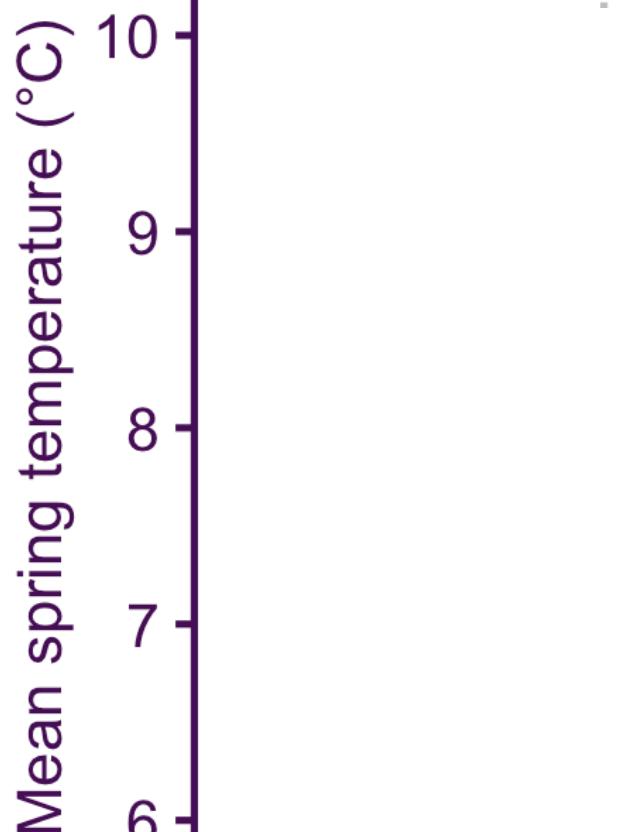


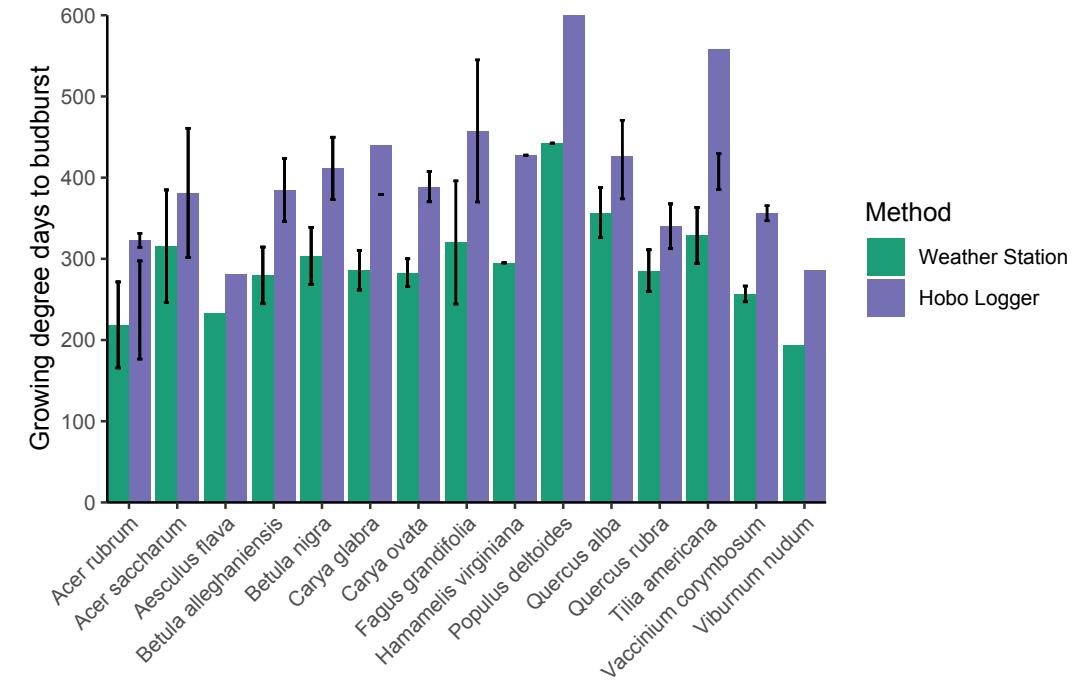
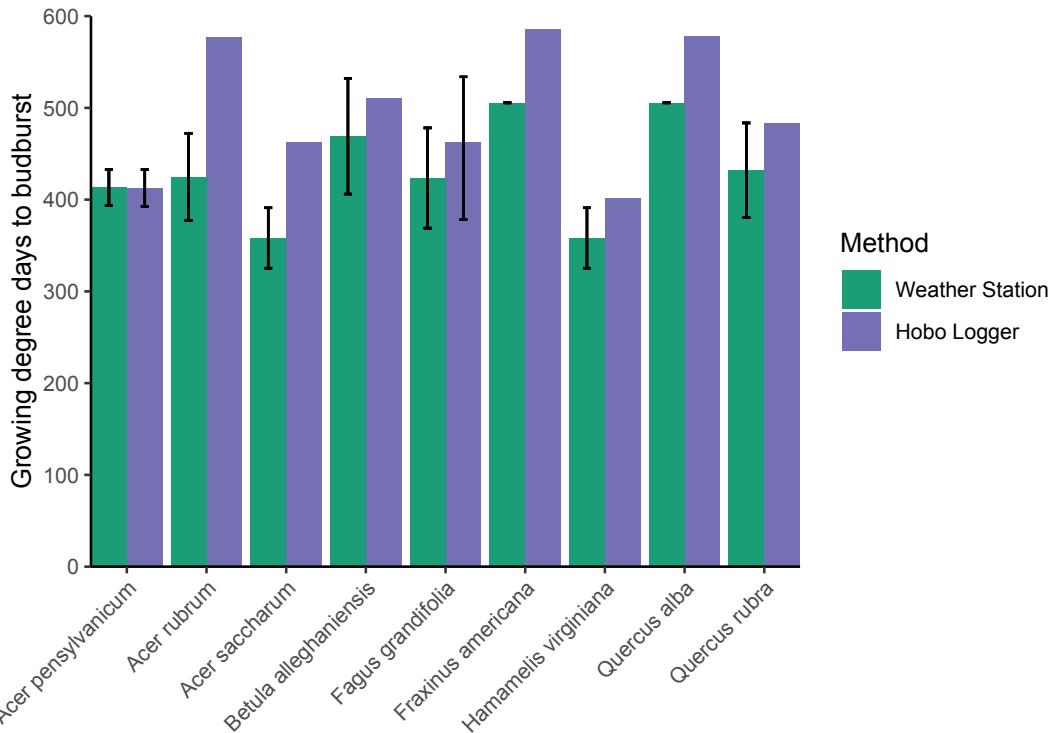
Carbon Sinks

# PHENOLOGY IS ADVANCING



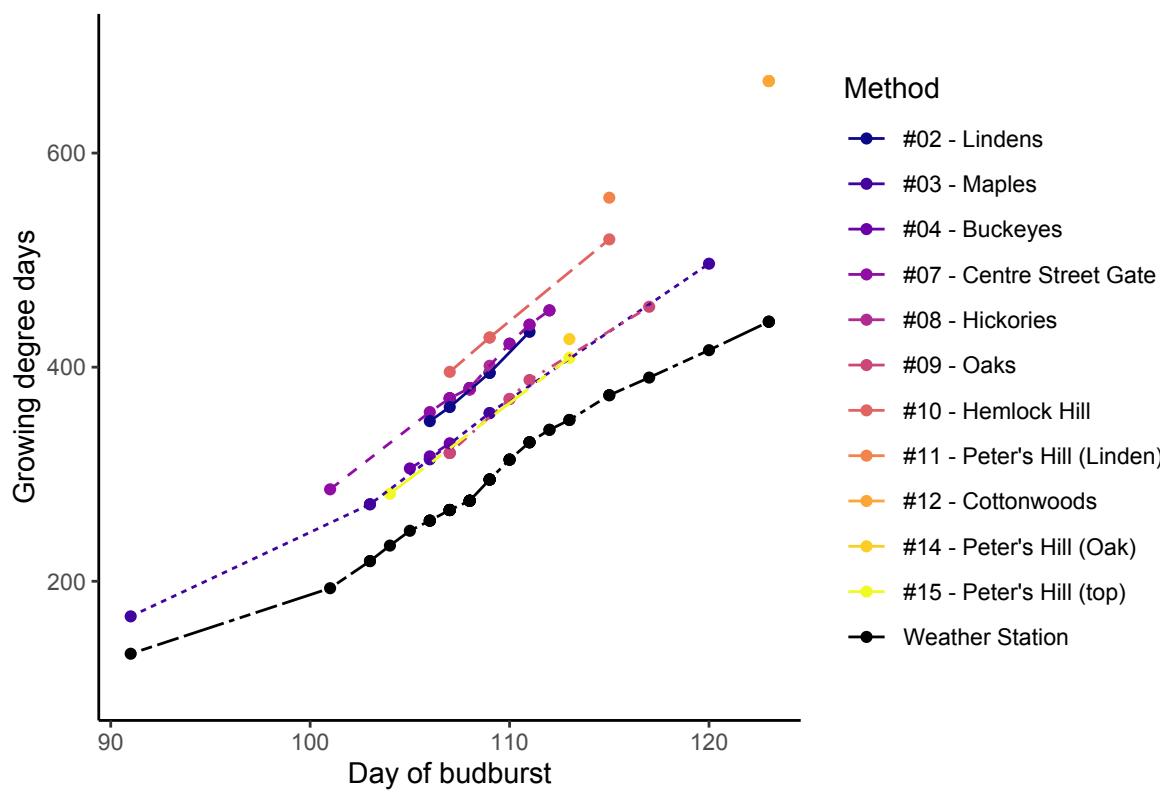
*Betula pendula*





# Breakdown of weather data

ARBORETUM



HARVARD FOREST

