The illusion of declining temperature sensitivity with warming

E. M. Wolkovich
University of British Columbia

PHENO 2022

Collaborators

Ailene Ettinger, Ignacio Morales-Castilla, Catherine Chamberlain and Daniel Buonaiuto

Questions

- Why are plant phenological responses to climate change slowing down?
- How can we better predict these changes?

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- How can we better predict these changes?

Declining sensitivity to temperature

LETTER

doi:10.1038/nature15402

Declining global warming effects on the phenology of spring leaf unfolding

Yongshuo H. Fu[1,2], Hor
Mengtian Huang[1], Ann

nature climate change

LETTERS

PUBLISHED ONLINE: 24 APRIL 2017 | DOI: 10.1038/NCLIMATE3277

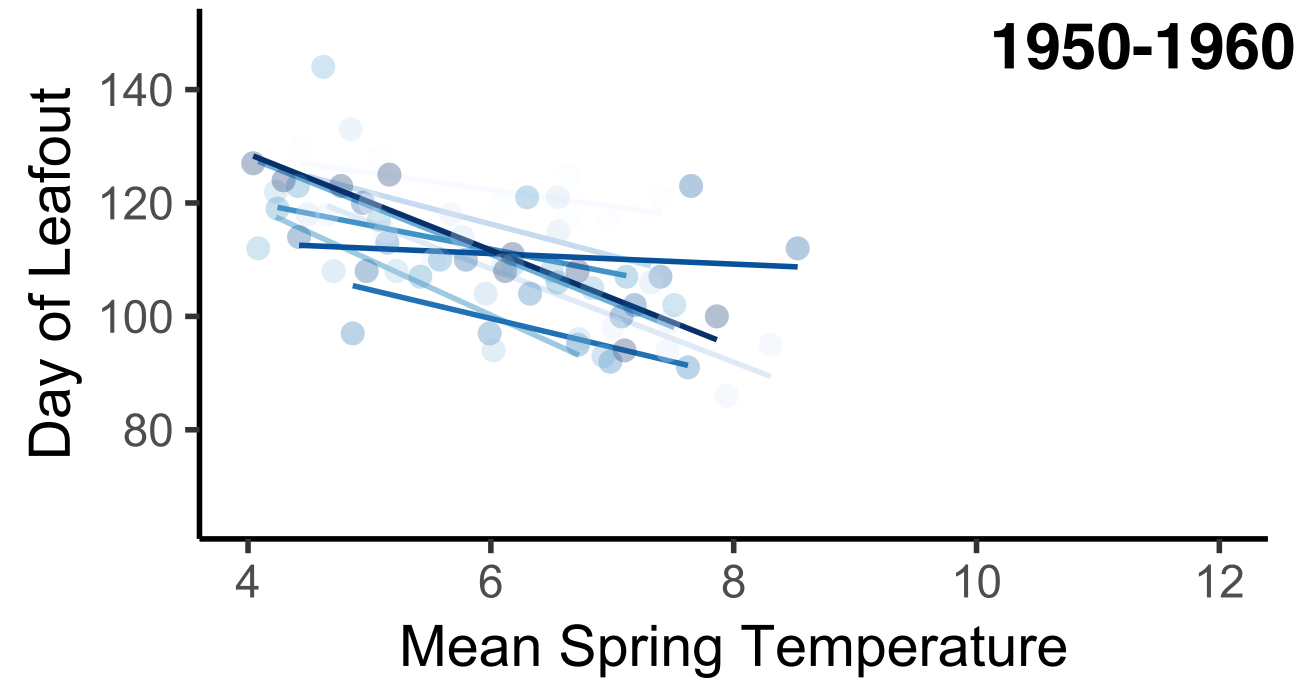
Weakening temperature control on the interannual variations of spring carbon uptake across northern lands

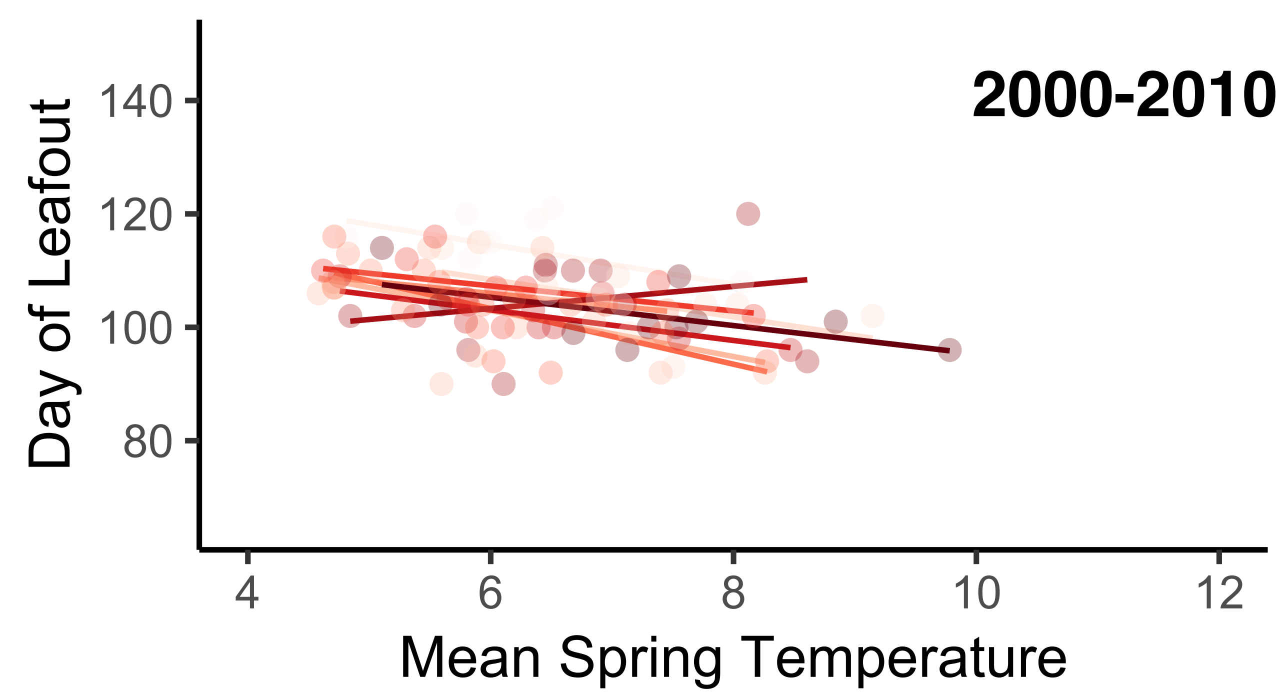
Shilong Piao[1,2,3★], Zhuo Liu[2], Tao Wang[1,3], Shushi Peng[2], Philippe Ciais[4], Mengtian Huang[2], Anders Ahlstrom[5], John F. Burkhart[6], Frédéric Chevallier[4], Ivan A. Janssens[7], Su-Jong Jeong[8], Xin Lin[4], Jiafu Mao[9], John Miller[10,11], Anwar Mohammat[12], Ranga B. Myneni[13], Josep Peñuelas[14,15], Xiaoying Shi[9], Andreas Stohl[16], Yitong Yao[2], Zaichun Zhu[2] and Pieter P. Tans[10]

Declining sensitivity to temperature

Silver birch
(*Betula pendula*)

45 sites from Europe



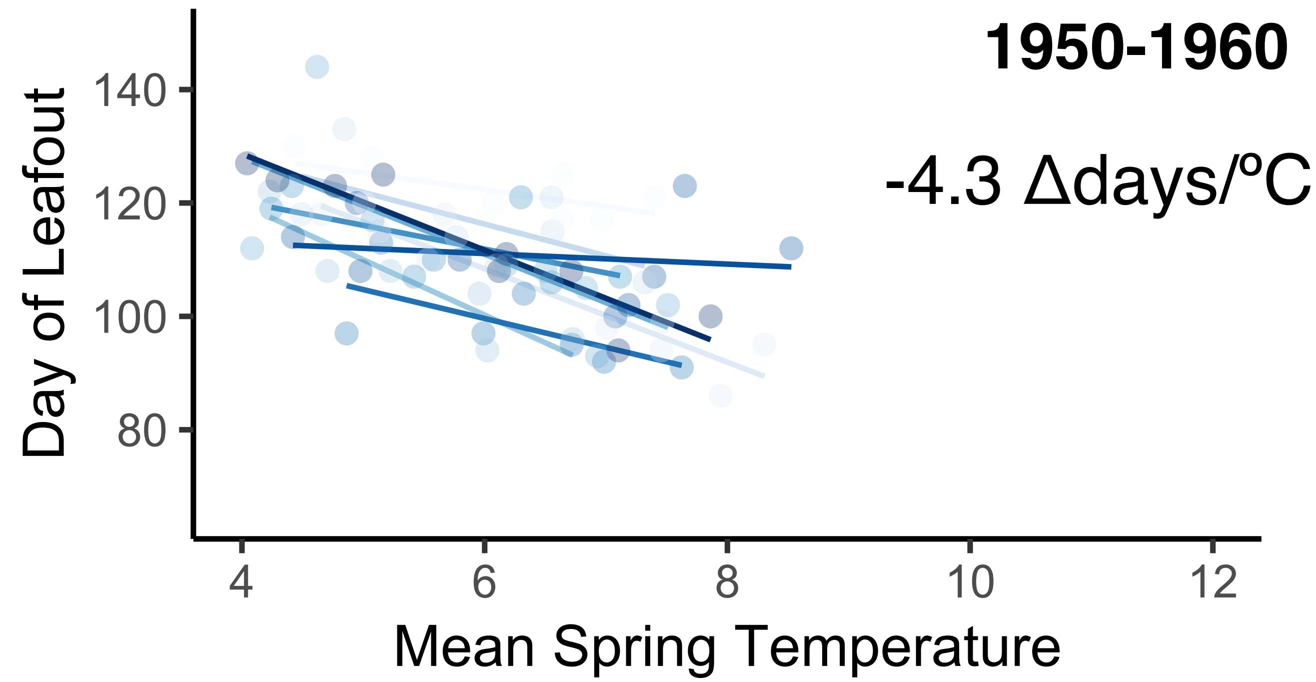


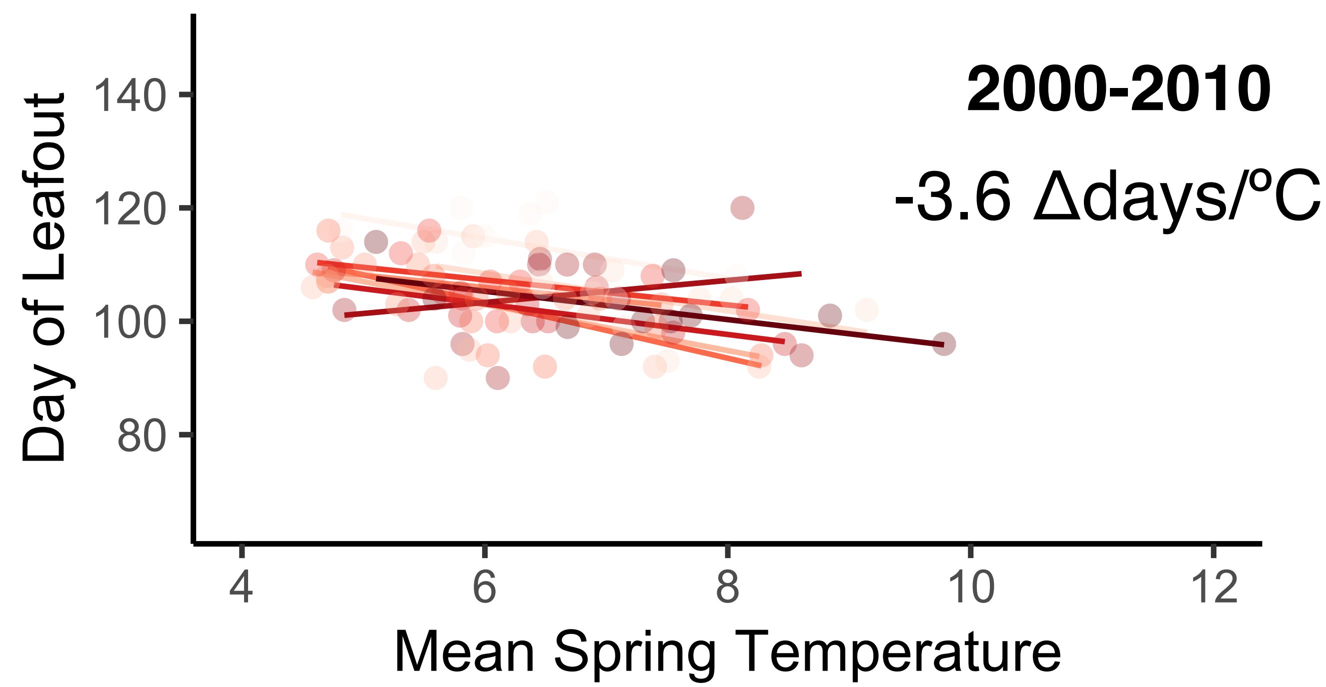
Declining sensitivity to temperature

Silver birch
(*Betula pendula*)

45 sites from Europe

Sensitivity measured as **slope of linear regression**: Δdays/ºC





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doi:10.1038/nature15402

Declining global warming effects on the phenology of spring leaf unfolding

Global Change Biology

Global Change Biology (2014) **20**, 170–182, doi: 10.1111/gcb.12360

Chilling outweighs photoperiod in preventing precocious spring development

JULIA LAUBE*†, TIM H. SPARKS*†‡, NICOLE ESTRELLA*†, JOSEF HÖFLER§, DONNA P. ANKERST§ and ANNETTE MENZEL*†

**Chair of Ecoclimatology, Technische Universität München, Hans-Carl-von-Carlowitz-Platz 2, Freising 85354, Germany, †Institute for Advanced Study, Technische Universität München, Lichtenbergstrasse 2a, Garching 85748, Germany, ‡Sigma, Coventry University, Priory Street, Coventry CV1 5FB, United Kingdom, §Chair of Biostatistics, Technische Universität München, Parkring 13, Garching-Hochbrück 85748, Germany*

LETTERS

E: 24 APRIL 2017 | DOI: 10.1038/NCLIMATE3277

on the

arbon uptake

Shilong Piao[1,2,3*], Zhuo Liu[2], Tao Wang[1,3], Shushi Peng[2], Philippe Ciais[4], Mengtian Huang[2], Anders Ahlstrom[5], John F. Burkhart[6], Frédéric Chevallier[4], Ivan A. Janssens[7], Su-Jong Jeong[8], Xin Lin[4], Jiafu Mao[9], John Miller[10,11], Anwar Mohammat[12], Ranga B. Myneni[13], Josep Peñuelas[14,15], Xiaoying Shi[9], Andreas Stohl[16], Yitong Yao[2], Zaichun Zhu[2] and Pieter P. Tans[10]

Declining sensitivity to temperature

LETTER

doi:10.1038/nature15402

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Plant, Cell & Environment

Plant, Cell and Environment (2015) **38**, 1725–1736

doi: 10.1111/pce.12431

Review

Photoperiod constraints on tree phenology, performance and migration in a warming world

Danielle A. Way[1,2] & Rebecca A. Montgomery[3]

Global Change Biology (201

Chilling outw
spring develo

JULIA LAUBE*†, TIM H. SPARKS*†‡, NICOLE ESTRELLA*†, JOSEF HÖFLER§, DONNA P. ANKERST§ and ANNETTE MENZEL*†

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LETTERS

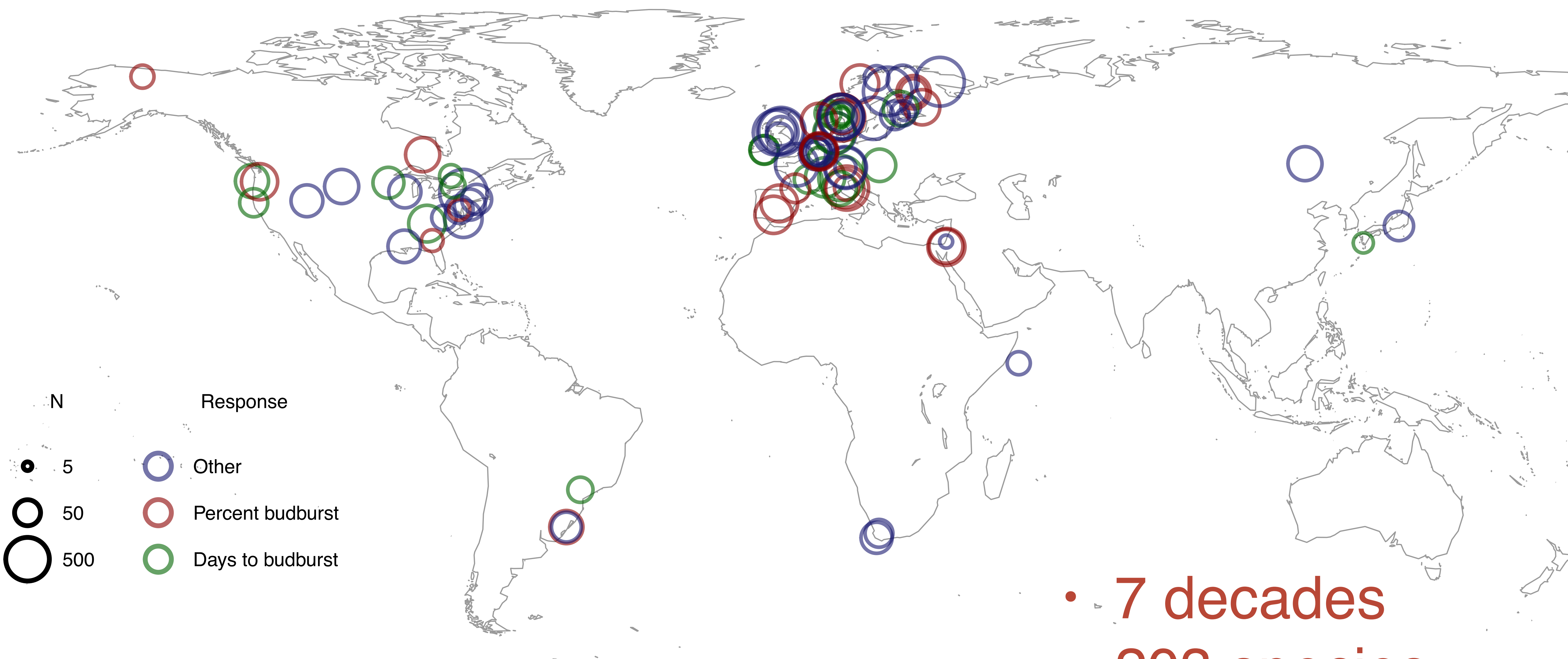
PUBLISHED ONLINE: 17 OCTOBER 2016 | DOI: 10.1038/NCLIMATE3138

nature climate change

Day length unlikely to constrain climate-driven shifts in leaf-out times of northern woody plants

Constantin M. Zohner[1]*, Blas M. Benito[2], Jens-Christian Svenning[2] and Susanne S. Renner[1]

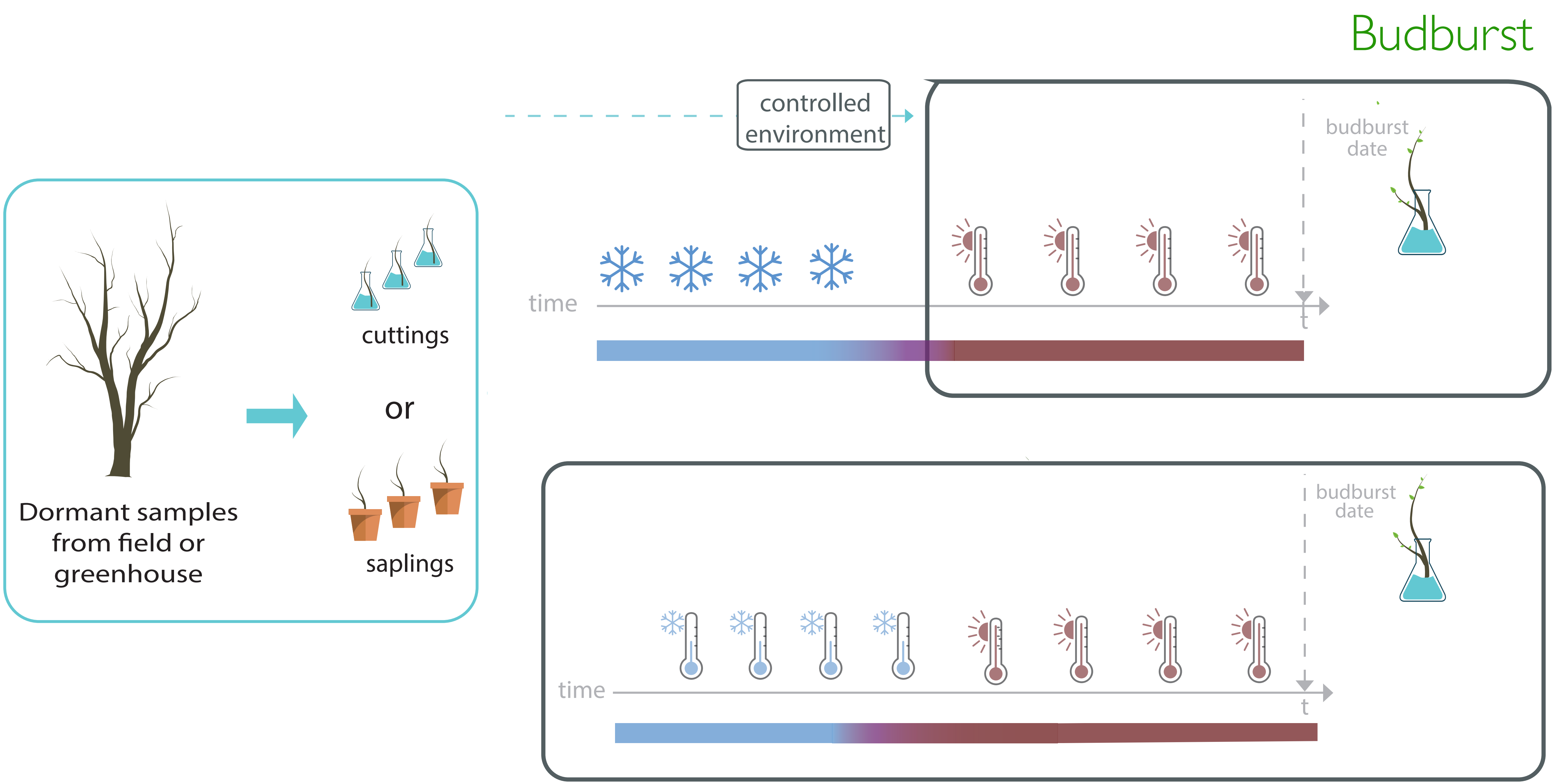
Meta-analysis of experiments



- 7 decades
- 203 species
- 72 studies

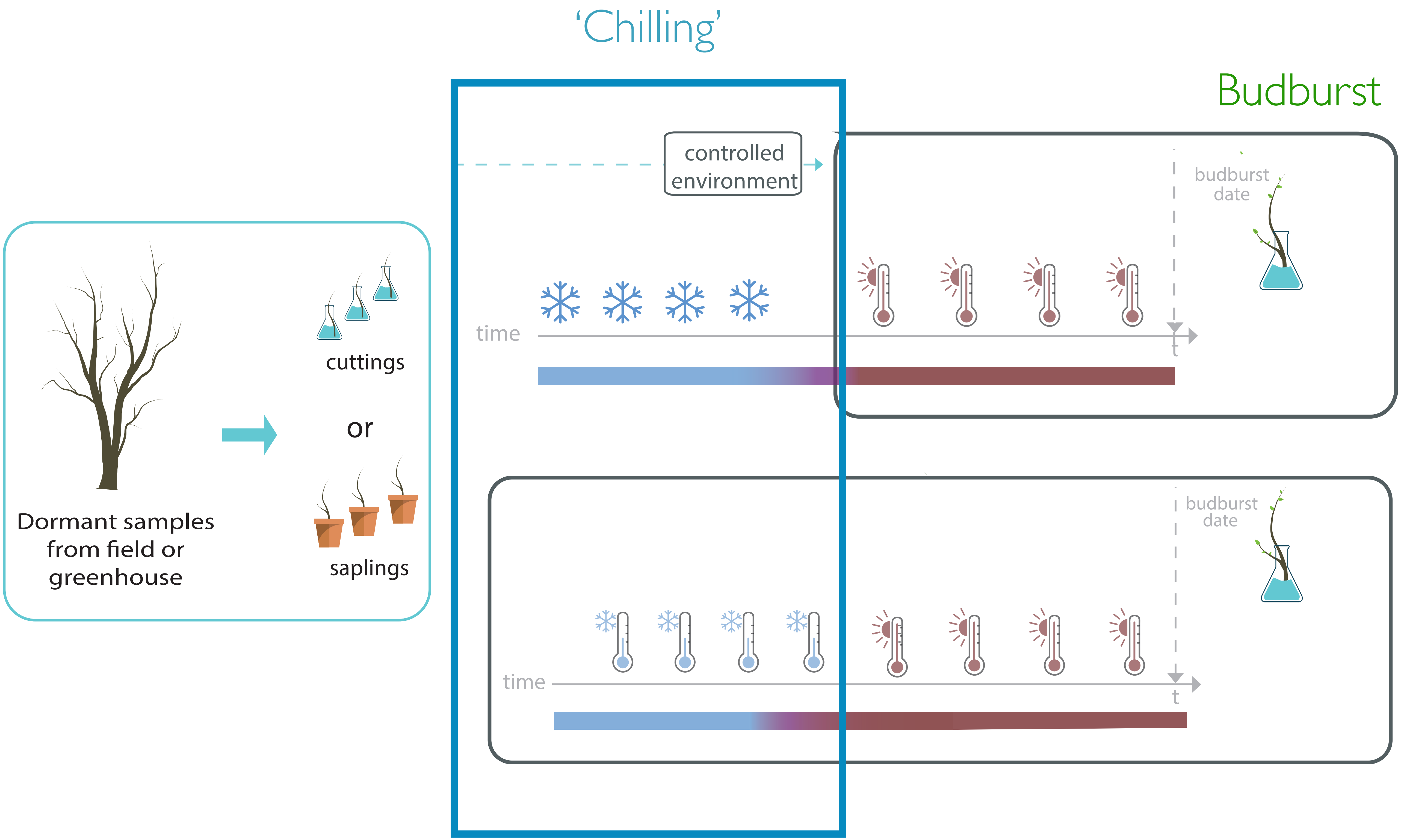

Controlled environments can disentangle cues

Controlled environment experiments



Ettinger *et al.* 2020

Controlled environment experiments



Ettinger *et al.* 2020

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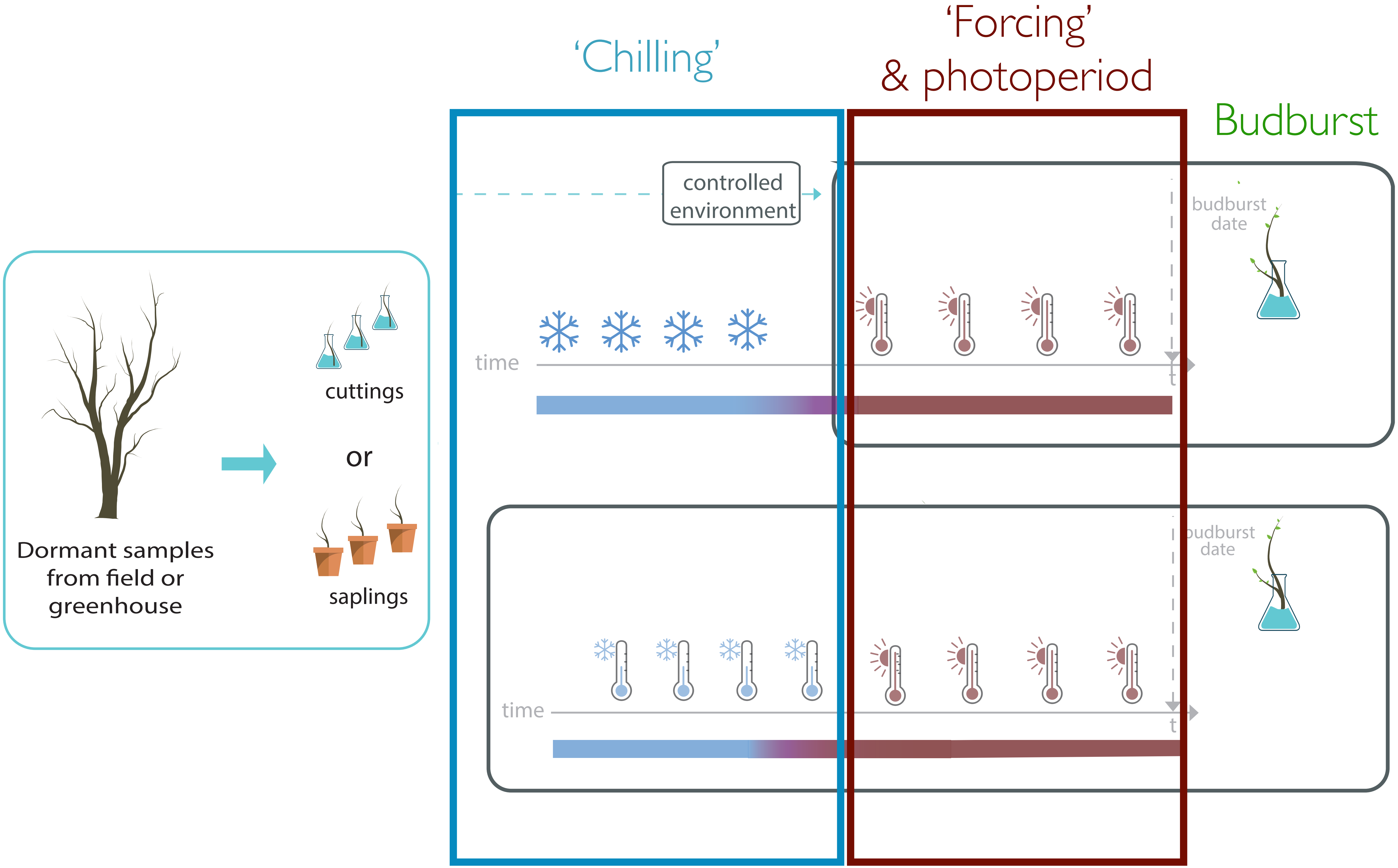
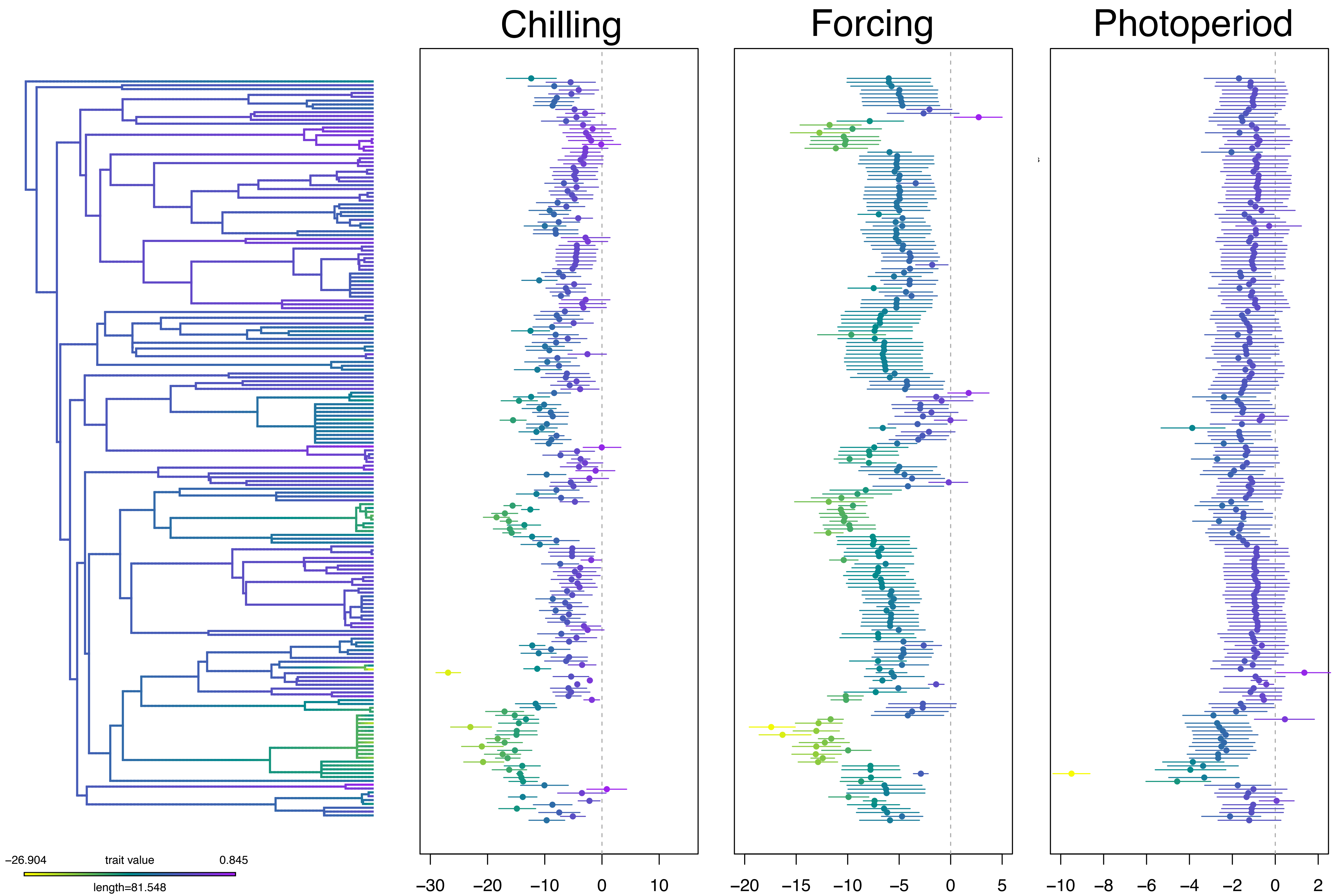


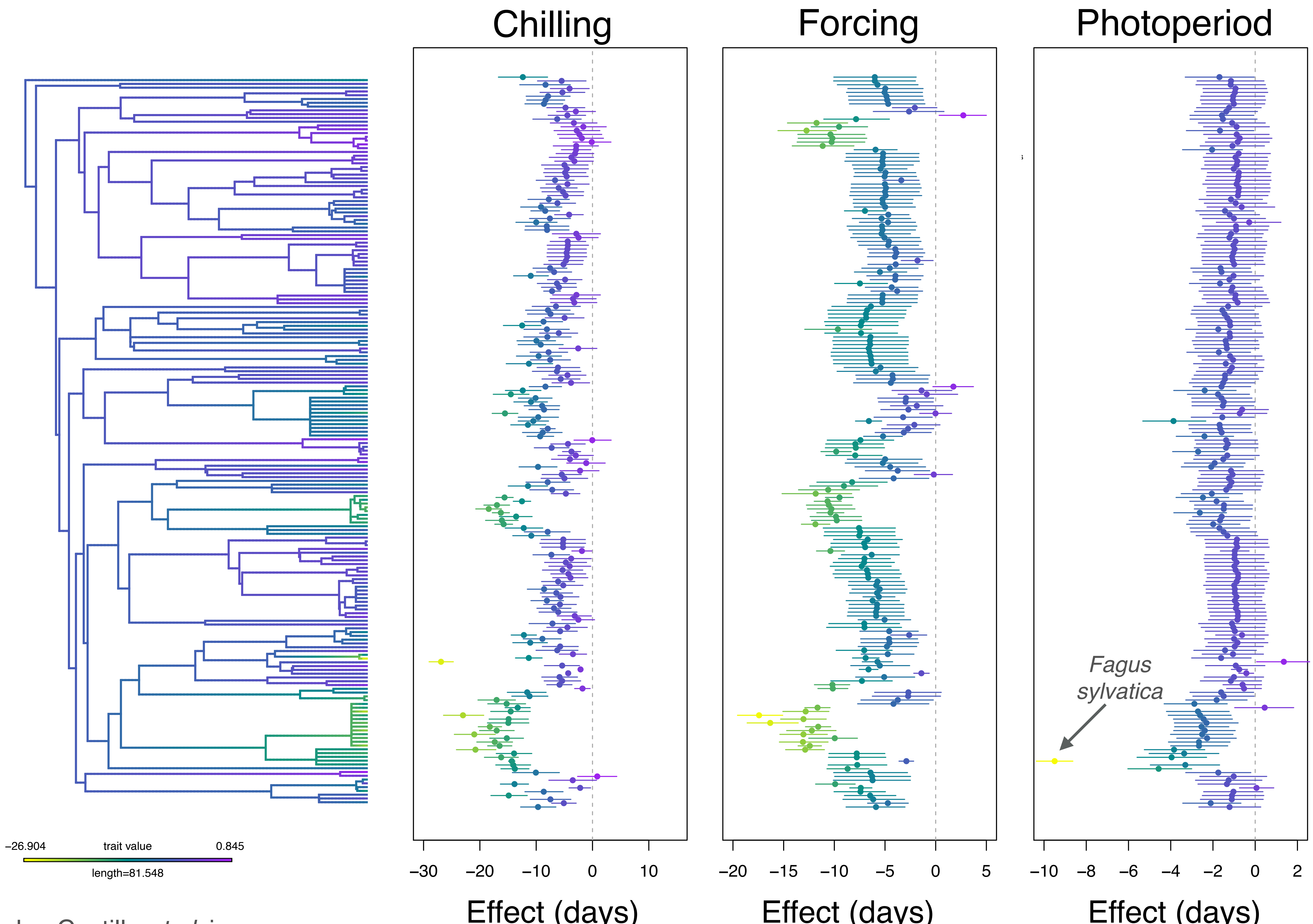
Ettinger *et al.* 2020

Strong chilling and forcing effects



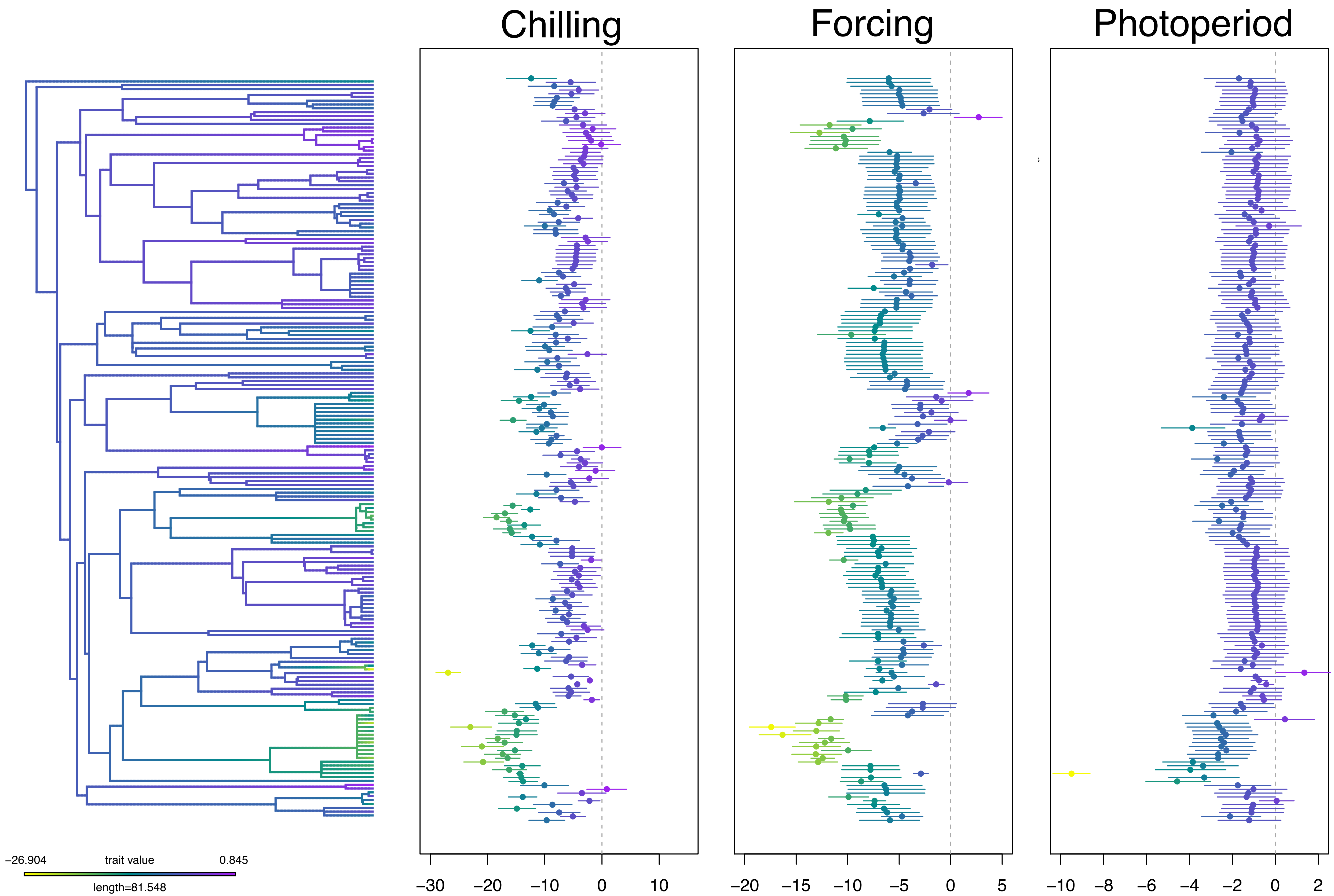
Morales-Castilla *et al.* in prep

Fagus sylvatica: outlier among species



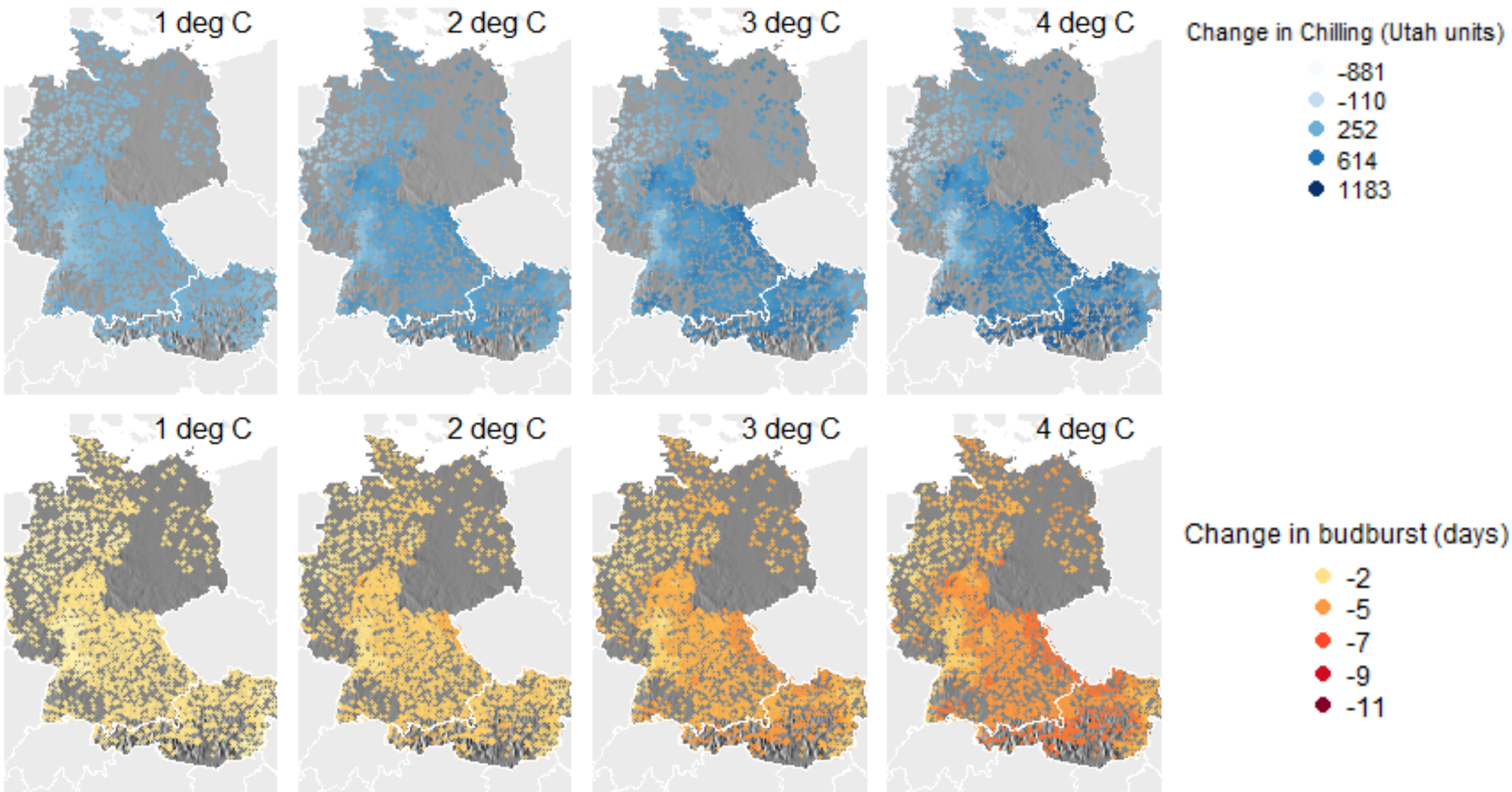
Morales-Castilla *et al.* in prep

Results predict stalled budburst



Morales-Castilla *et al.* in prep

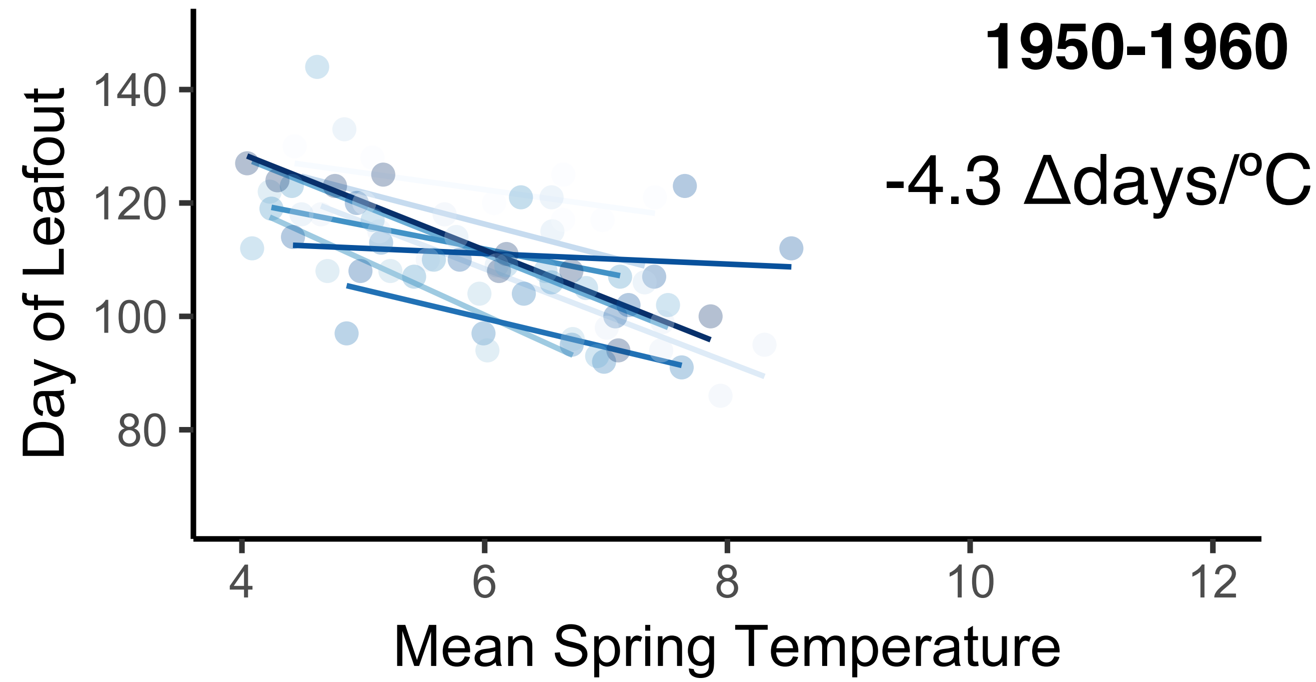
Model does not predict stalled leafout when applied to *in situ* data

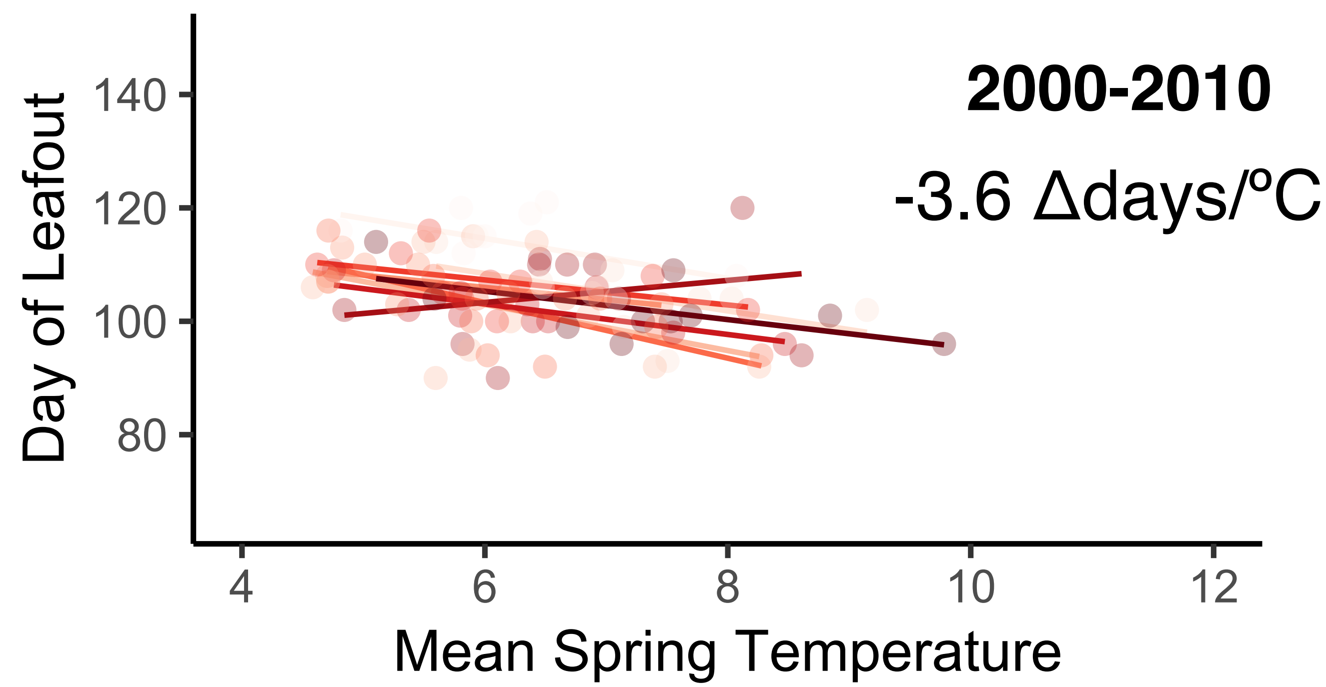


Ettinger *et al.* 2020, *NCC*

What underlies declining sensitivities?

- We simulated a simple model …
- Leafout occurs after a certain thermal sum
- Simulated across different temperatures





What underlies declining sensitivities?

$$n = \text{day since temperatures start to accumulate}, \; n = 0, 1, ..., N$$

$$S_0^n = \sum_{i=0}^{n} X_i, \text{the cumulative daily temperature from day 0 to day } n$$

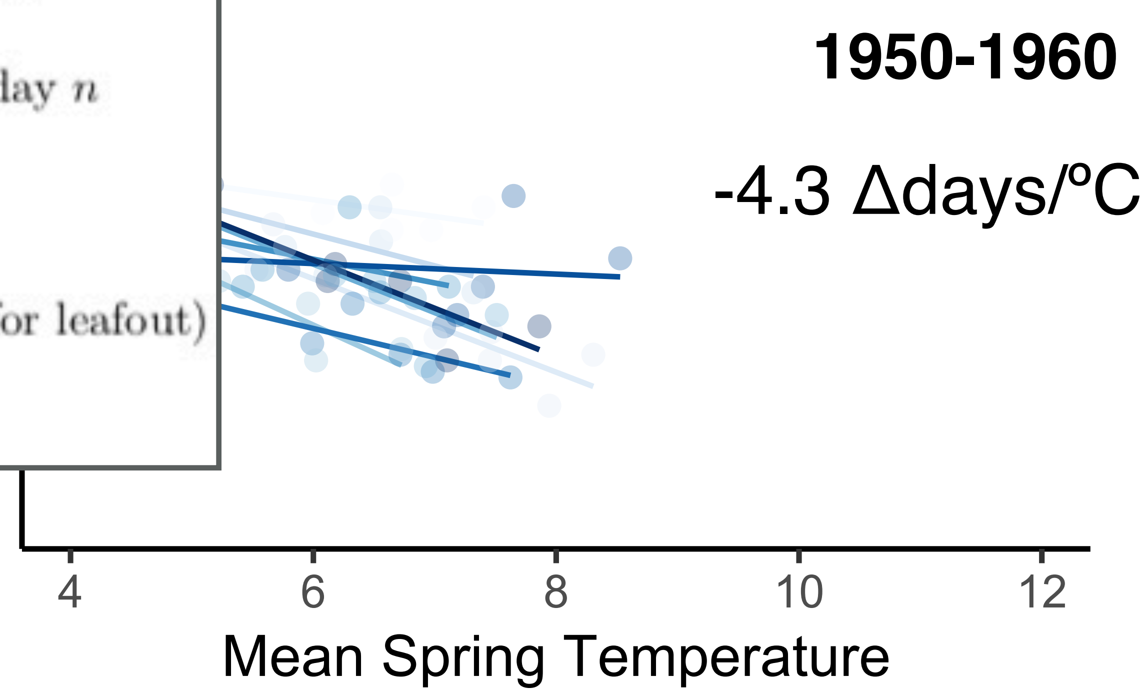
$$M_0^n = \frac{S_0^n}{n}, \text{the average daily temperature from day 0 to day } n$$

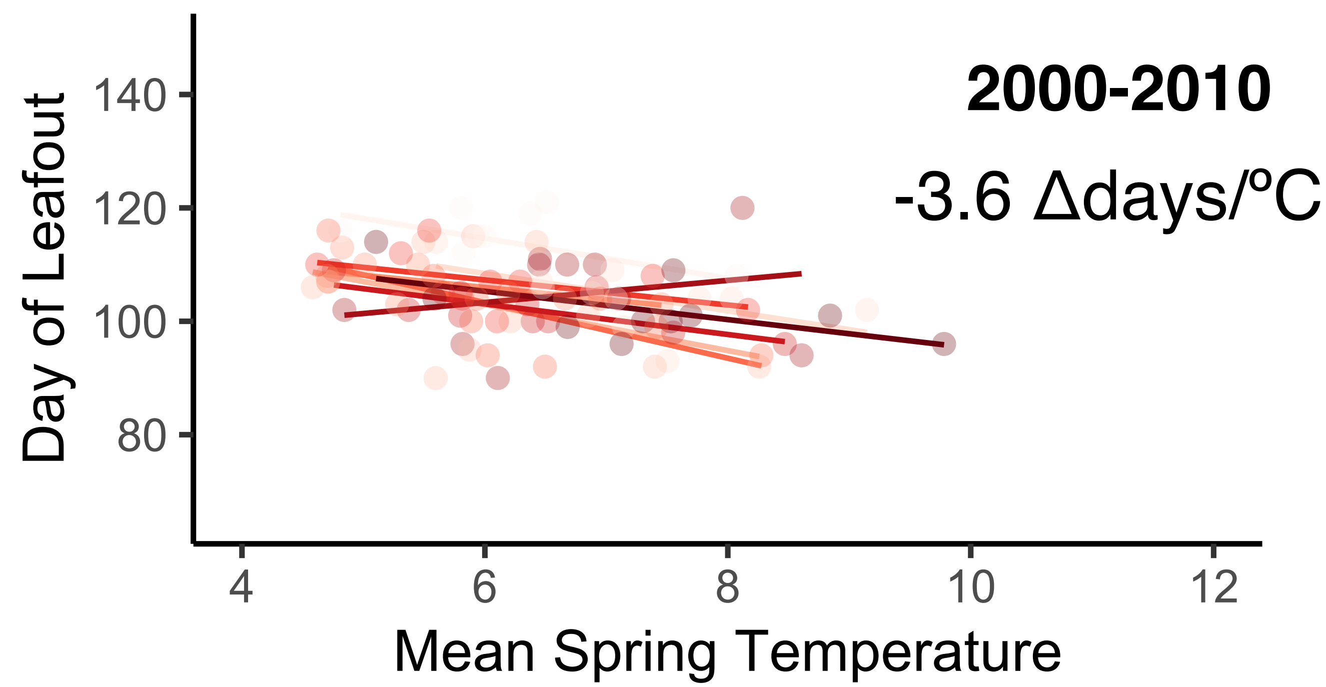
$$\beta = \text{the threshold of interest}, \; \beta > 0, \; \text{(thermal sum required for leafout)}$$

$$n_\beta = min(\; S_n > \beta), \; \text{leafout day}$$

thermal sum

- Simulated across different temperatures





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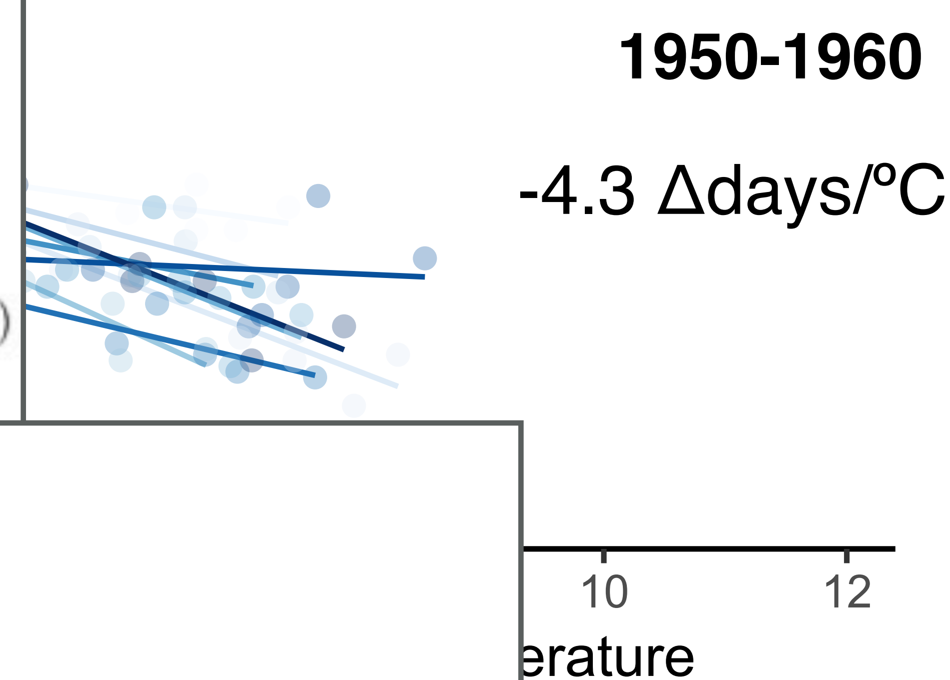
β = the threshold of interest, $\beta > 0$, (thermal sum required for leafout)

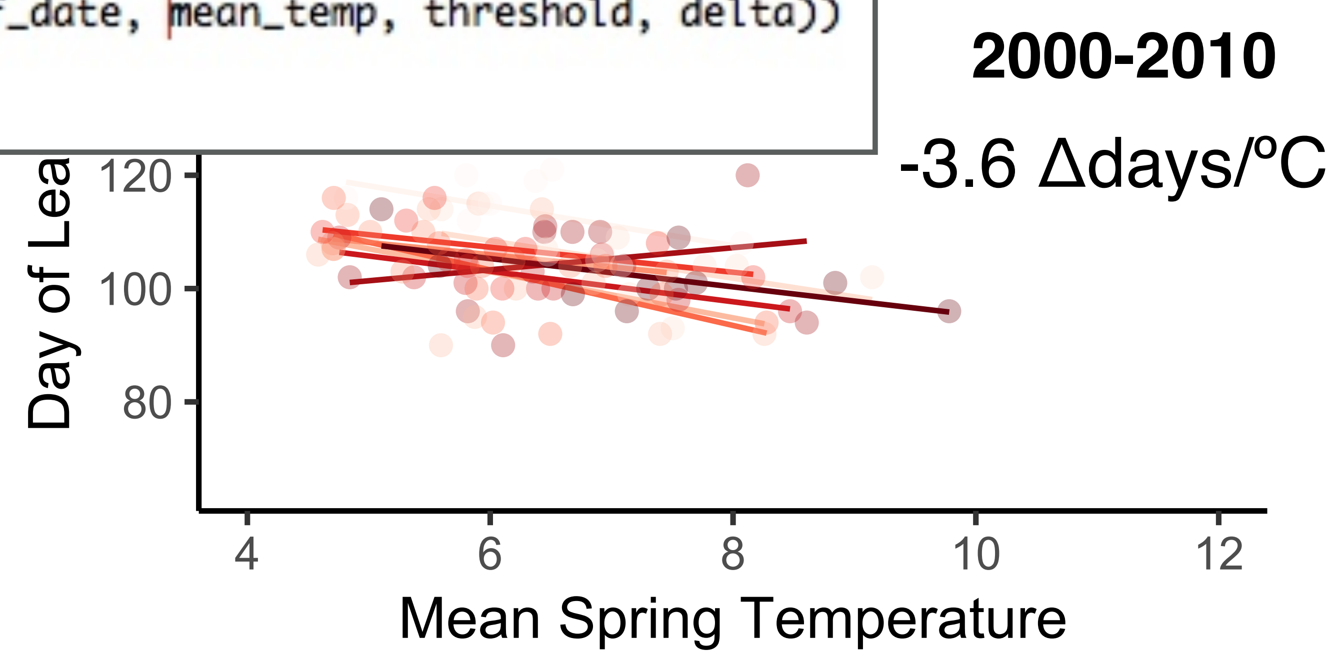
$n_\beta = min(\ S_n > \beta)$, leafout day

```
threshold <- 500
for(delta in c(5, 10, 15, 20)) {
  for(sim in 1:1000) {
    temp <- delta * (1:100) + rnorm(100, 0, 50)
    leaf_date <- which.min(cumsum(temp) < threshold)
    mean_temp <- mean(temp[1:leaf_date])
    data <- rbind(data, data.frame(leaf_date, mean_temp, threshold, delta))
  }
}
```

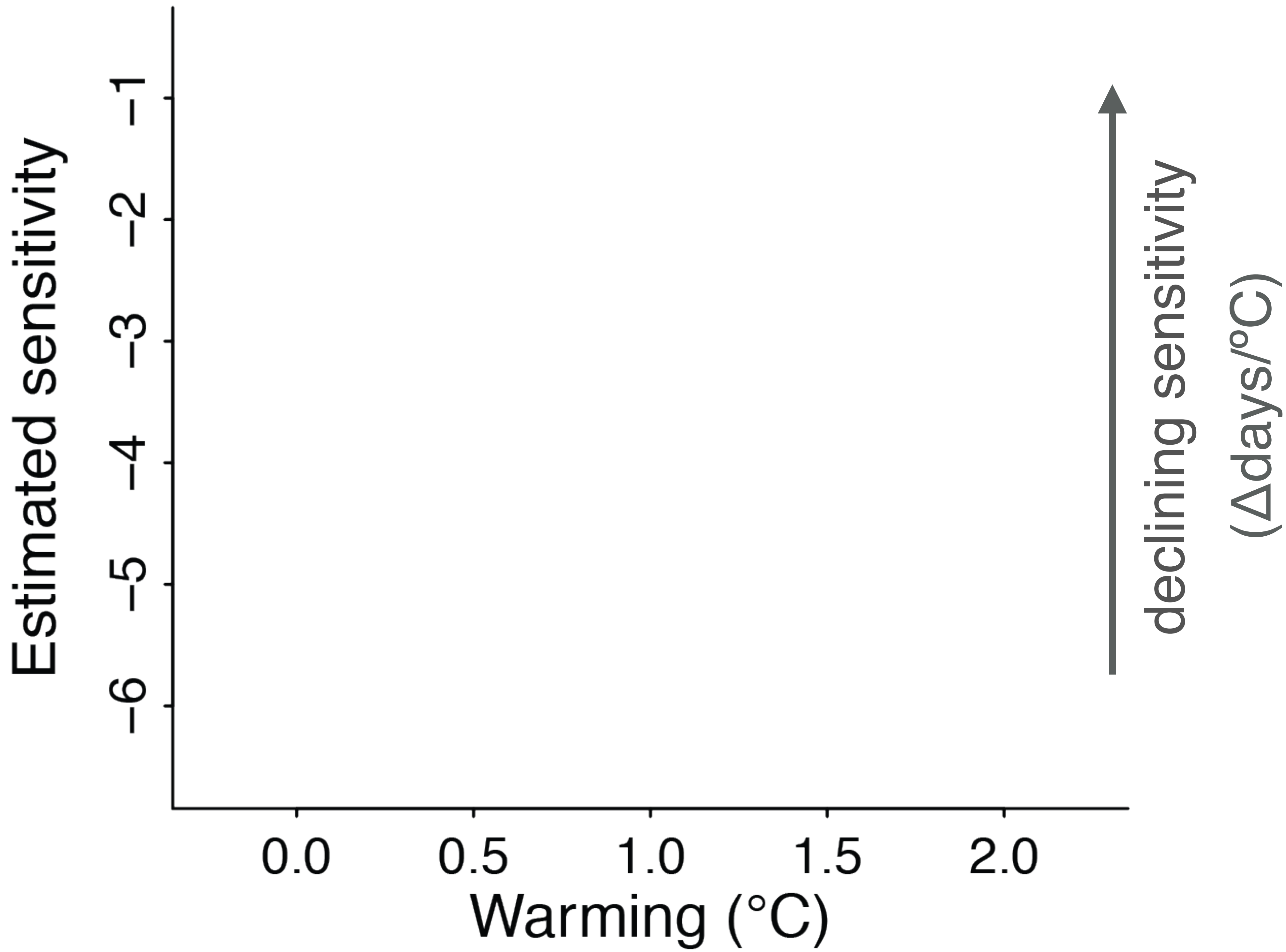
the

- Si
  dif
  temperatures

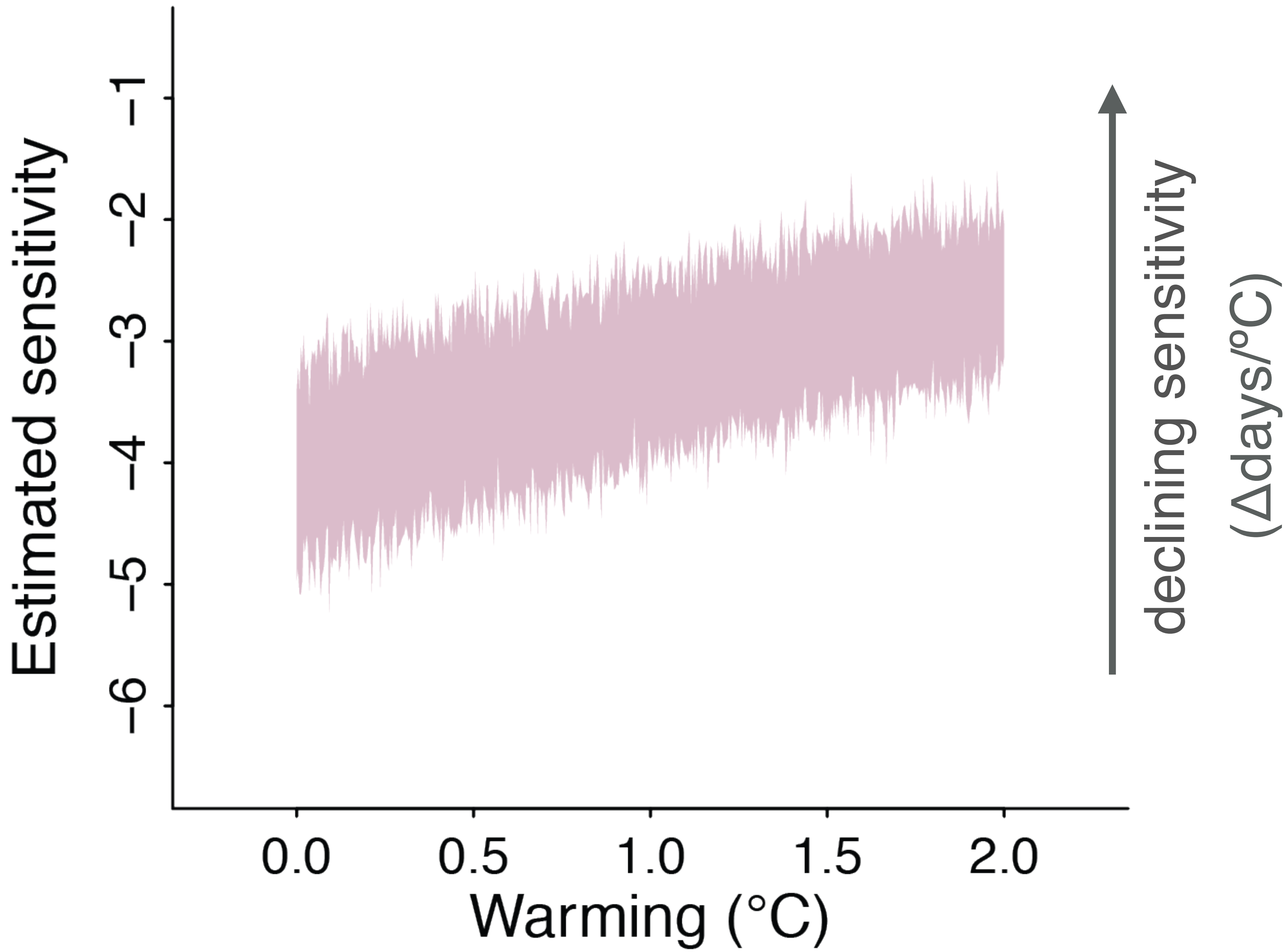




Simulations of thermal sum model

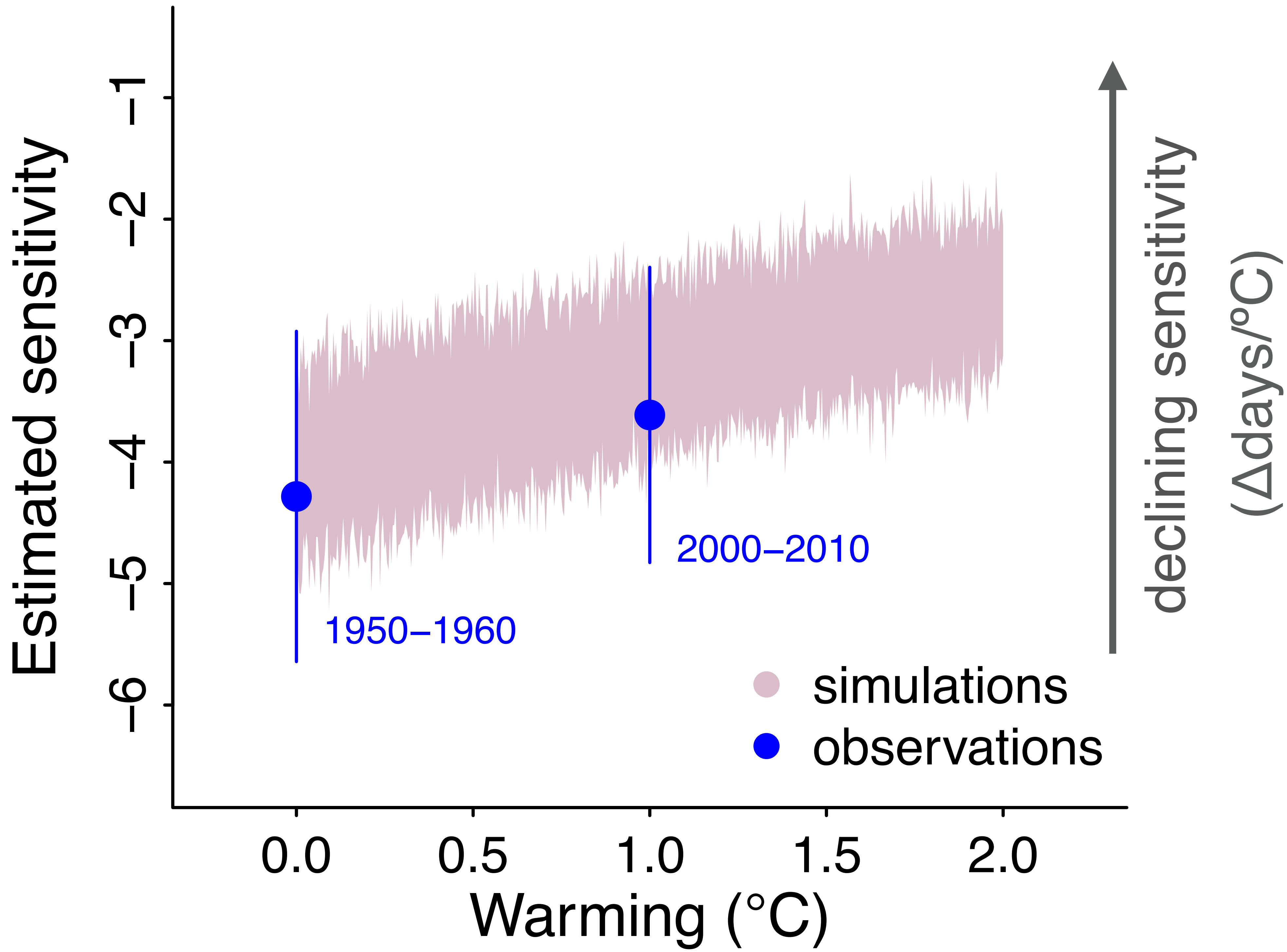


Simulations predict observed decline



Wolkovich *et al.* 2021

Simulations predict observed decline



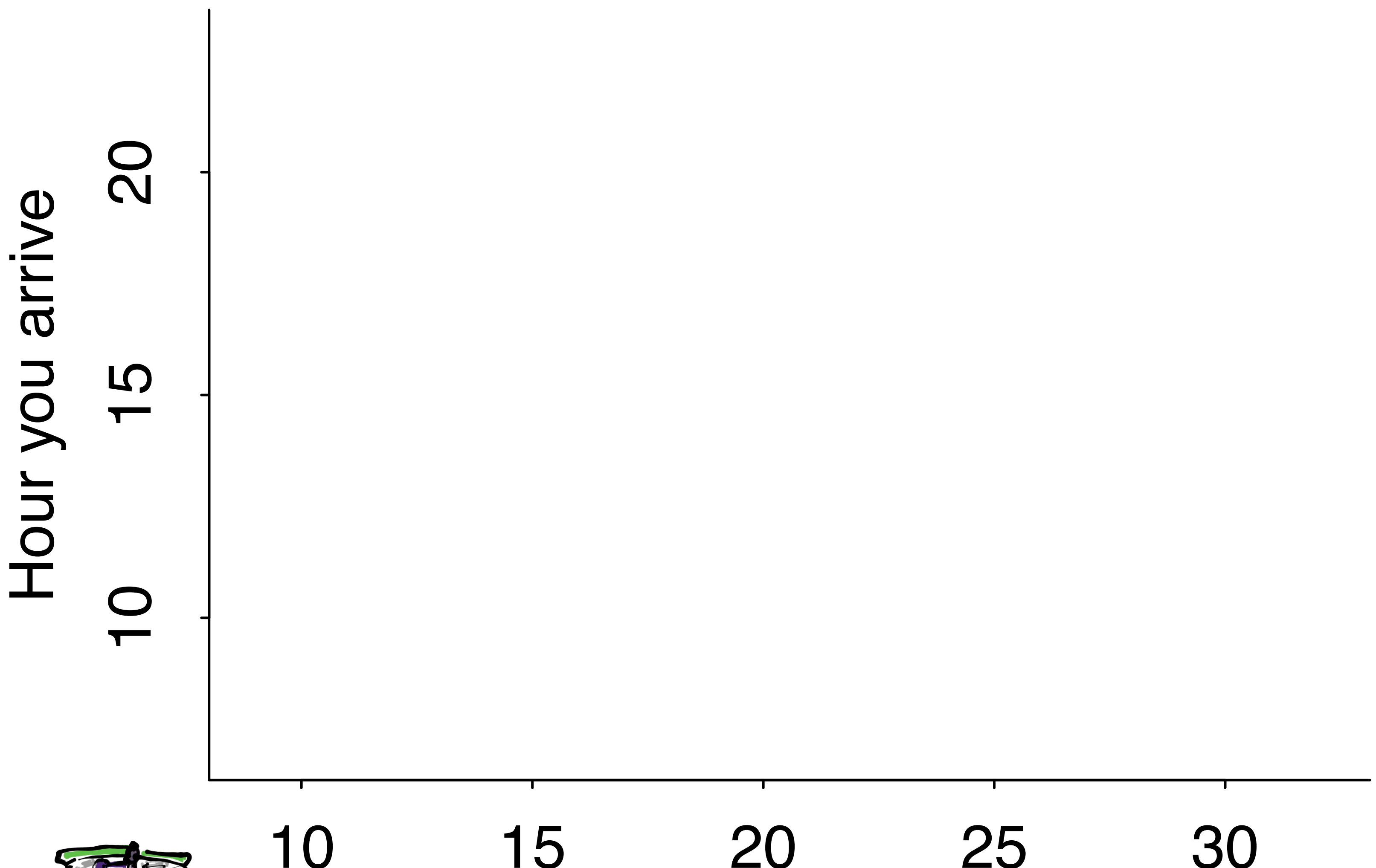
Wolkovich *et al.* 2021


Andrew
Gelman


StanCon 2017
StanCon 2017

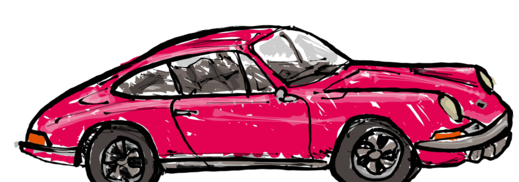

Jonathan
Auerbach

Rate dependent process



Grandma lives
200 miles away

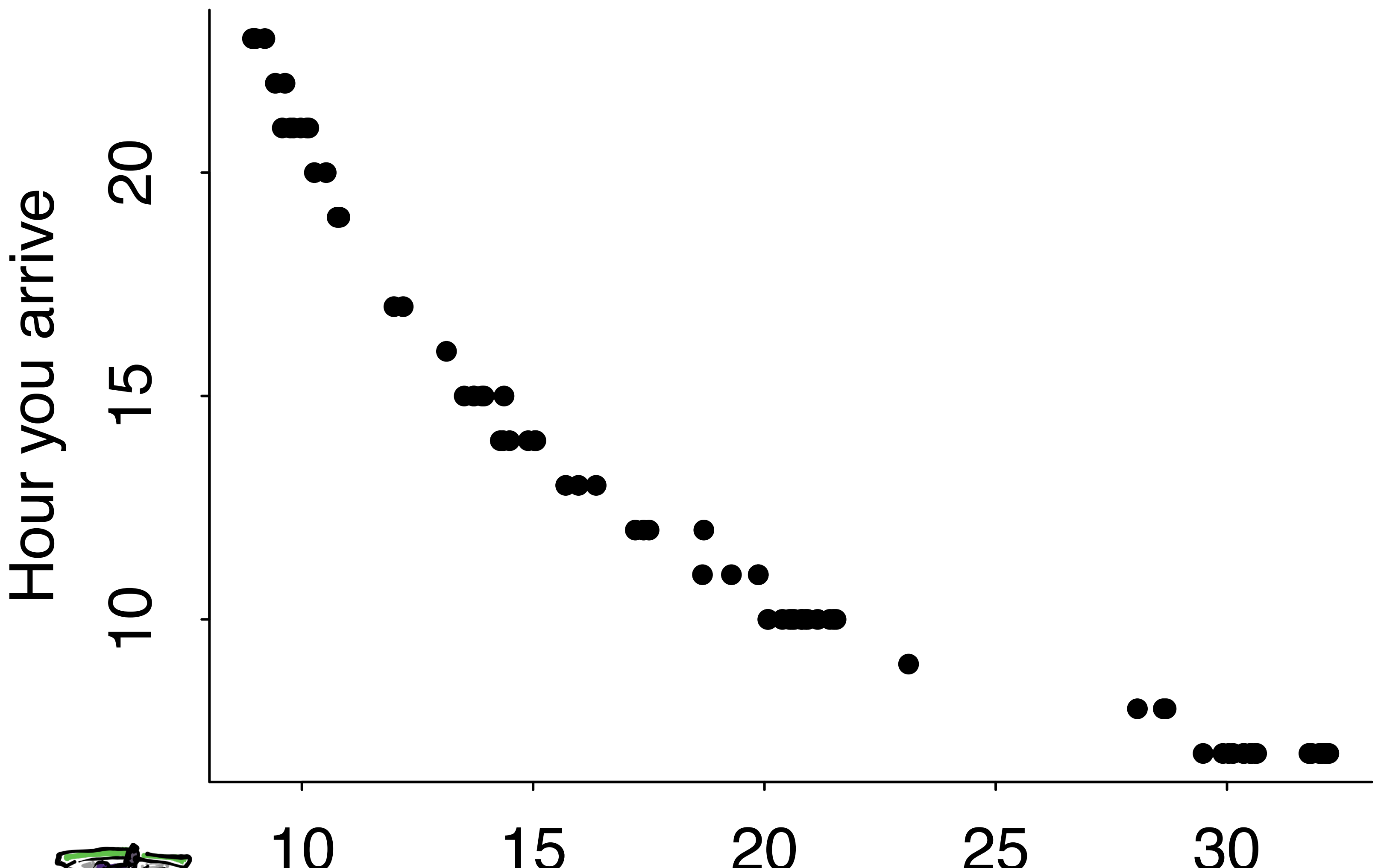
slow



fast!

Art by Faith Jones

Rate dependent process



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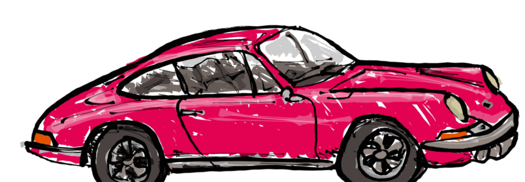
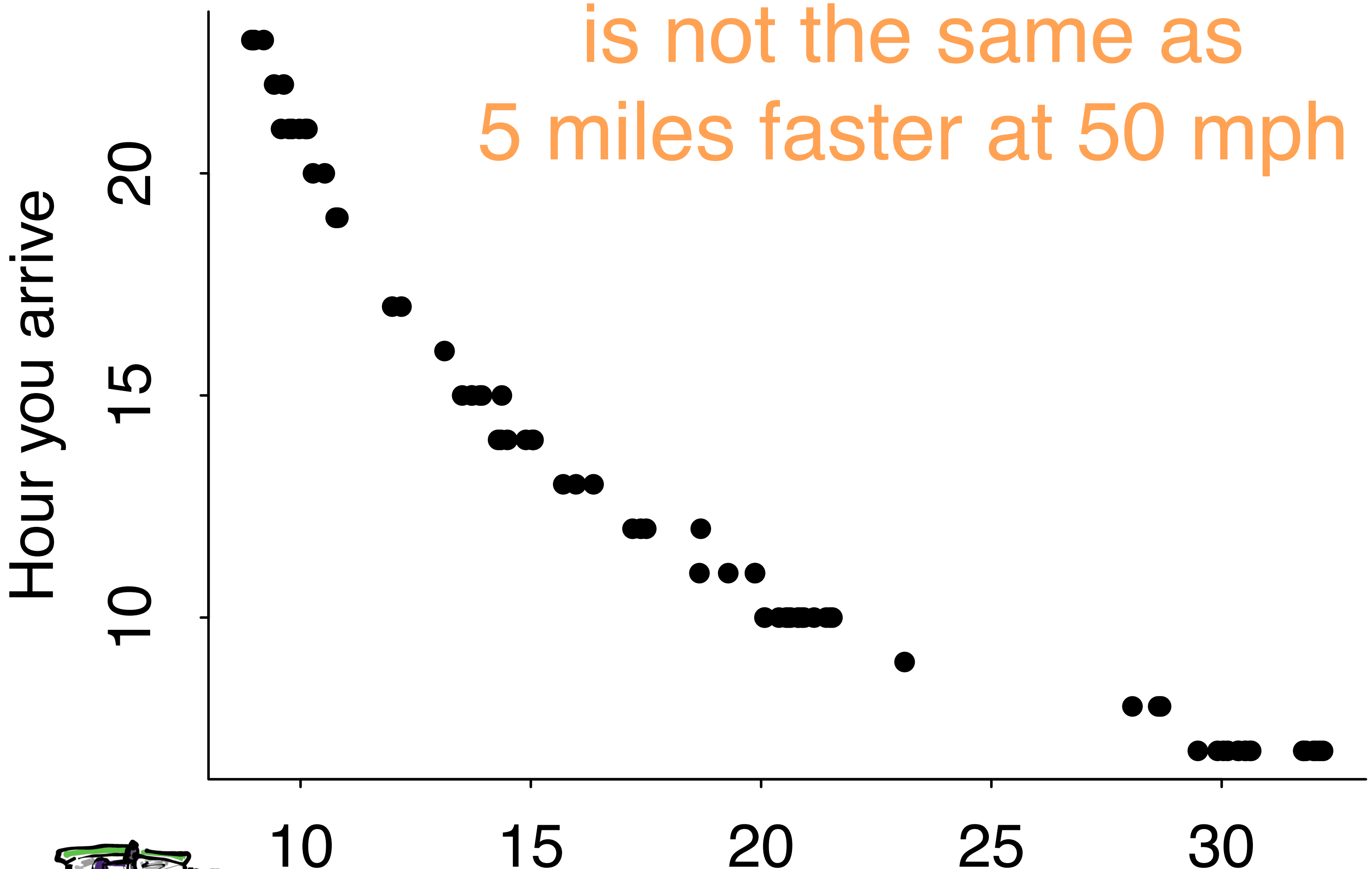


fast!

Art by Faith Jones

Rate dependent process

5 miles faster at 10 mph,
is not the same as
5 miles faster at 50 mph



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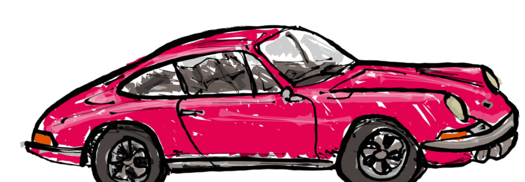
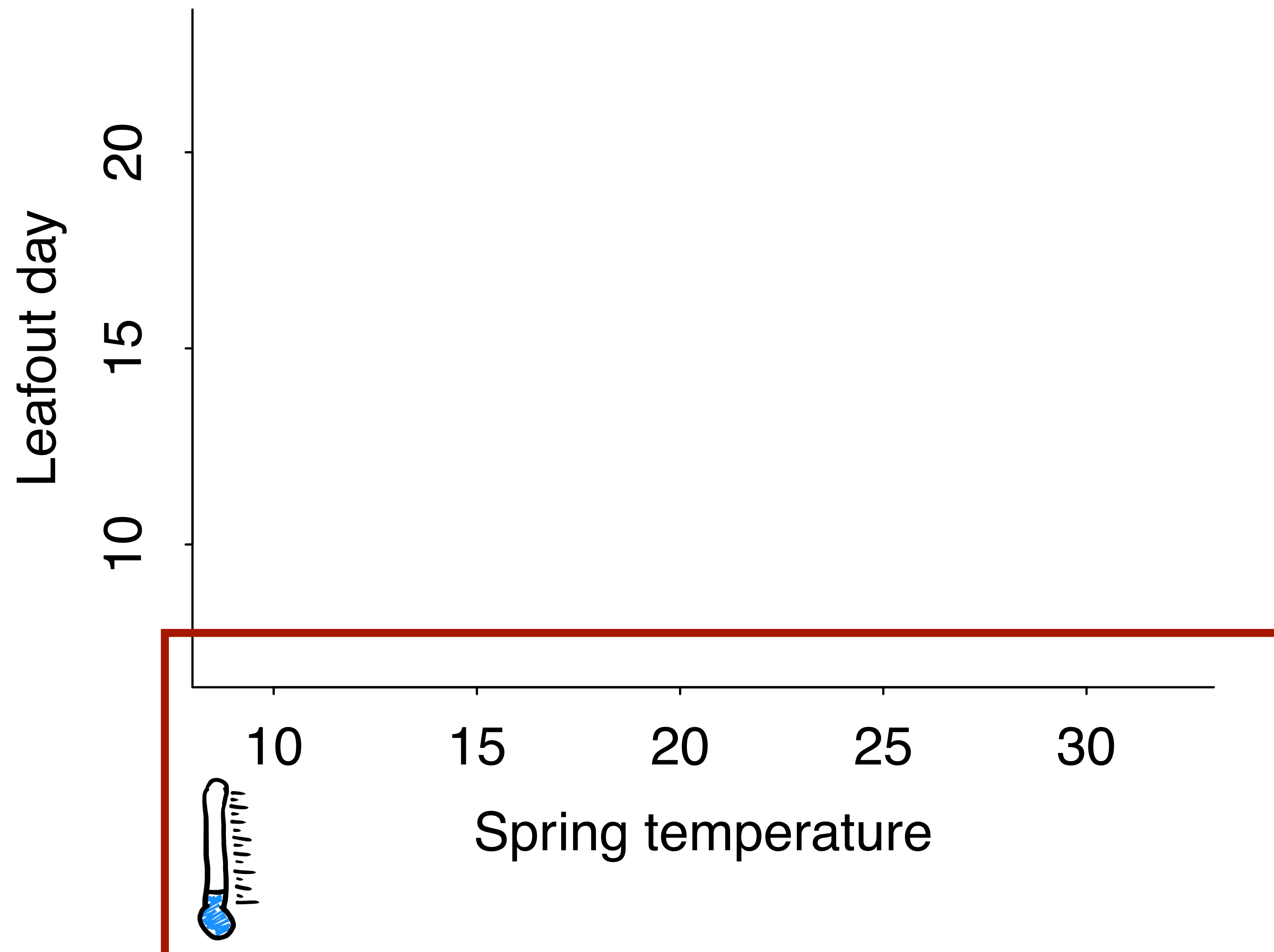


fast!

Art by Faith Jones

Leafout is rate dependent



Leafout takes
200 thermal units

Art by Faith Jones

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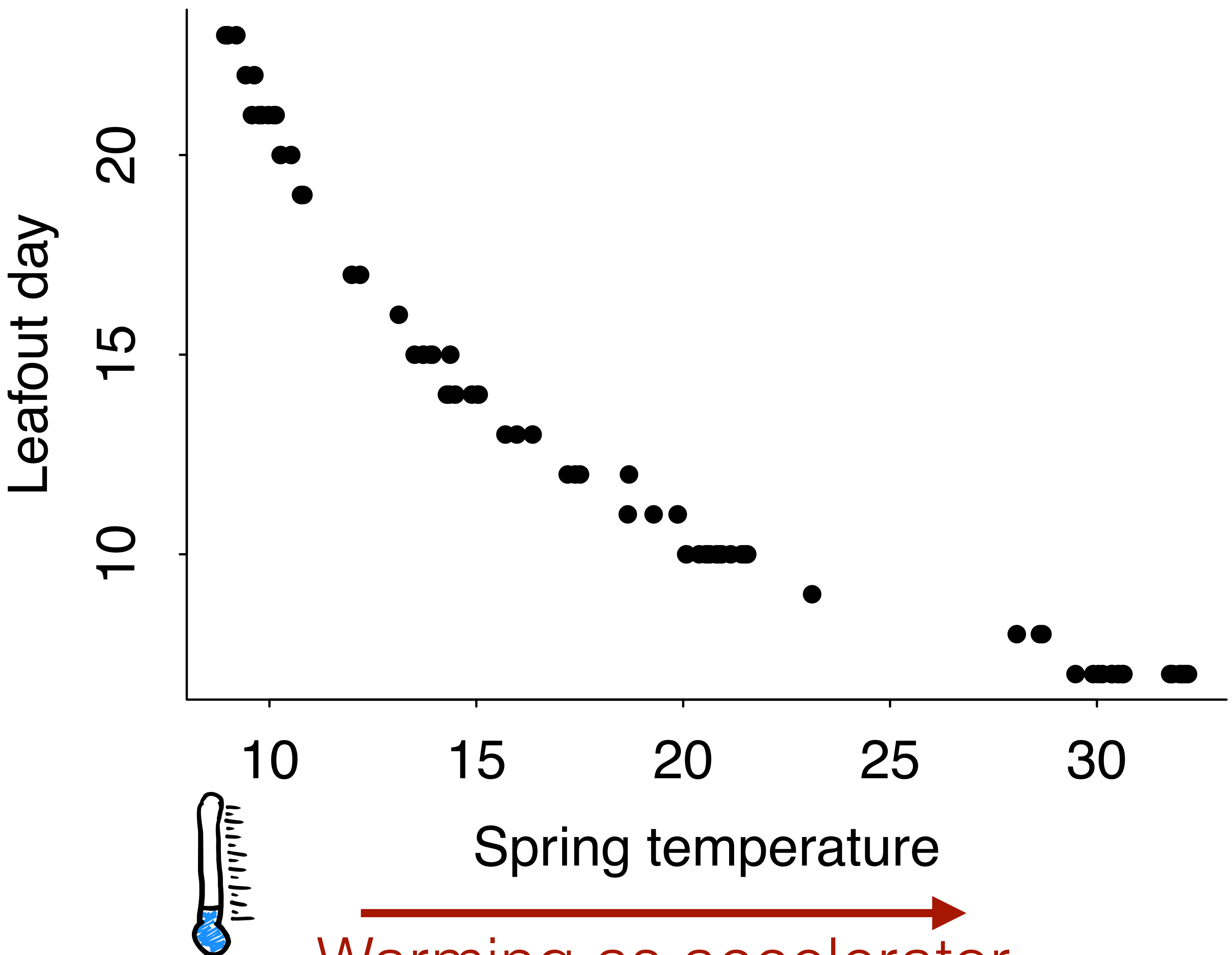

Leafout takes
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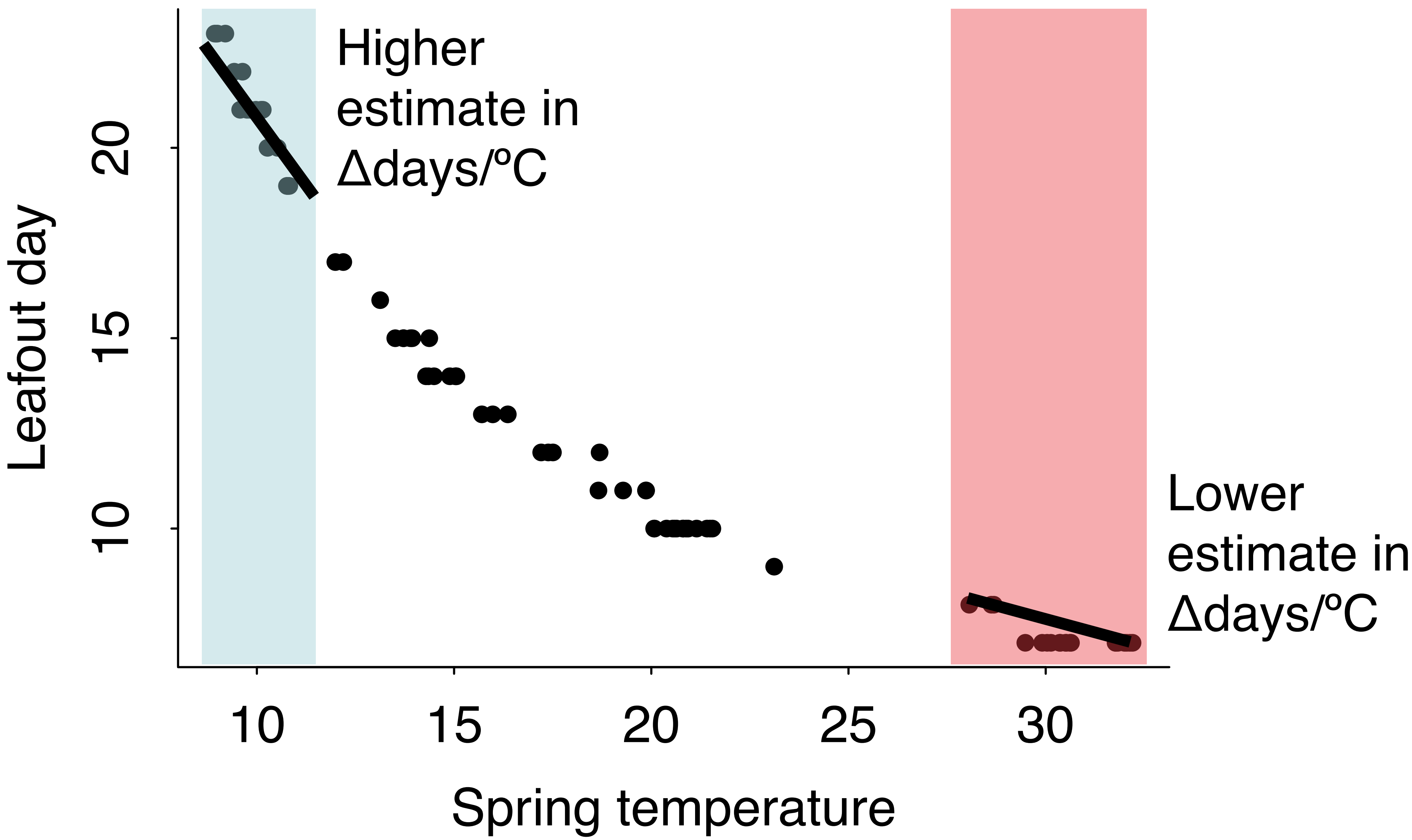
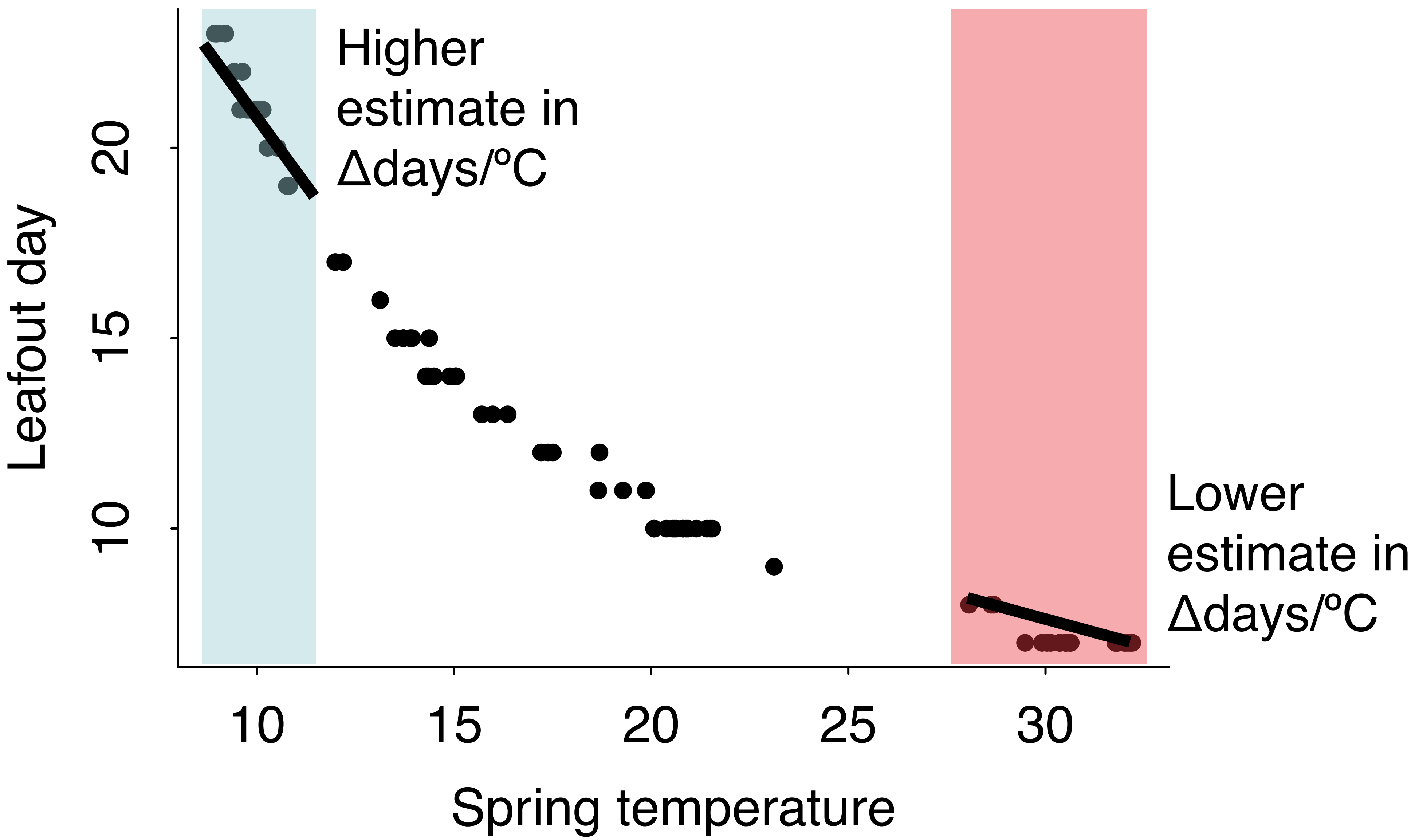
Art by Faith Jones

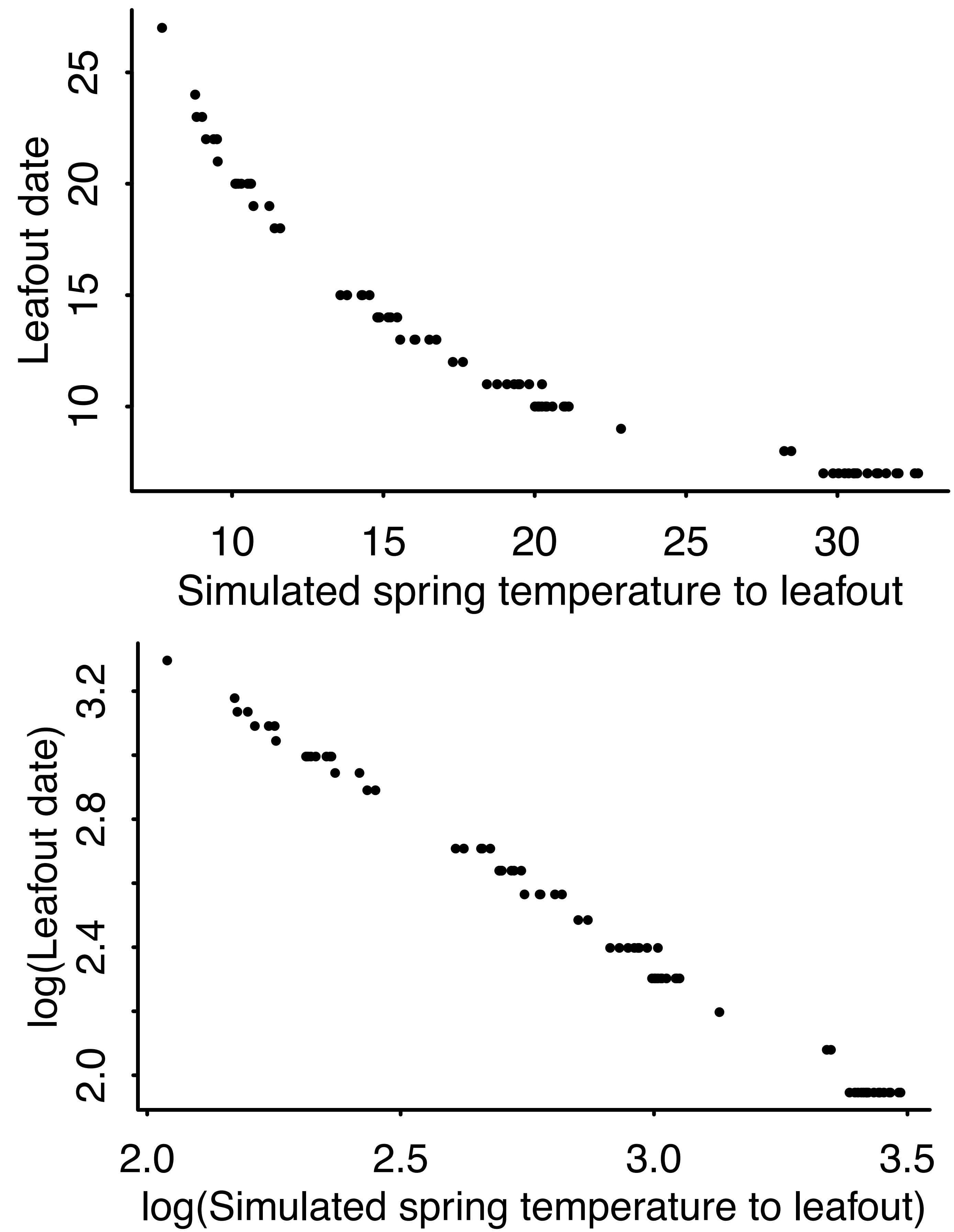
Linear approximation works only within a range

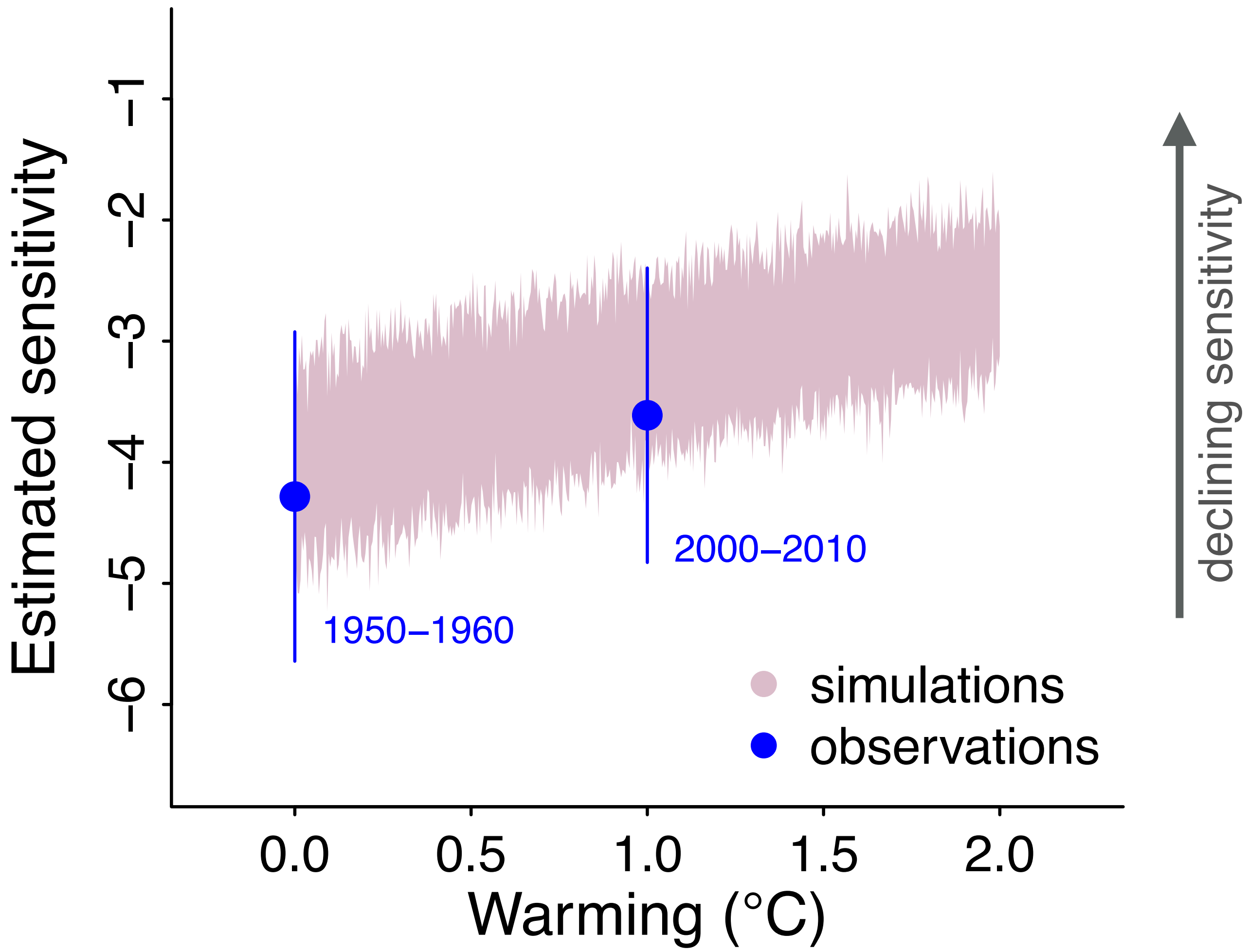


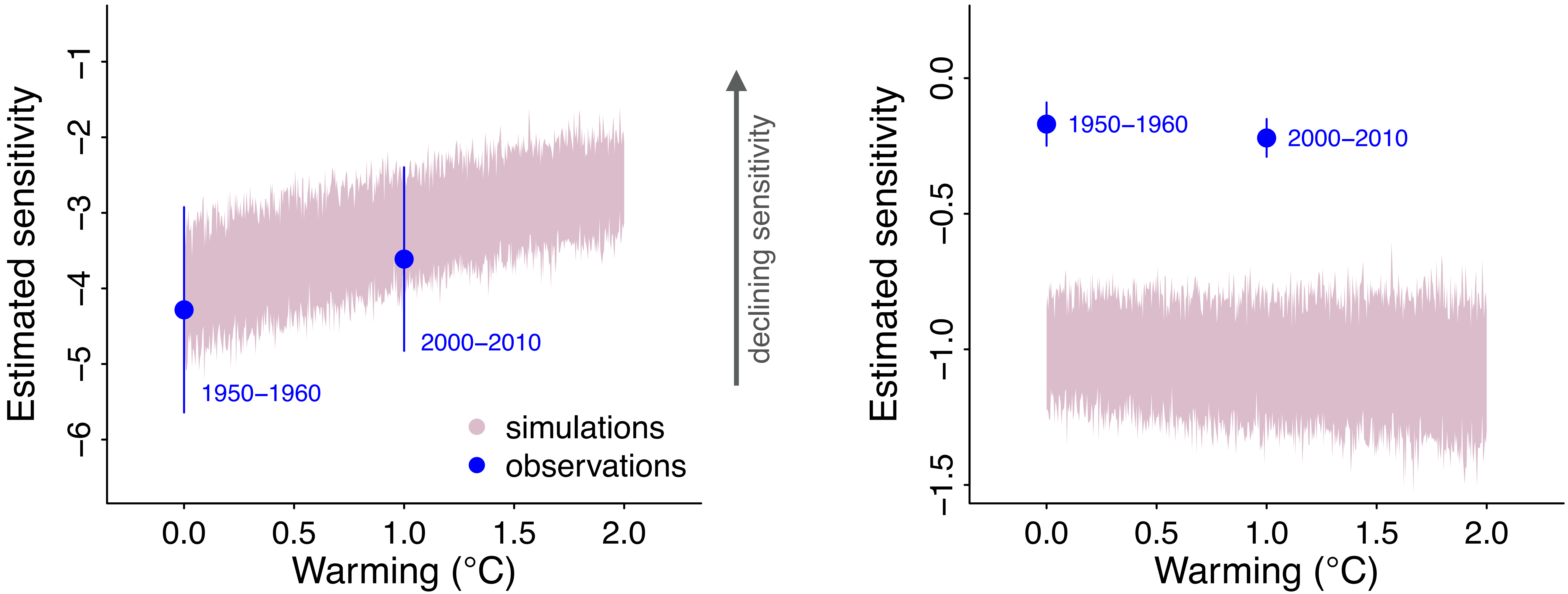
How do we address this?



Option 1: Log linearizes inverse

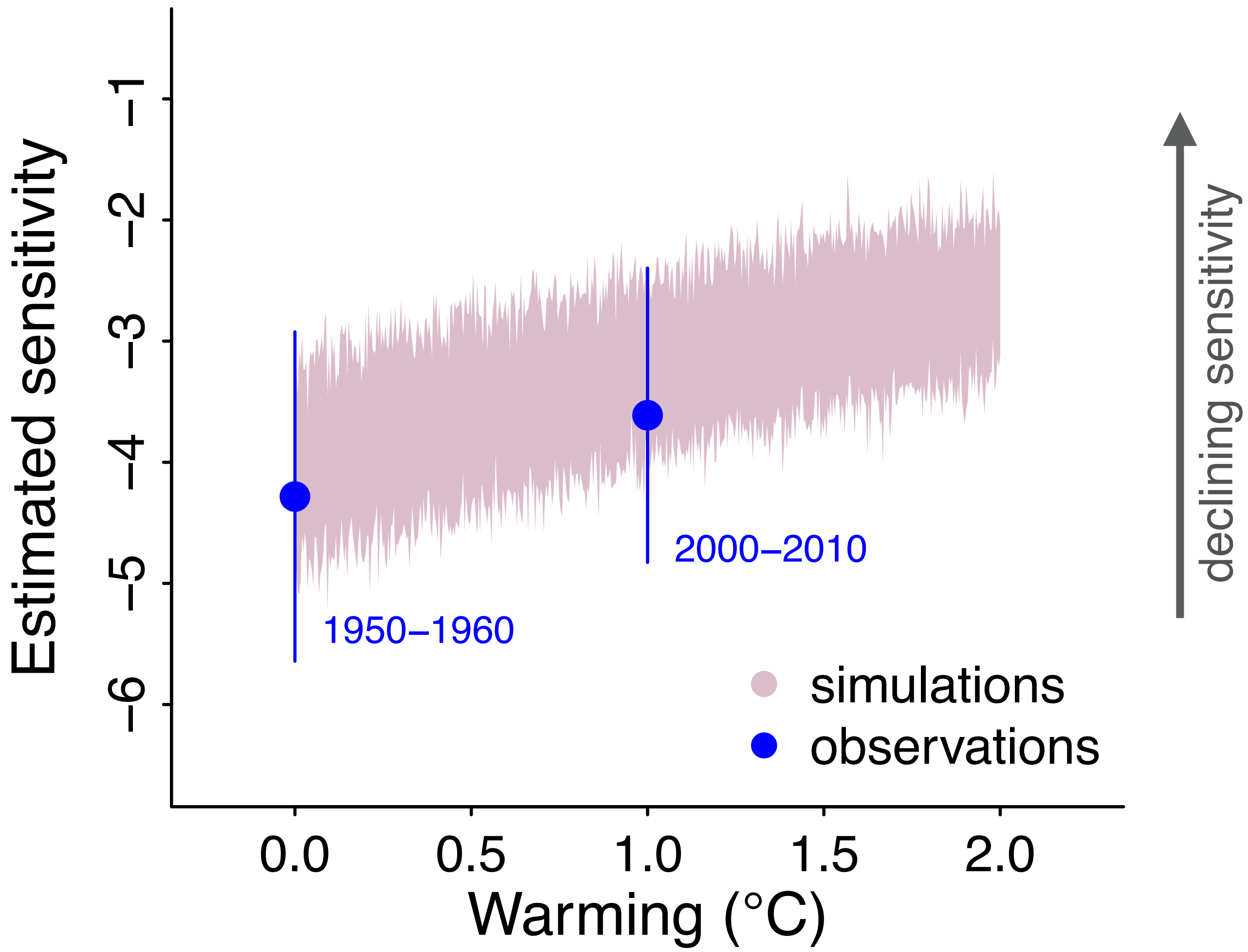


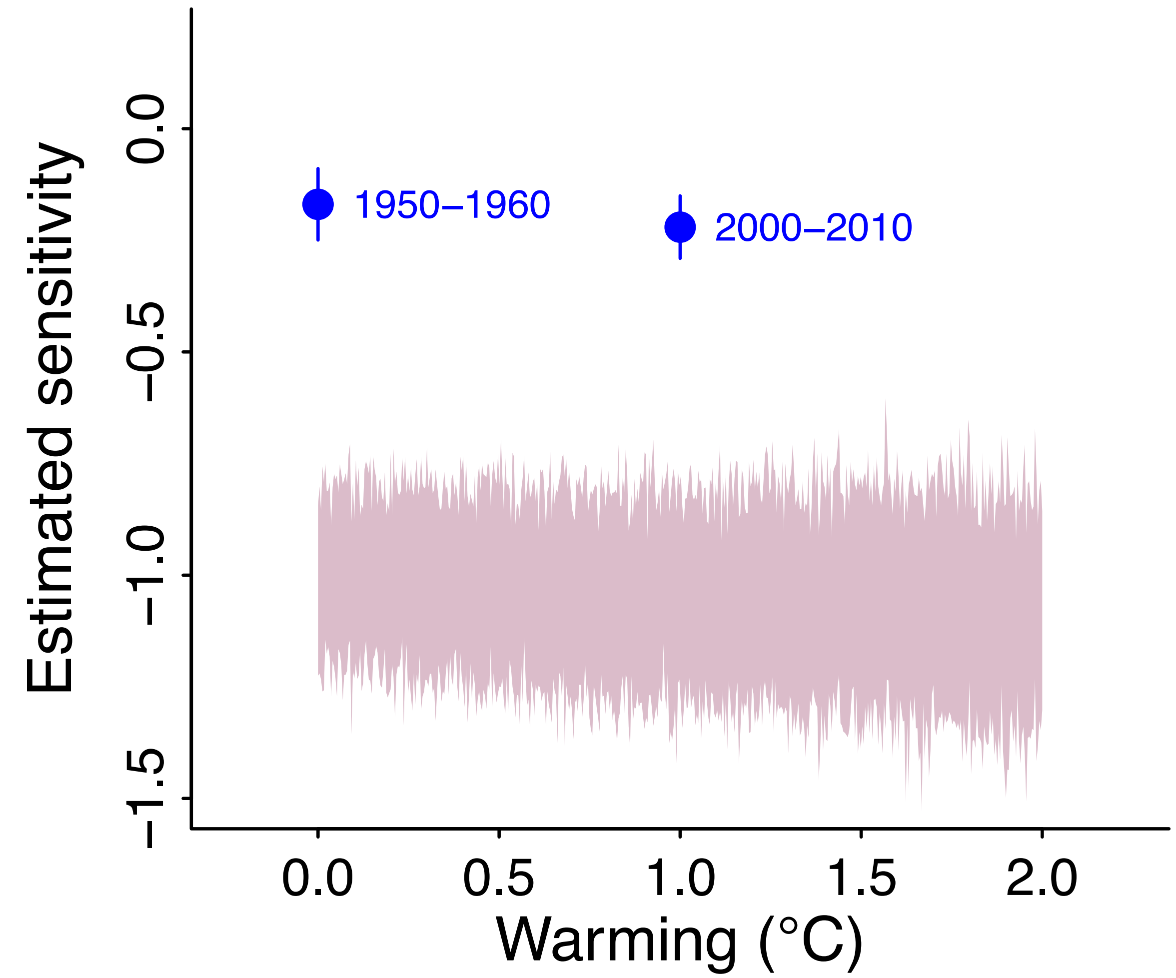

Estimated sensitivity
−1
−2
−3
−4
−5
−6
0.0
0.5
1.0
1.5
2.0
Warming (°C)
1950−1960
2000−2010
simulations
observations
declining sensitivity



Wolkovich *et al.* 2021

No evidence of decline





Wolkovich *et al.* 2021

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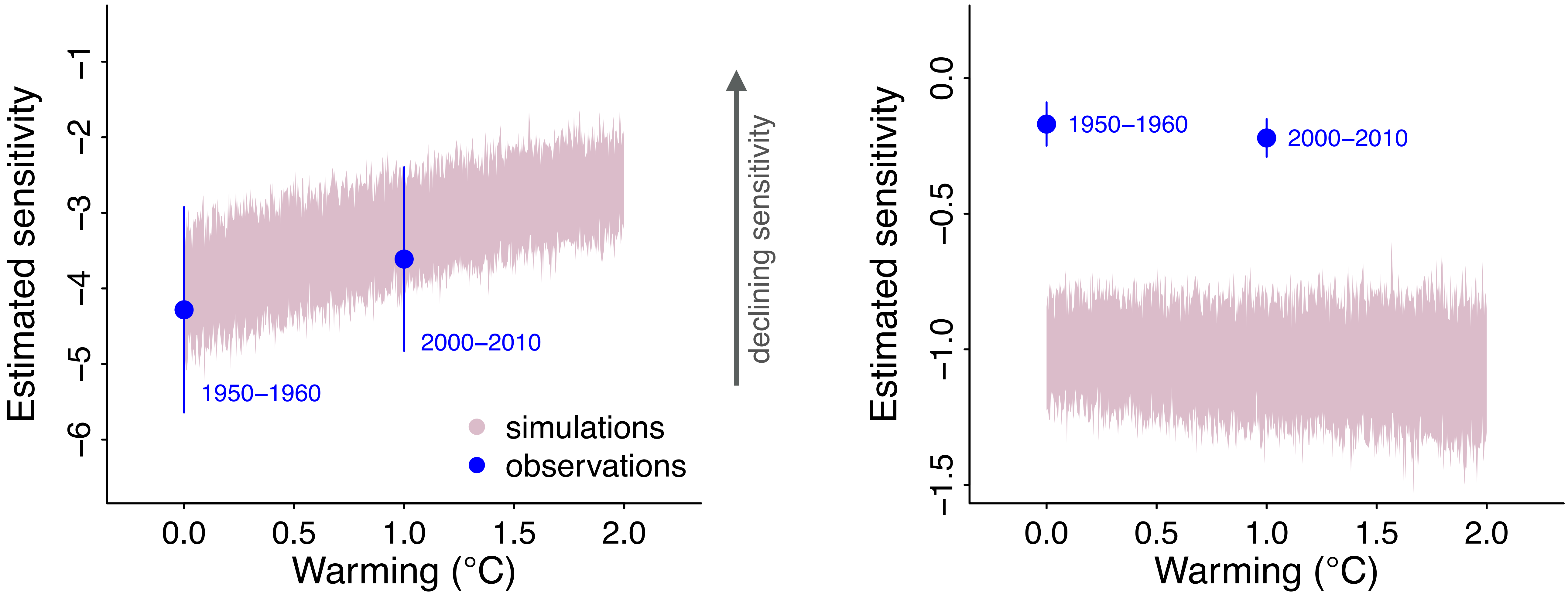

‘Declining sensitivities’ disappear with log-transformation in many long-term phenology datasets

Wolkovich *et al.* 2021

Option 2: Build a generative model

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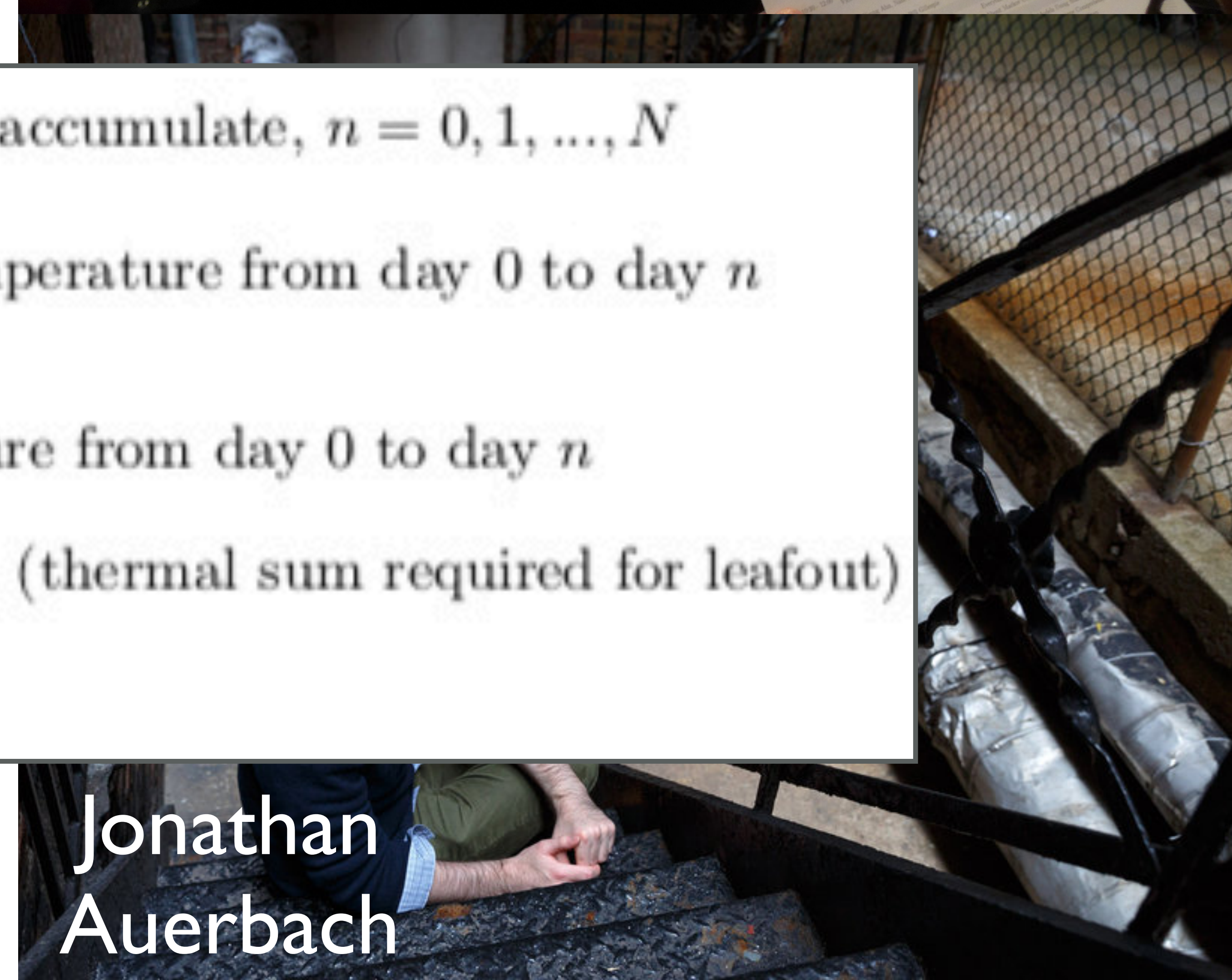
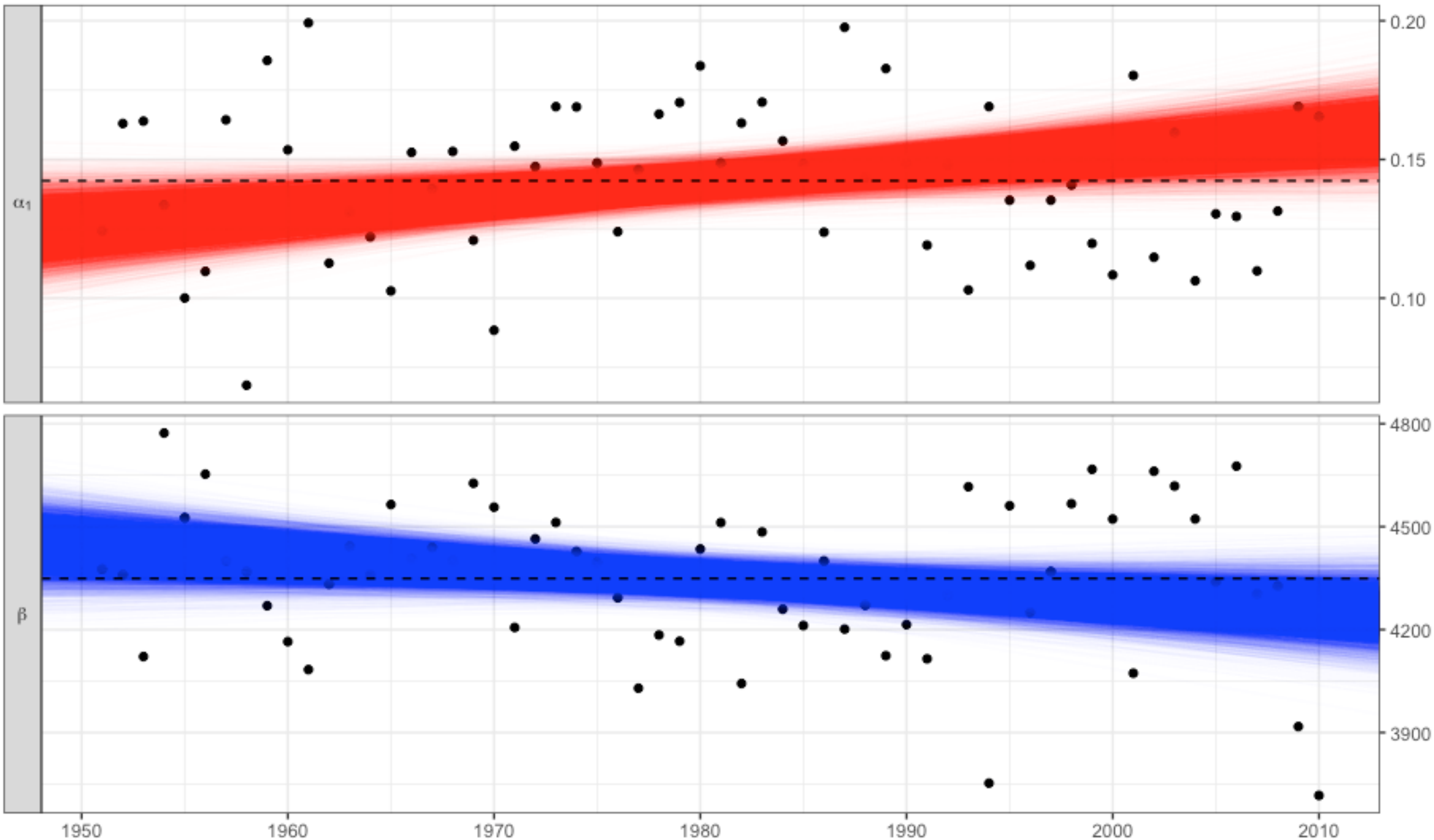
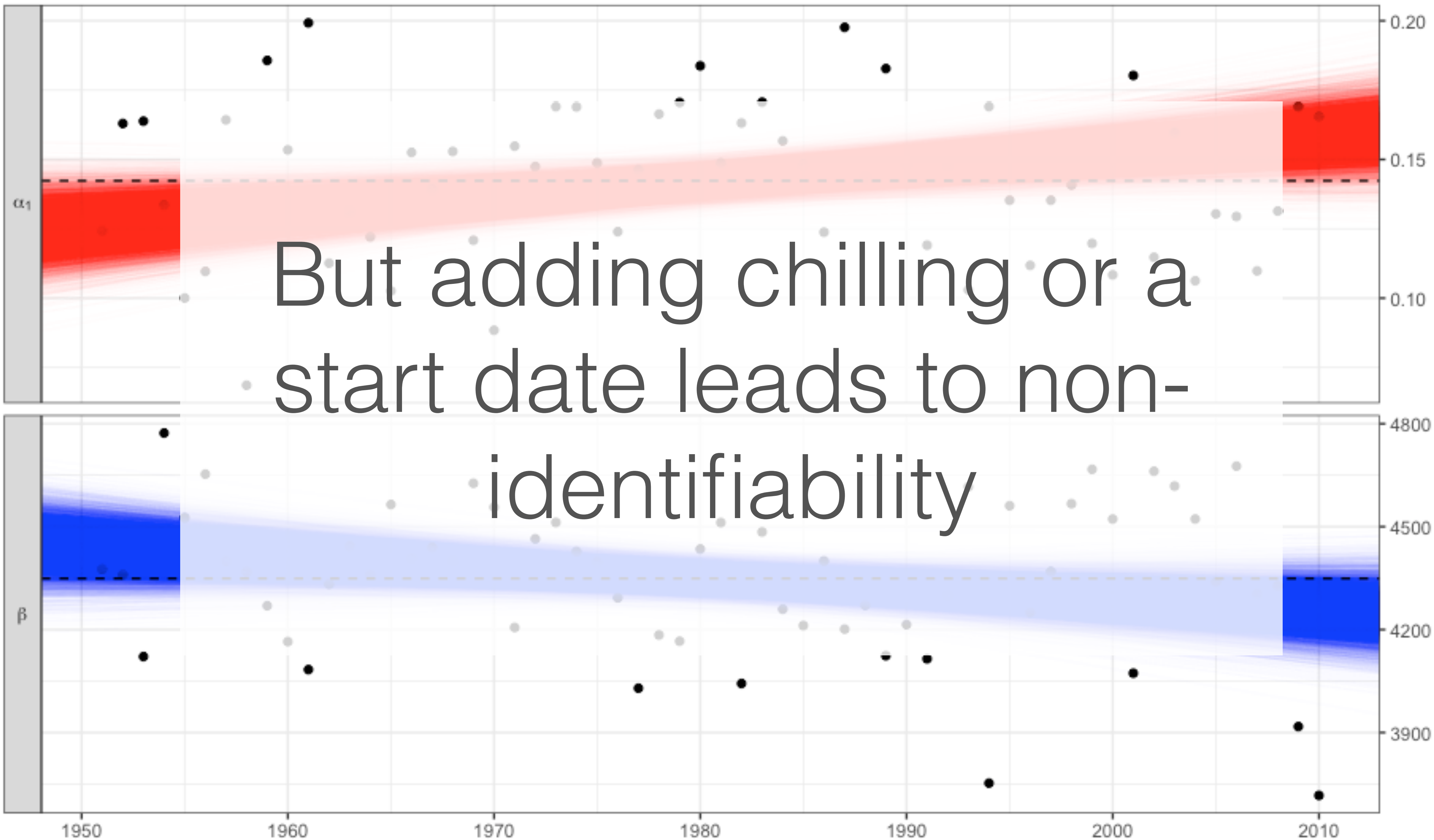


Thermal sum declining in simple model



Auerbach *et al. in prep*

Thermal sum declining in simple model



But adding chilling or a start date leads to non-identifiability

Auerbach *et al. in prep*

Questions

- Why are plant phenological responses to climate change slowing down?
    - Because biological time has sped up (but calendar time has not)
- How can we better predict these changes?

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- Why are plant phenological responses to climate change slowing down?
  - Because biological time has sped up (but calendar time has not)
- How can we better predict these changes?

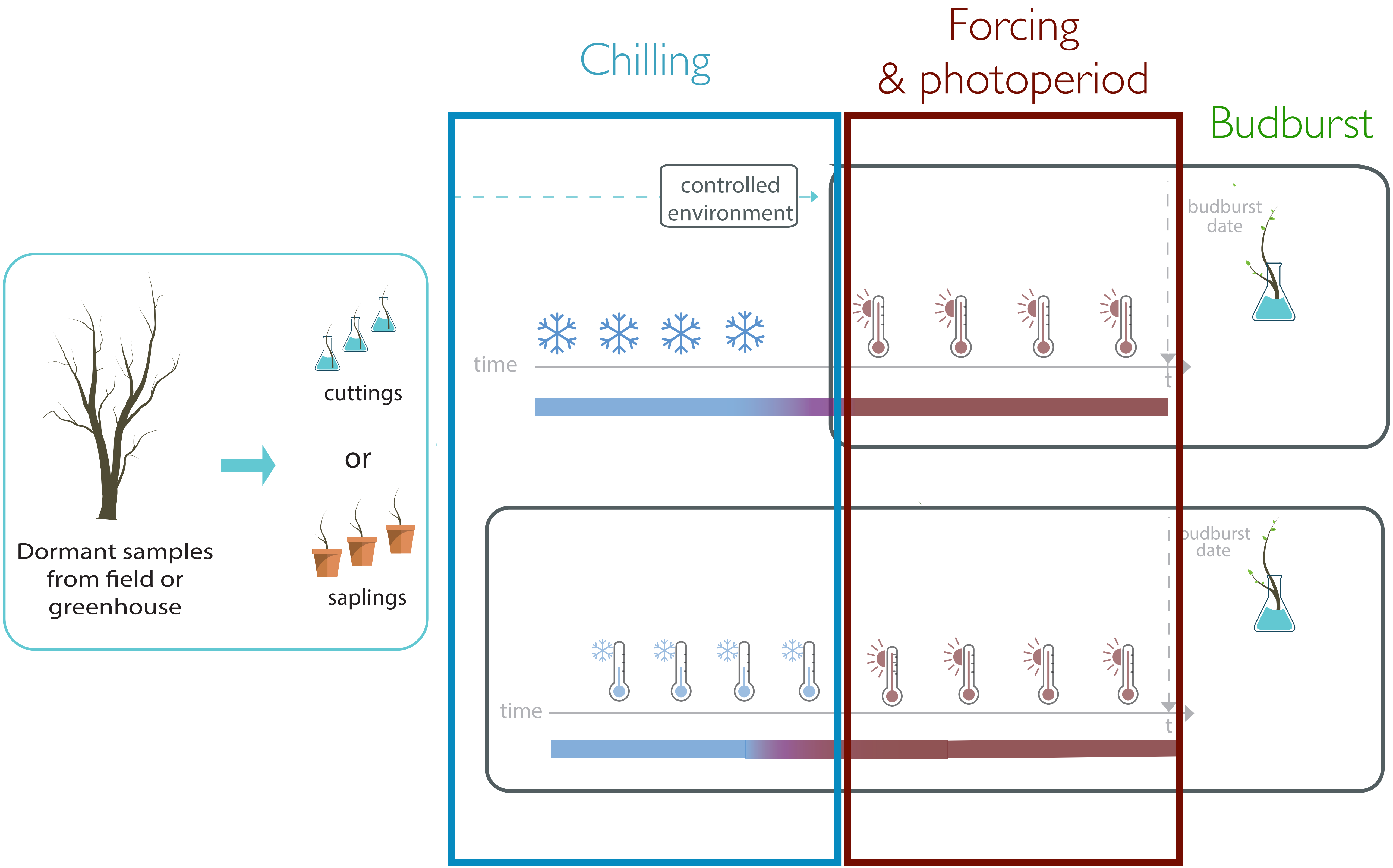
How do we address this? (Easier)

- Always compare to simpler models
- Test multiple metrics
  - GDD, days/°C
  - Variance

Wolkovich *et al.* 2021


Latent
‘chilling’ &
‘forcing’
LI-820

Waiting for physiological advances



Ettinger *et al.* 2020

How do we address this? (Harder)

- Test for and report non-identifiability
- Simulate data
- Model experiments and observational together
- Race the same data

How do we address this? (Harder)

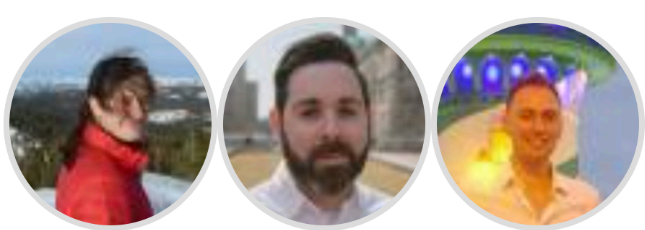
George Mason University | Statistics

Cherry Blossom Peak Bloom competition

George Mason's Department of Statistics is pleased to announce its first ever prediction competition:

When will the Cherry Trees bloom in Washington D.C.?

Contestants will submit their predictions for D.C. and two other cities, along with a compelling narrative and reproducible analysis containing any data or code used. Complete entries will be eligible to win more than $5,000 in cash and prizes—based on categories such as best prediction, best model, and best narrative. See the complete competition rules for details.



https://competition.statistics.gmu.edu/


Questions?