A model of the inter-individual variability of leaf out that predicts frost damage in temperate deciduous tree populations

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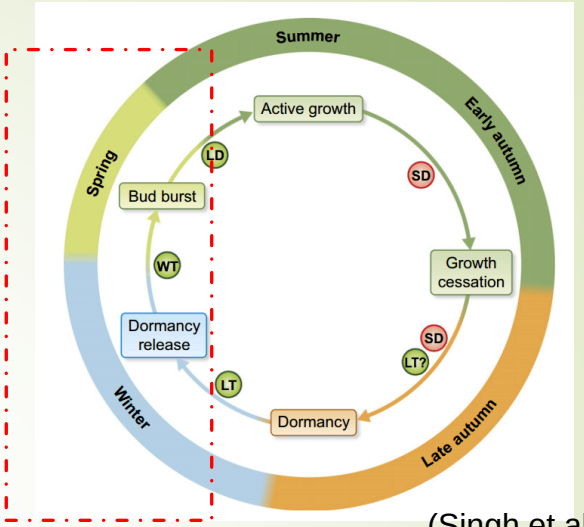
01 introduction

Phenology is the study of recurrent biological events



(Singh et al. 2017)

Current research status:

- Focus on the inter-annual and inter-population variability
- Focus on the average date of spring phenology (e.g. leaf out, flowering)

→ **Few studies considering the variability within population**

Goal 1:

- Construct a model to simulate the within-population variability of leaf out (WPV model)

Within-population variability of leaf phenology is large

- typically from 1 to 3 weeks

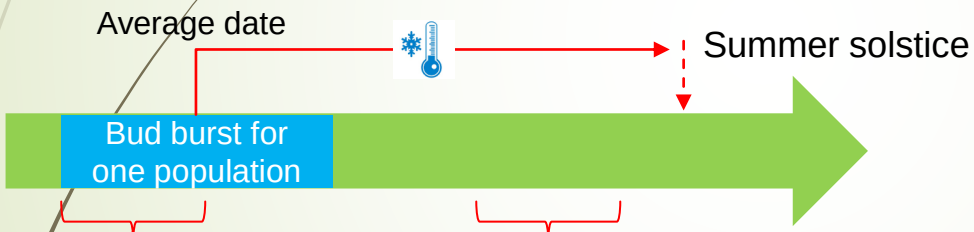
01 introduction

With the climate warming

Advanced spring phenology

Freezing events

Possibility of frost damage



1. Frost damage occurs in early trees

2. Frost resistance

3. The extent of frost damage

Goal 2:

- Evaluate the ability of our model for predicting frost damage and retrospect frost damage in past 61 years

02 Material and method

Phenology dataset

OBF dataset (observed and recorded by ourselves)

Site: Orsay, Barbeau and Fontainebleau

Date: 2000 to 2021

Species: Oak (Chêne, *Quercus Petraea*)

Beech (Hêtre, *Fagus sylvatica*)

Ash tree (Frêne, *Fraxinus excelsior*)

Chestnut (Châtaignier, *Castanea sativa*)

Hornbeam (Charme, *Carpinus betulus*)

- Observe the stage of bud burst in individual tree crowns
- Observation completed after at least 50% bud burst

Temperature dataset

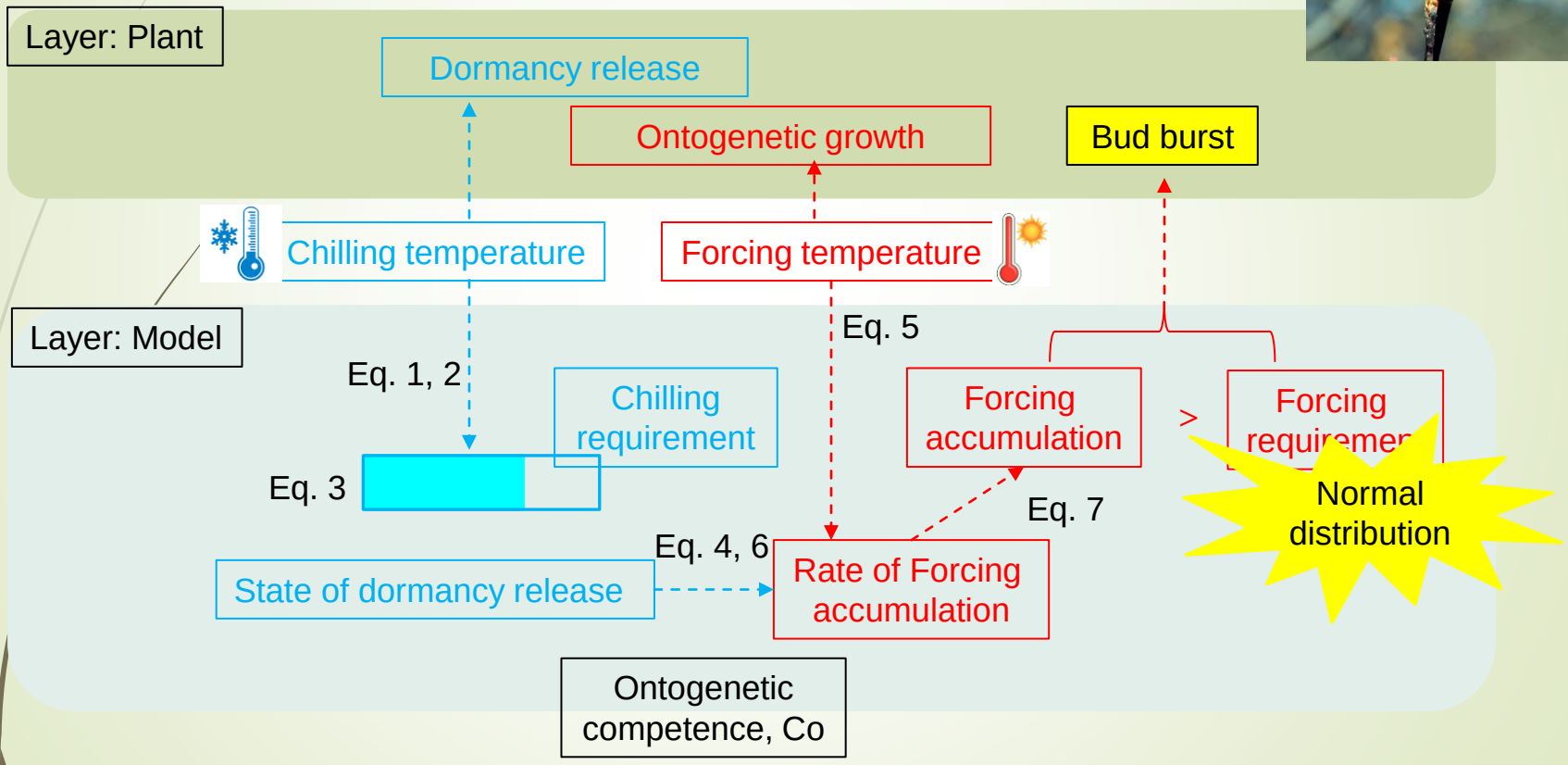
Local meteorological data
(Gometz, Barbeau, Melun)

Obtained from the nearest meteorological station

02

Material and method

Parallel model of bud burst for one tree



02 Material and method

Chilling phase

$$Rc = \begin{cases} 1, & Tmean < Tbc \\ 0, & Tmean \geq Tbc \end{cases}$$ Eq. 1

$$Ctot = \sum_{d=270}^{i} Rc$$ Eq. 2

$$Sr = Ctot/Ccri$$ Eq. 3

$$Co = g \times Tmean + h + Sr * (1 - h)$$ Eq. 4

Rc: rate of chilling accumulation
Tbc: threshold of chilling temperature
Ccri: chilling requirement
Sr: state of chilling accumulation
Co: ontogenetic competence
Rf,pot: potential rate of forcing accumulation
Rf: true rate of forcing accumulation
Tb: threshold of forcing temperature
F*: threshold of forcing requirement

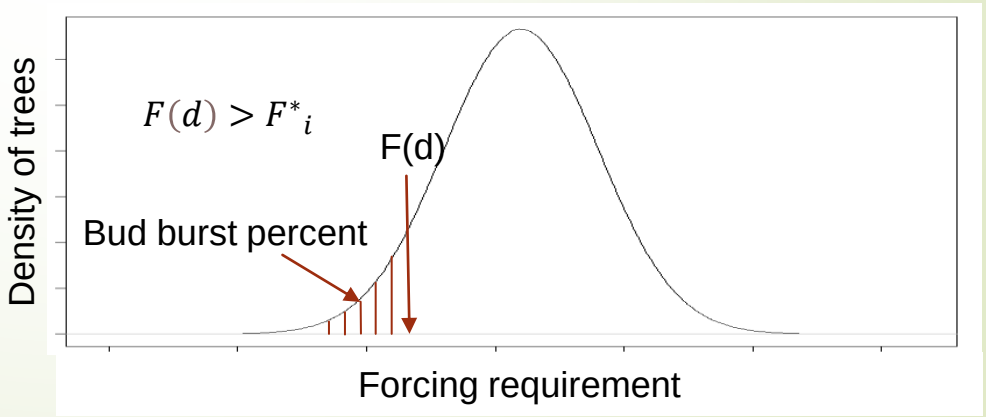
Forcing phase

$$Rf_{pot} = \begin{cases} 0, & Tmean < Tb \\ Tmean - Tb, & Tmean \geq Tb \end{cases}$$ Eq. 5

$$Rf = Rf_{pot} * Co$$ Eq. 6

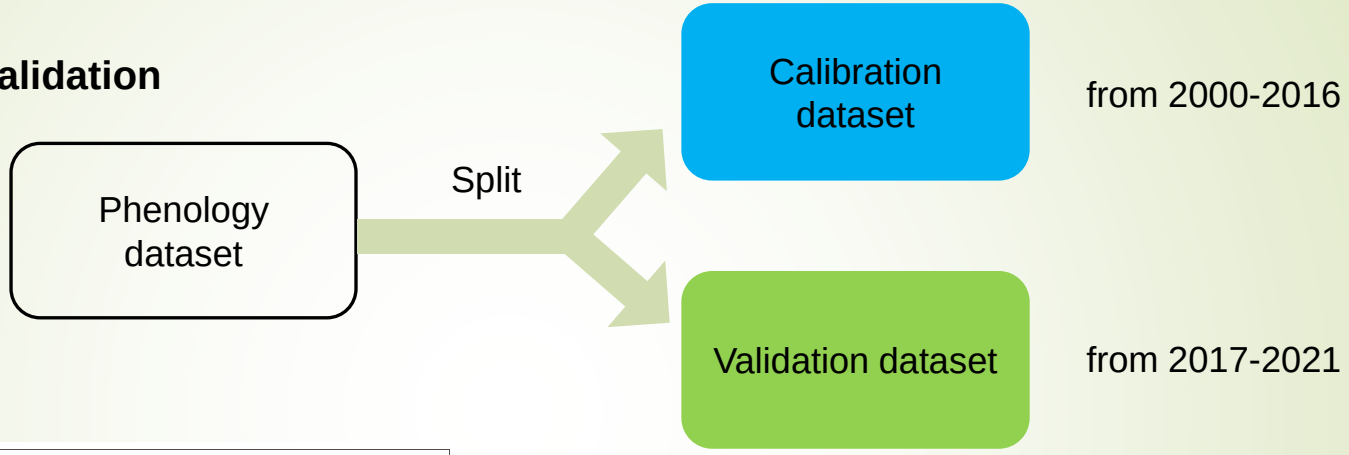
$$F(d) = \sum_{d}^{i} Rf$$ Eq. 7

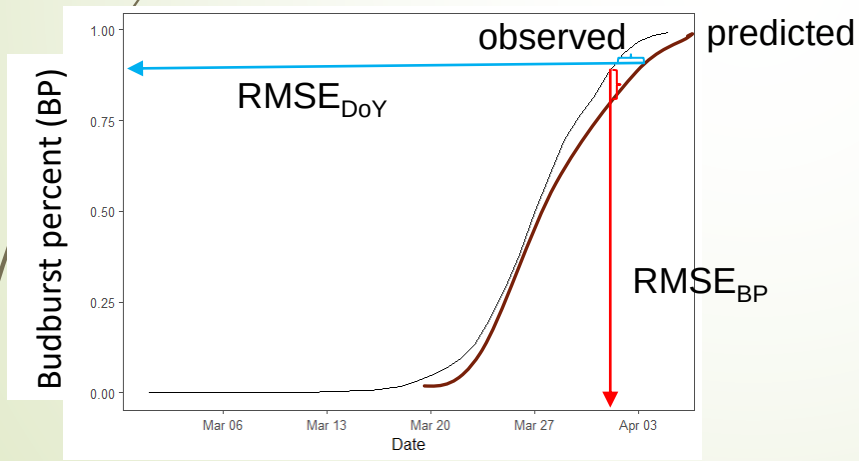
$$F^* = (\mu, \sigma^2)$$ Eq. 8



02 Material and method

Model validation





Method of RMSE calculation:

- RMSE$_{BP}$: calculate the difference of BP at the same date
- RMSE$_{DoY}$: calculate the difference of DoY at the same BP

02 Material and method

Frost prediction

How to define frost damage:

- It is assumed that there is frost damage if freezing temperature occurs within 25 days after bud burst

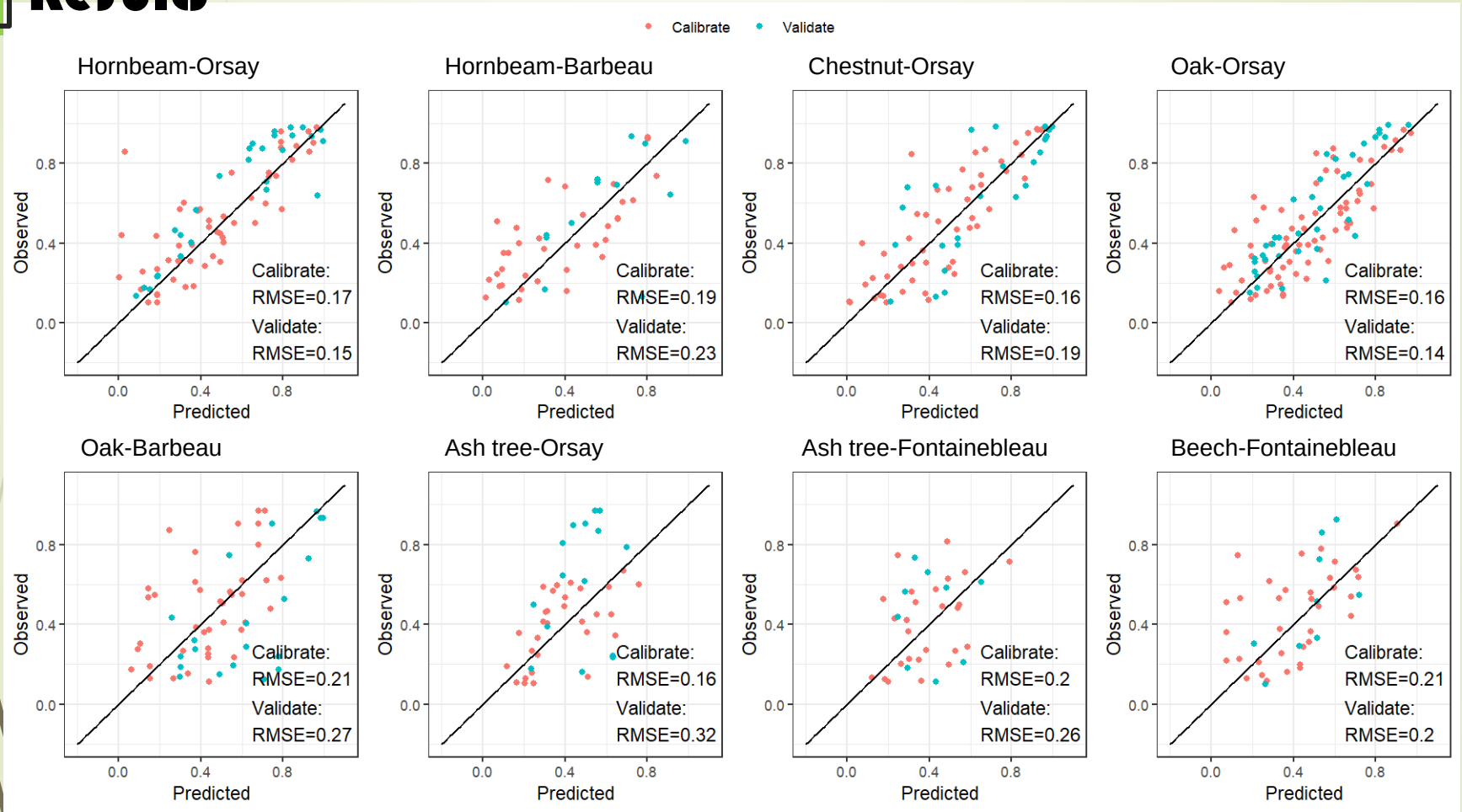
Frost temperature:

Species	Frost temperature/^{o}C	Reference
Oak - Adult tree	-3	Observed in 2021 in Orsay
Oak - Young tree (<11 years)	-1.2	Observed in 2017 in Toulenne

03

Results

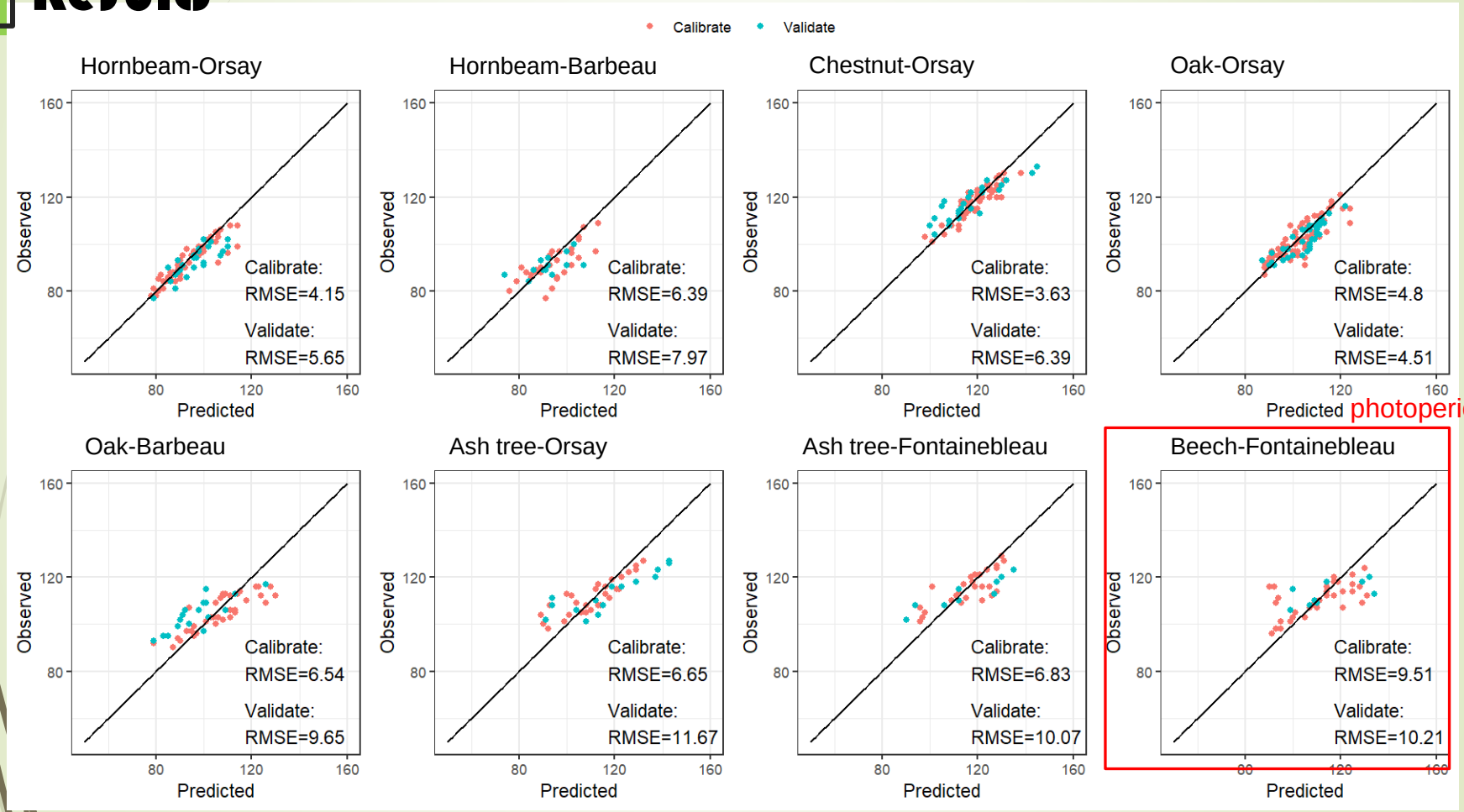
WPV model evaluation over validation data—Budburst Percent



03

Results

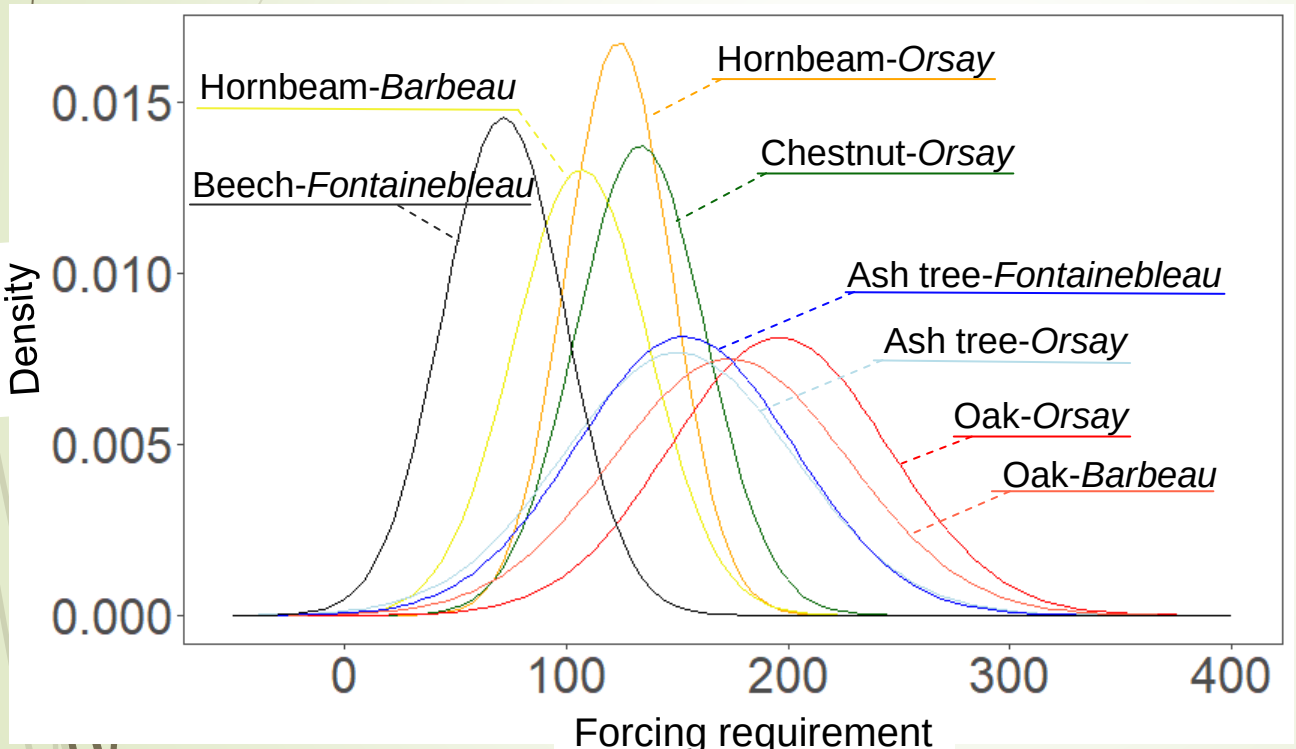
WPV model evaluation over validation data--DoY



photoperiod

03 Results

The distribution of F* for different species

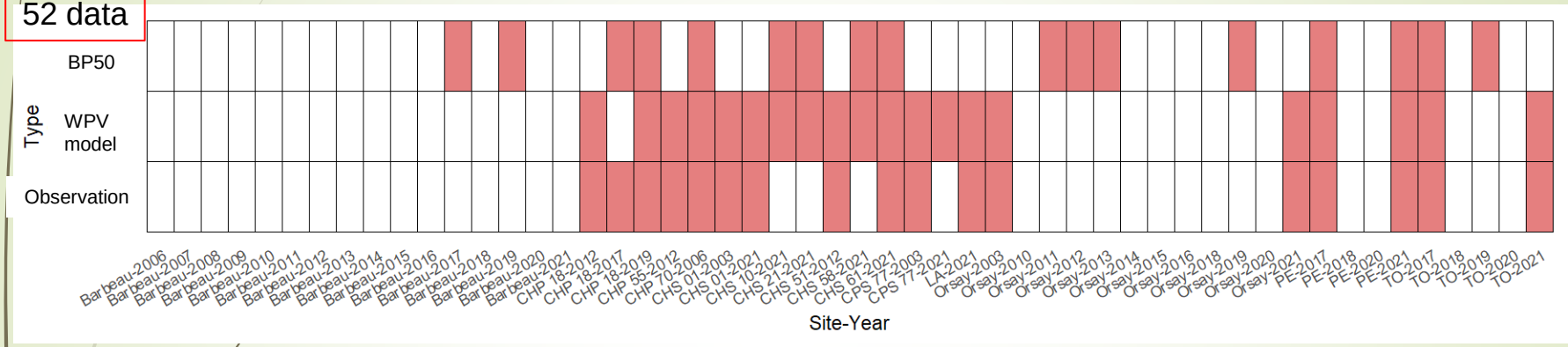


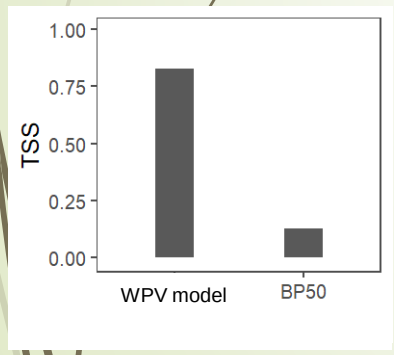
- The different species have different forcing requirement.
- The same species has different forcing requirement in different sites
- The difference among populations of same species is smaller than the variability within population

03 Results

52 data

Frost prediction -- Oak



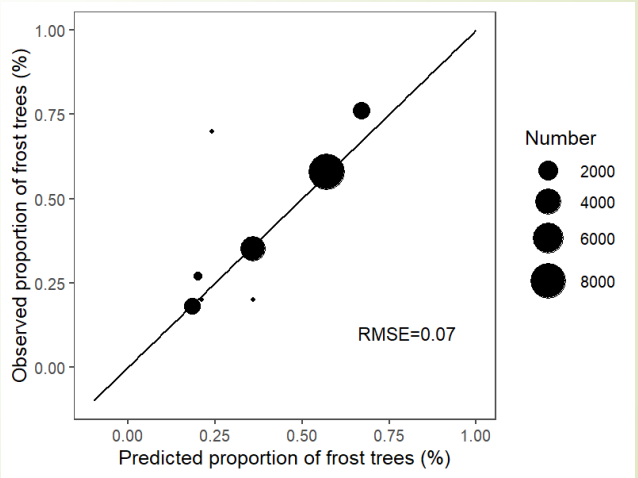


True skill statistic (TSS)

TSS=sensitivity+specificity-1

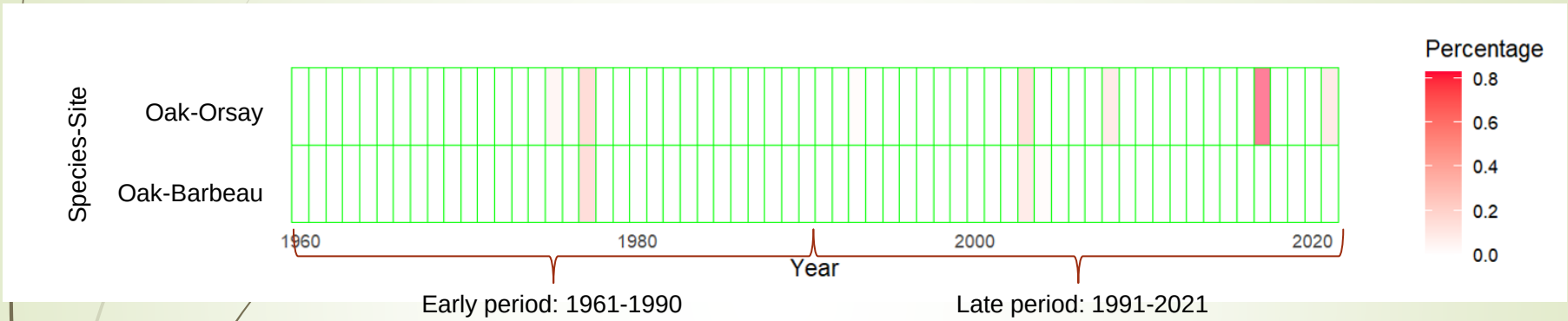
$$\text{Sensitivity} = \frac{\text{Correctly predicted presences}}{\textit{All presences in observation}}$$

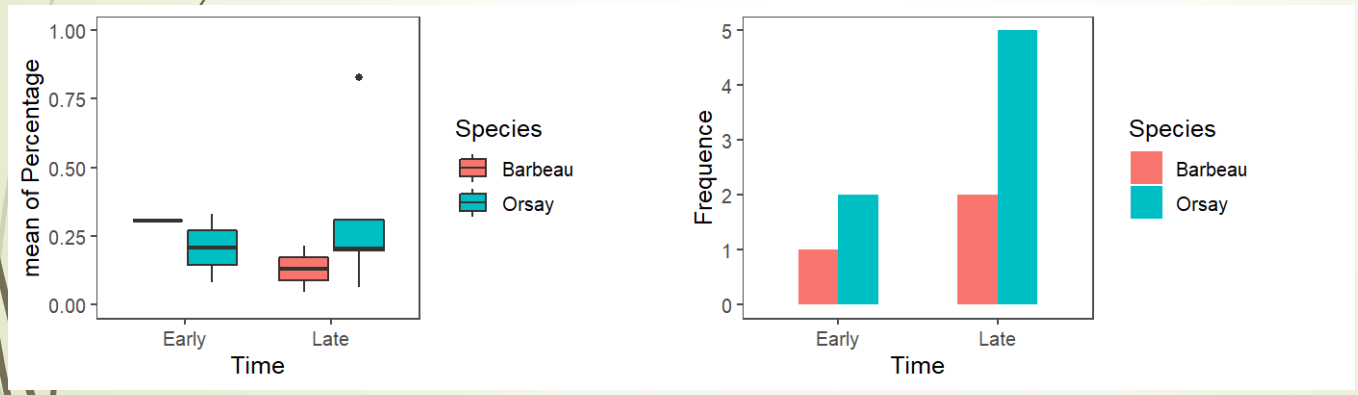
$$\text{Specificity} = \frac{\text{Correctly predicted absences}}{\textit{All absences in observation}}$$



03 Results

Frost prediction between 1961-2021





Over time, probability of frost damage increase

03 Results

Summary

- Construct within-population variability model for leaf out
- The model can be used to predict frost damage and evaluate the extent of frost damage
- The possibility of frost damage increases from 1961-2021

- The distribution of F* may be not a standard normal distribution due to natural selection
- Other environmental factors should be considered
- Experiment is necessary
- Extend the data for frost event

Acknowledgement

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Thank you for your attention