

# Development of a new phenological model based on the carbon balance of tree in boreal conifers

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EGU21

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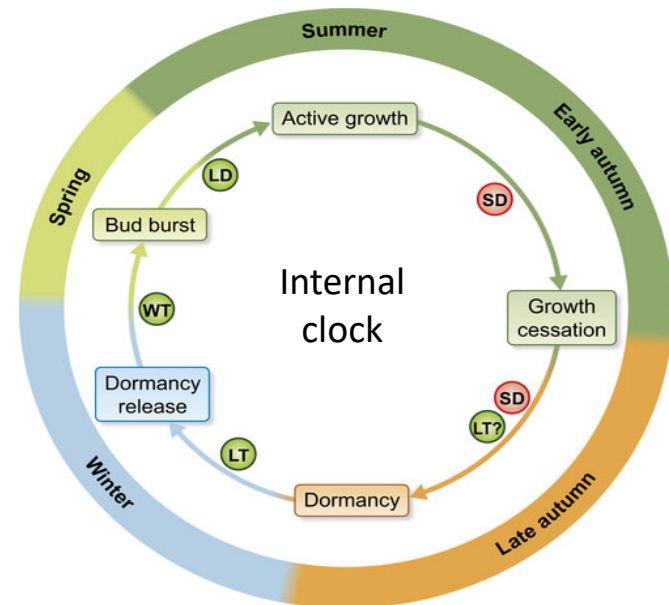
# Introduction: Current model for predicting phenology

The current phenological model are mainly based on:

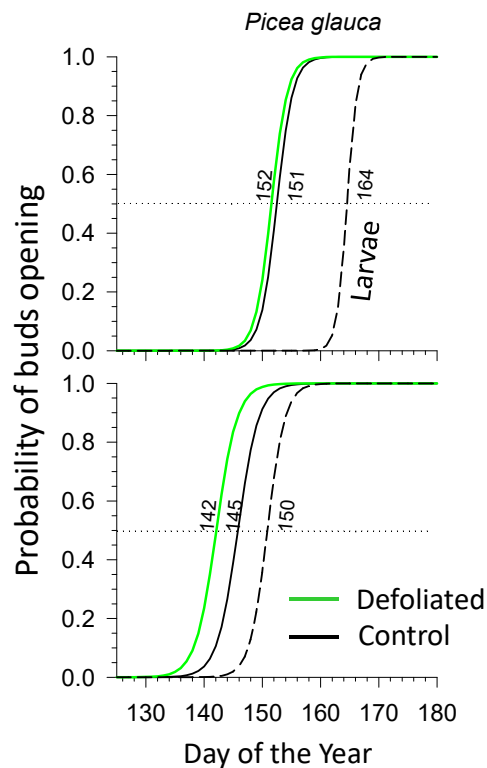
- Temperature sum ( $\Sigma$ )
- Photoperiod (hour )
- Chilling unit 

The physiological processes behind the internal clock are not considered

- Low biological - physiological support
- Defoliation is not considered



# Bud opening occurs earlier in defoliated plants because of changes in sugar allocation

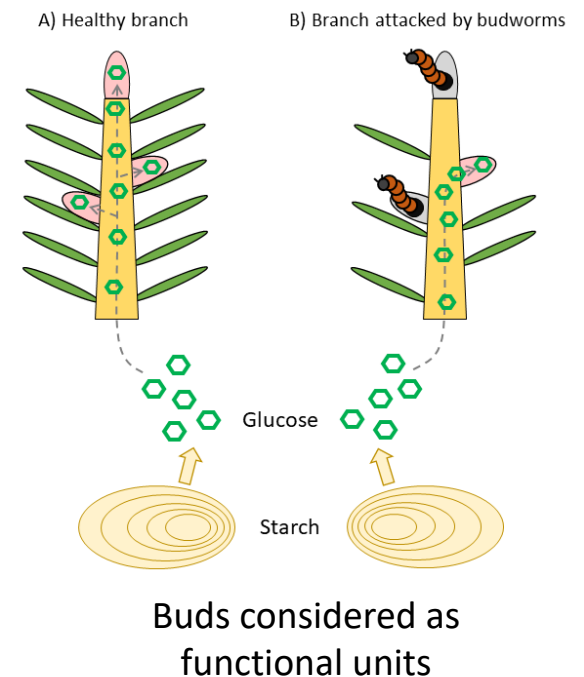


Similar bud opening



Earlier bud opening in defoliated trees

- White spruce: 3 days
- Black spruce: 6 days
- Balsam fir: 7 days

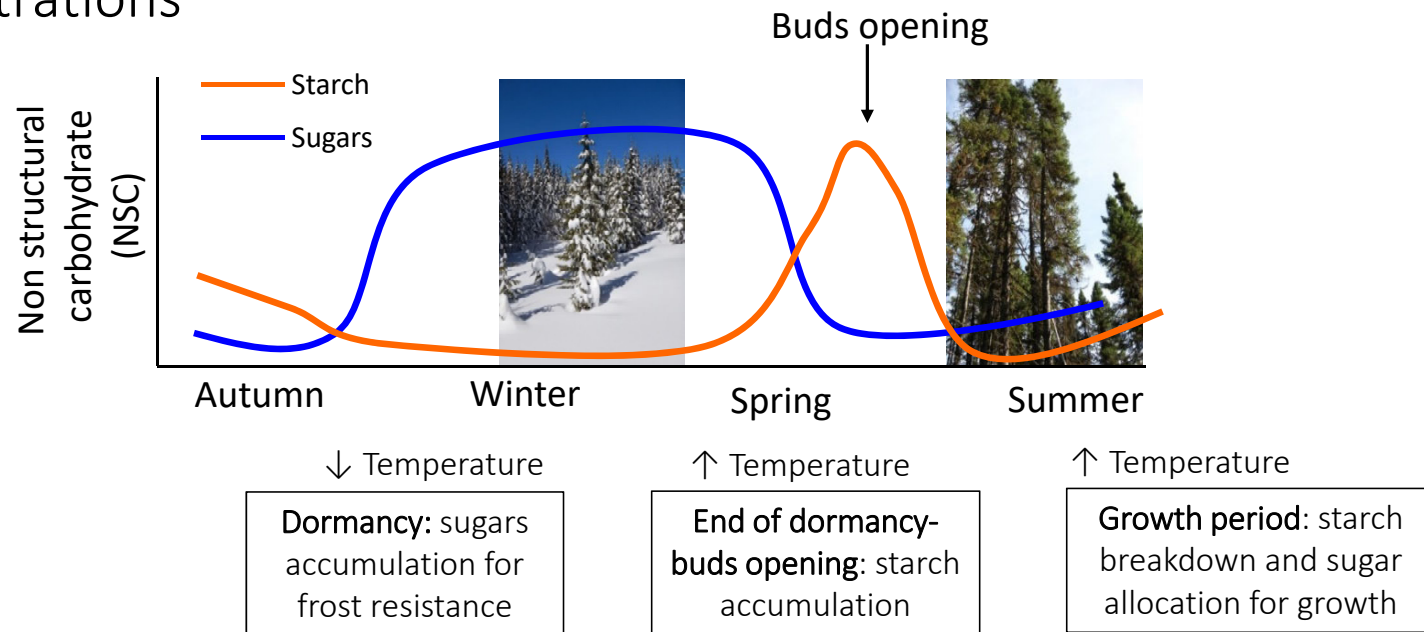


Deslauriers et al. Tree Physiology 2019

# Defining new phenological models



Seasons (the internal clock) affect the sugar and starch concentrations



# Defining new phenological models



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How to include defoliation in phenological models?

- **Factors that anticipate bud opening under defoliation**

- Reduction of the number of buds

- **Factors that delay bud opening under defoliation**

- Reduction in leaf area
- Reproductive buds?



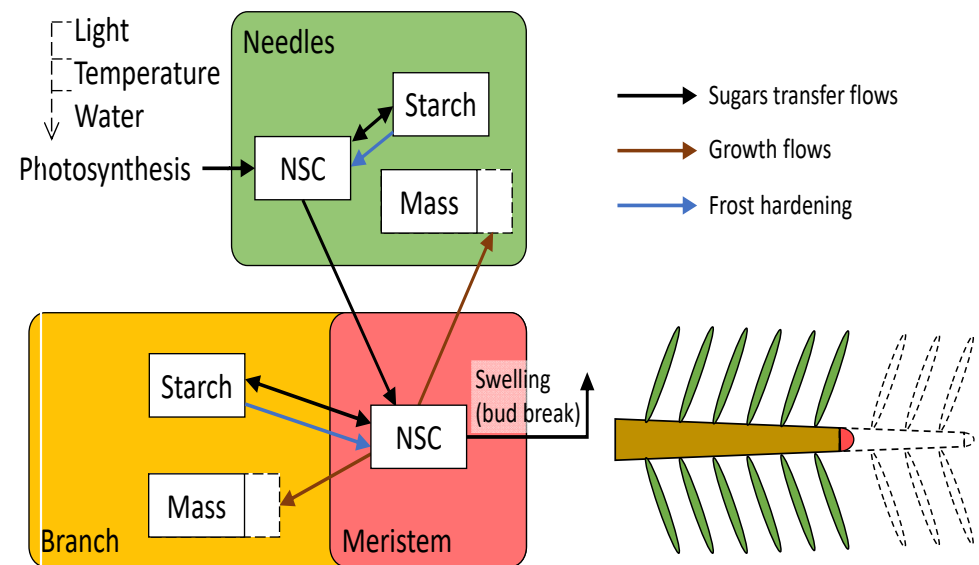
# Defining new phenological models: Carbon balance model

## Model input




- Temperature ( $^{\circ}\text{C}$ )
- PAR ( $\mu\text{mol}/\text{m}^2/\text{s}^{-1}$ )
- Current defoliation (%)
- Species

## Model output

- Bud opening (date)
- Growing season (days)
- Shoot growth (period and growth in mm)
- Sugars dynamics ( $\text{mg}\cdot\text{g}_{\text{dw}}^{-1}$ )

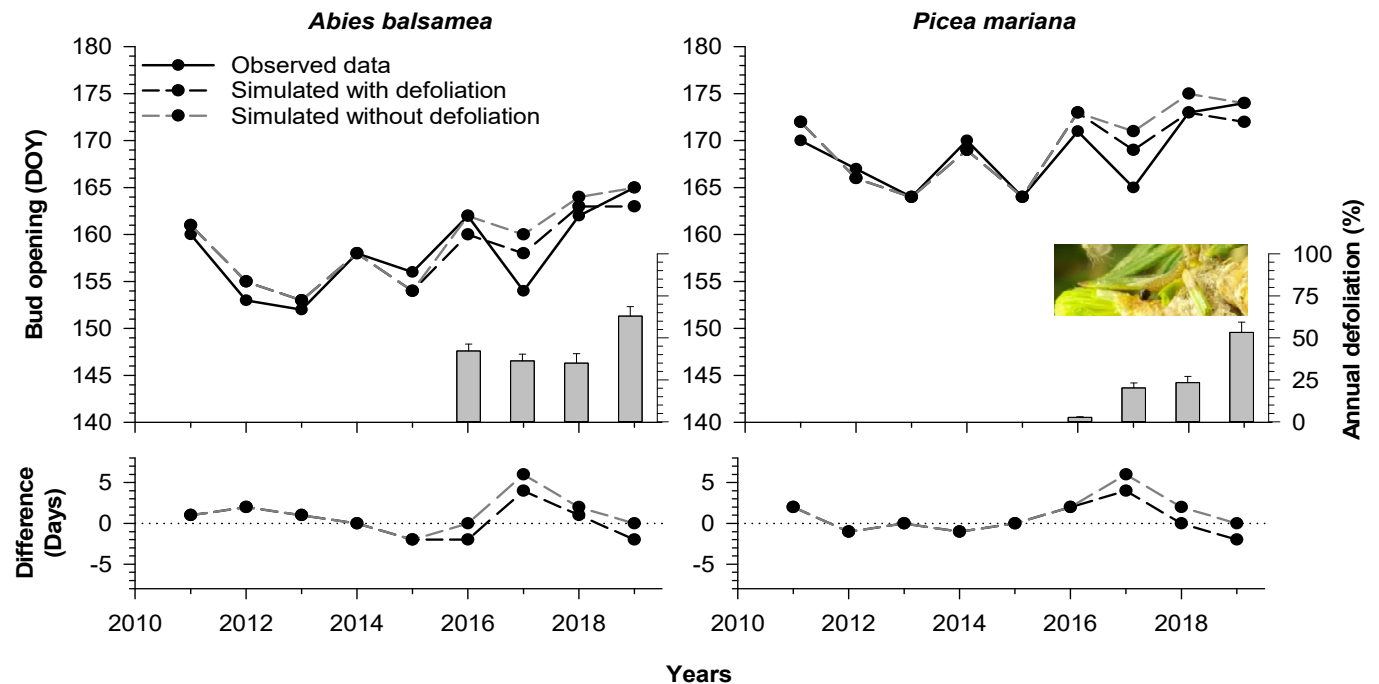


# Dataset and measurements used for calibration and validation

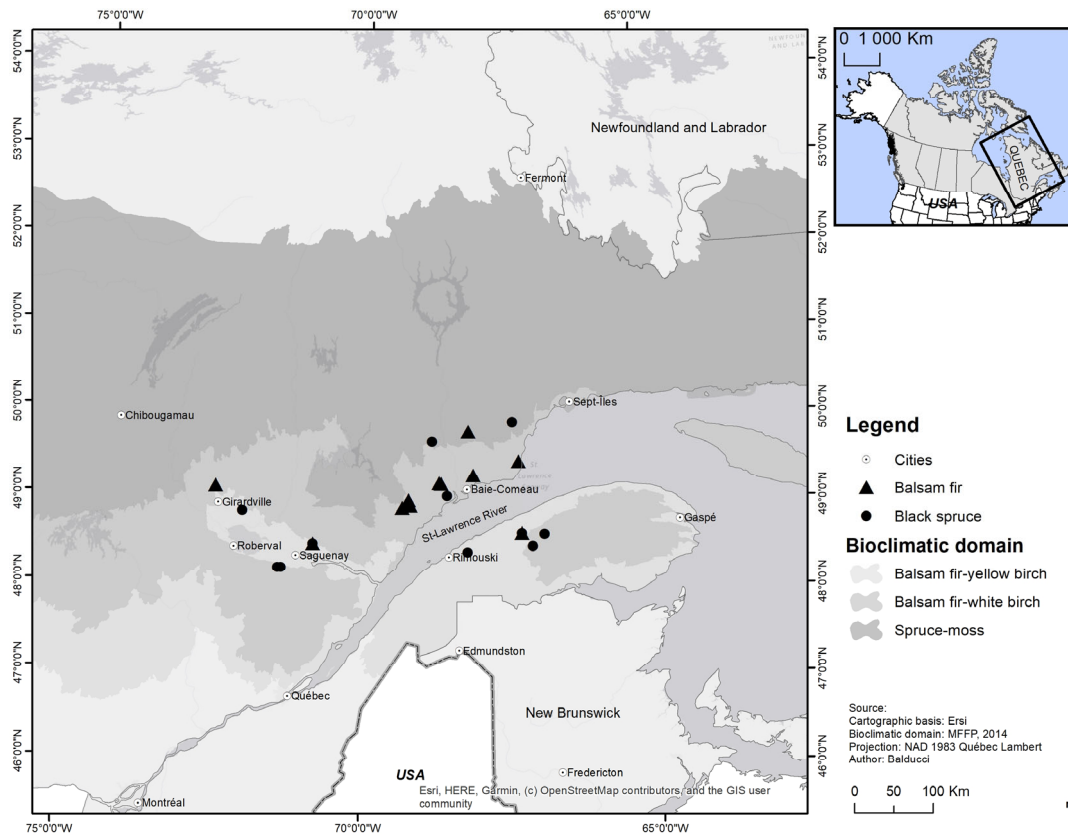
	Experimental plots	Biological variables	Disturbance data	Climatic data	Output predictions
<b>1) Model development and calibration (Greenhouse)</b>	<ul style="list-style-type: none"> <li>2015-2016</li> <li>4 year-old saplings</li> <li>Black and white spruce, balsam fir (Deslauriers et al., 2019)</li> </ul>	<p>Needle, stem biomass</p> <p>Shoot growth Bud development on terminal buds (Dhont et al., 2010; Rossi and Isabel, 2017)</p>  <p>Starch</p> <p>Total soluble sugars (Antonucci et al., 2015; Deslauriers et al., 2019; Fierravanti et al. 2019)</p> <p>Time (DOY)</p>	<p>Defoliation intensities (%) of current and last year (Fettes, 1950; Piene et al., 1981)</p> <p>Time (DOY)</p>	<p>Photosynthetically active radiation</p> <p>Daily air temperature</p> <p>Average yearly temperature in situ (Antonucci et al., 2015; Deslauriers et al., 2019) and extracted by BioSIM v 11</p> <p>Time (DOY)</p>	<p><b>Bud break date in springtime, sugar starch branch length over the year</b></p>
<b>2) Model calibration in field (long-term plot)</b>	<ul style="list-style-type: none"> <li>2011 to 2019</li> <li>Mature trees</li> <li>Black spruce, balsam fir</li> </ul>	<p>Bud development = Number of individual by all stages (Modified by Juneau 1989)</p> <p>Time (DOY)</p> 			
<b>3) Model validation in field (large scale plots)</b>	<ul style="list-style-type: none"> <li>2015 to 2018</li> <li>Mature trees</li> <li>Black spruce, balsam fir</li> <li>20 plots</li> </ul>	<p>Bud development = Number of individual by all stages (Modified by Juneau 1989)</p> <p>Time (DOY)</p> 			

# Predicting phenology from 2011-2019: Before and during spruce budworm outbreak

Boreal Forest,  
Saguenay (Québec)  
Canada

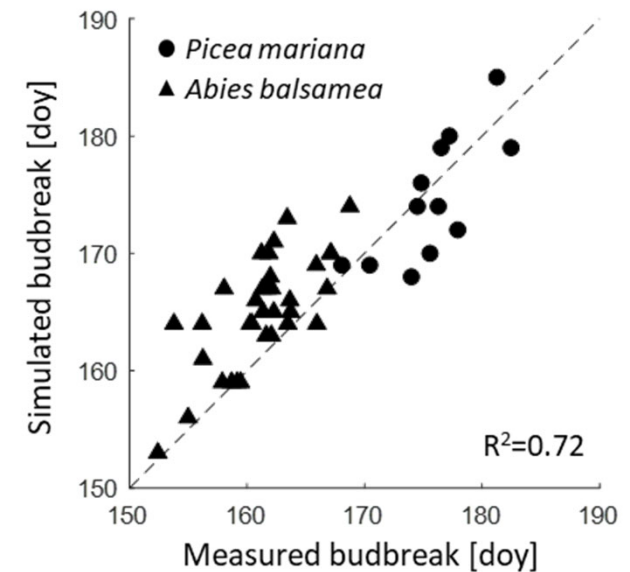


# 20 other experimental plots in Québec (Canada)



Average error for balsam fir:  $\pm 4.1$  days  
Average effort for black spruce:  $\pm 3.1$  days

Sites were at different levels of defoliation



# Temperature related predictions of bud opening

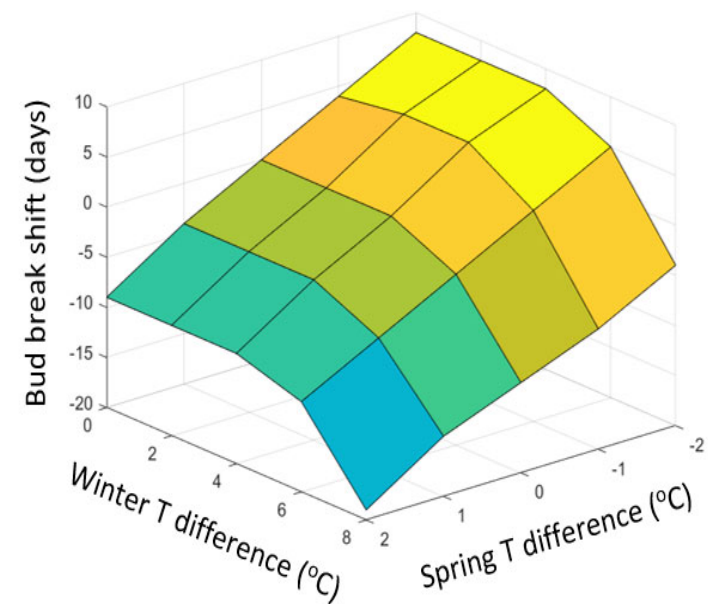
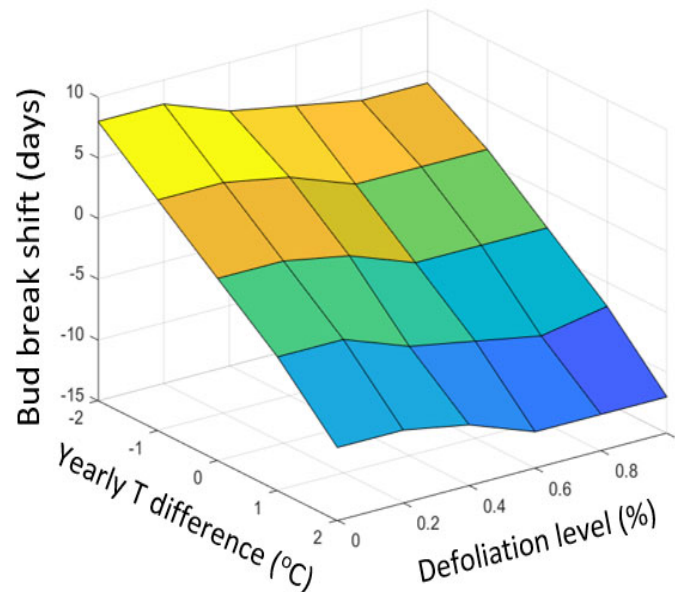
## □ Temperature effect

### □ During winter:

- Colder = anticipation
- Warmer = delay

### □ During spring

- Colder = delay
- Warmer = anticipation



# Conclusion

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- Based on known physiological processes
  - ▣ Physiological explanation of chilling and forcing
  - ▣ Calibrated in the greenhouse – Forest,
  - ▣ Good simulation of buds opening in the main conifers during defoliation

# Team

## Model development (equation) and calibration:

- Fabrizio Cartenì (Prof.)
- Stefano Mazzoleni (Prof.)
- Emiliano Salucci (Tech.)



## Phenology and carbon allocation experiments (greenhouse and field):

- Annie Deslauriers (Prof.)
- Lorena Balducci (Post doc)
- Alain Dupont (SOPFIM)
- Several MSc students



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**Organizations** (in Canada) that funded the development of the phenology model

