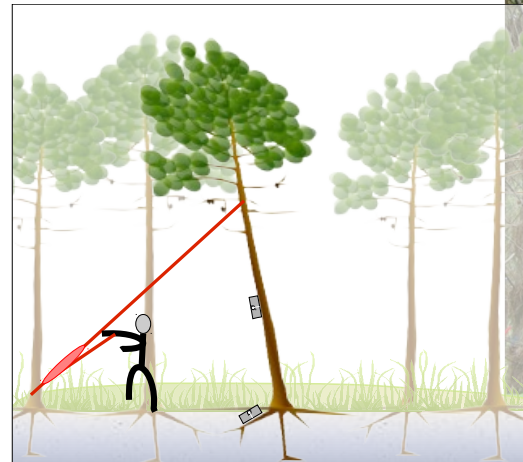


# Vers la prise en compte du vent dans la modélisation fonctionnelle de la croissance du Pin maritime

**A. Bosc<sup>1</sup>, F. Rajaonalison<sup>1</sup>, B. Gardiner<sup>2</sup>, C. Meredieu<sup>3</sup>, P. Defossez<sup>1</sup>**

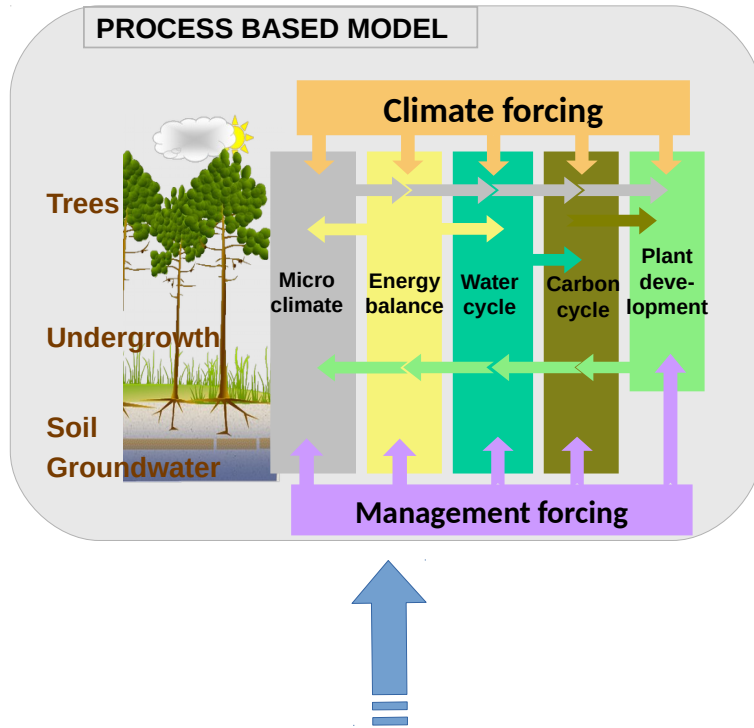
1 - INRA UMR ISPA, 2 - EFI Atlantic, 3 - INRA UE Forêt Pierroton



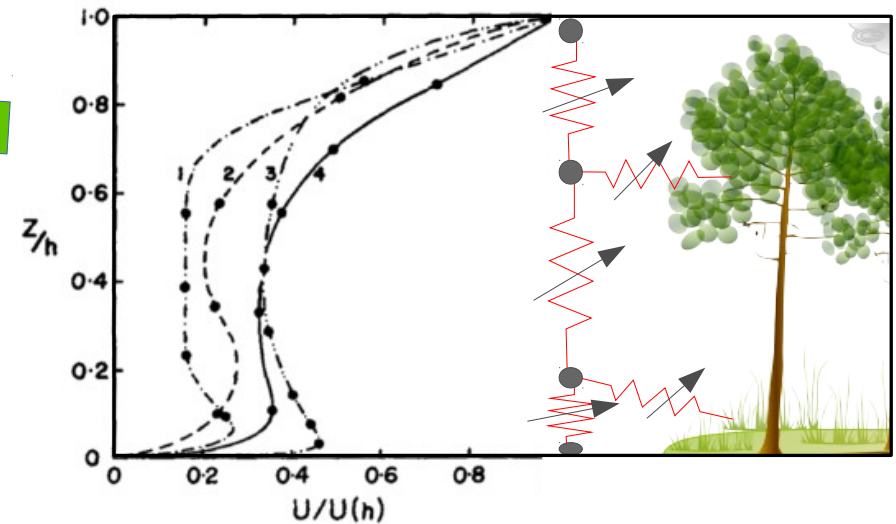
« CAQSIG » 27-29 mars 2018.  
Clermont Ferrand

INRA

# Context: what about wind in our forest process based model ?



## 1. Aerodynamic effects are modeled



2. Vulnerability and stability are studied and modeled. But not yet included in process based model.



## 3. Thigmomorphogenesis.

Development plasticity.

Nothing is known for *Pinus p.* and it appears difficult to integrate literature results.



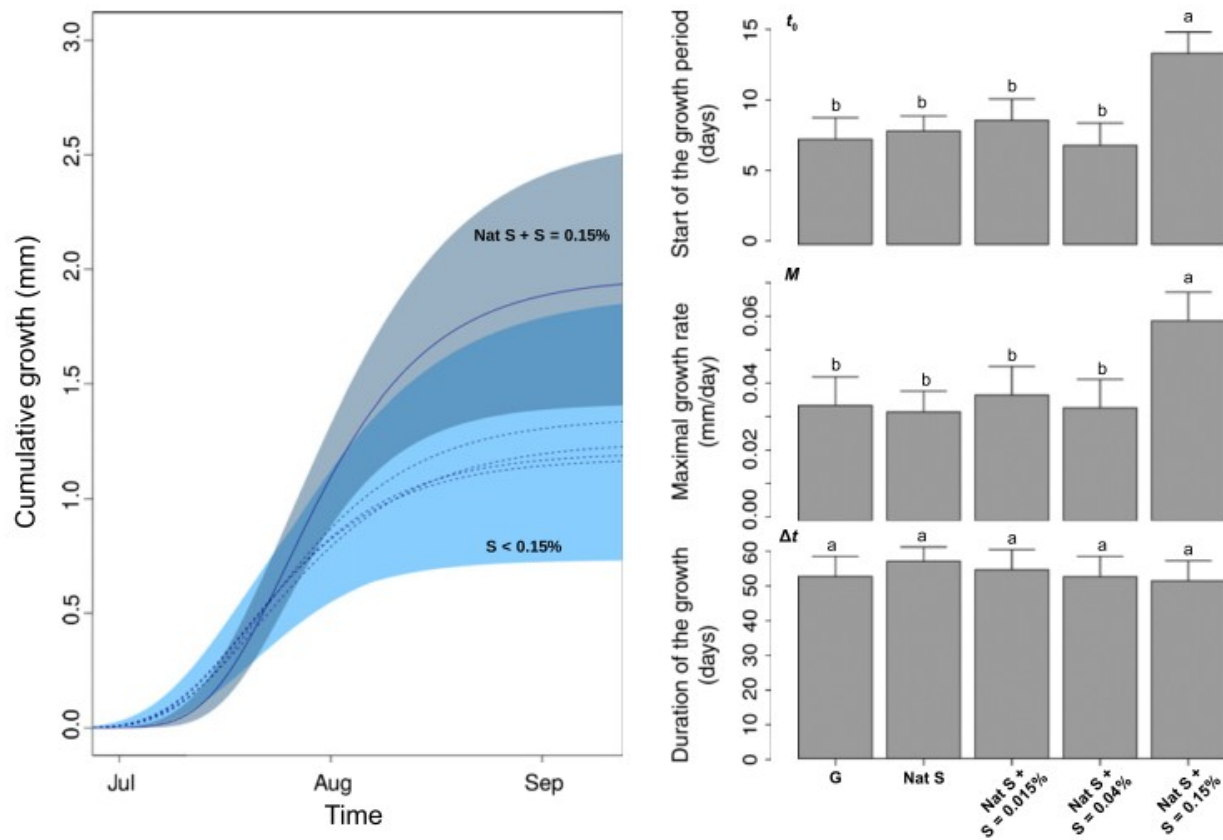


# Are there any thigmomorphogenic effects in the forest ?

Yes for *Fagus Sylvatica*

Forest trees filter chronic wind-signals to acclimate to high winds

Vivien Bonnesoeur<sup>1,2</sup>, Thiéry Constant<sup>1,2</sup>, Bruno Moulia<sup>3,4</sup> and Meriem Fournier<sup>1,2</sup>



**Fig. 4** Effects of the mechanical treatments on the growth response. On the left panel, the cumulative radial growth of *Fagus sylvatica* is represented through time. The growth is predicted at the population level (envelope of confidence at 95%). The treatments G, Nat S, Nat S + S = 0.015% and Nat S + S = 0.04% are not significantly different and grouped as 'S < 0.15%'. Dark blue envelope and straight line: 'Nat S + S = 0.15%' treatment, light blue envelope and dotted line: other mechanical treatments 'S < 0.15%'. The right panel shows the additive effects of the mechanical treatments on the start of the growth period, the maximal growth rate of the tree and on the duration of the growth period. Error bars are SD. Significant differences ( $P < 0.05$ ) between mechanical treatments are indicated by different letters.

# Objectives

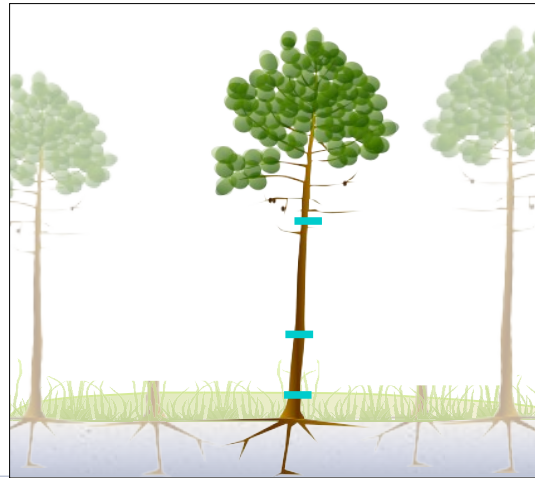
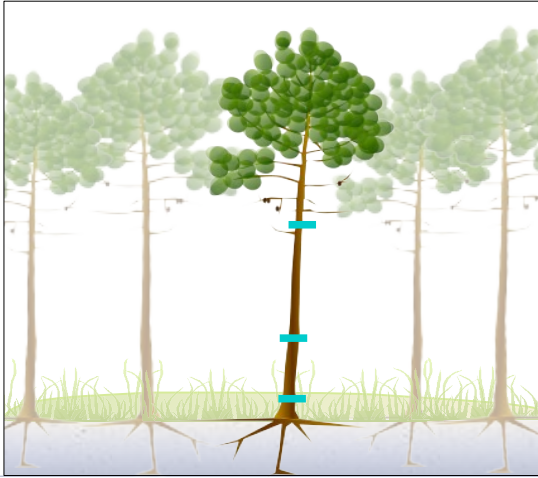
Integrate wind effect in interaction with others climatic drivers in our process based model.

→ Acquire the biological knowledges necessary for integration

→ We need an ecophysiological approach :

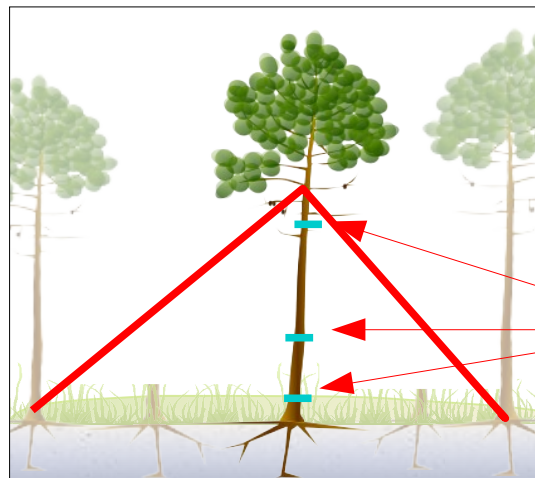
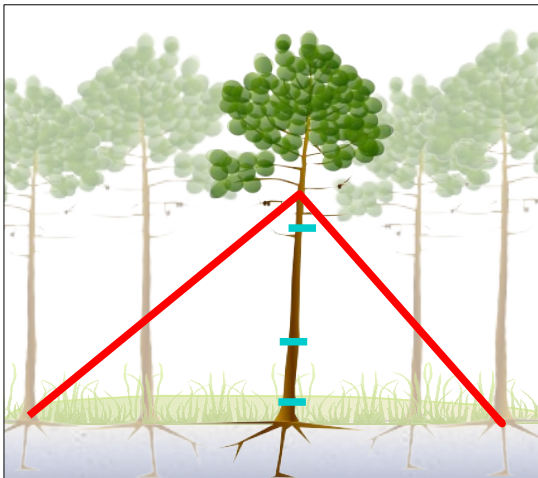
- determine effect at tissue level in a dose-response approach for natural condition
- determine modalities to integrate from tissue to plant level
- determine modalities to integrate over the life time

# Long term reaction of trees to a change of wind loading



## Modalités

- 2 traitements → 4 modalités
- Eclairci / Non éclairci
- Haubané / libre
- 6 répétitions par modalité



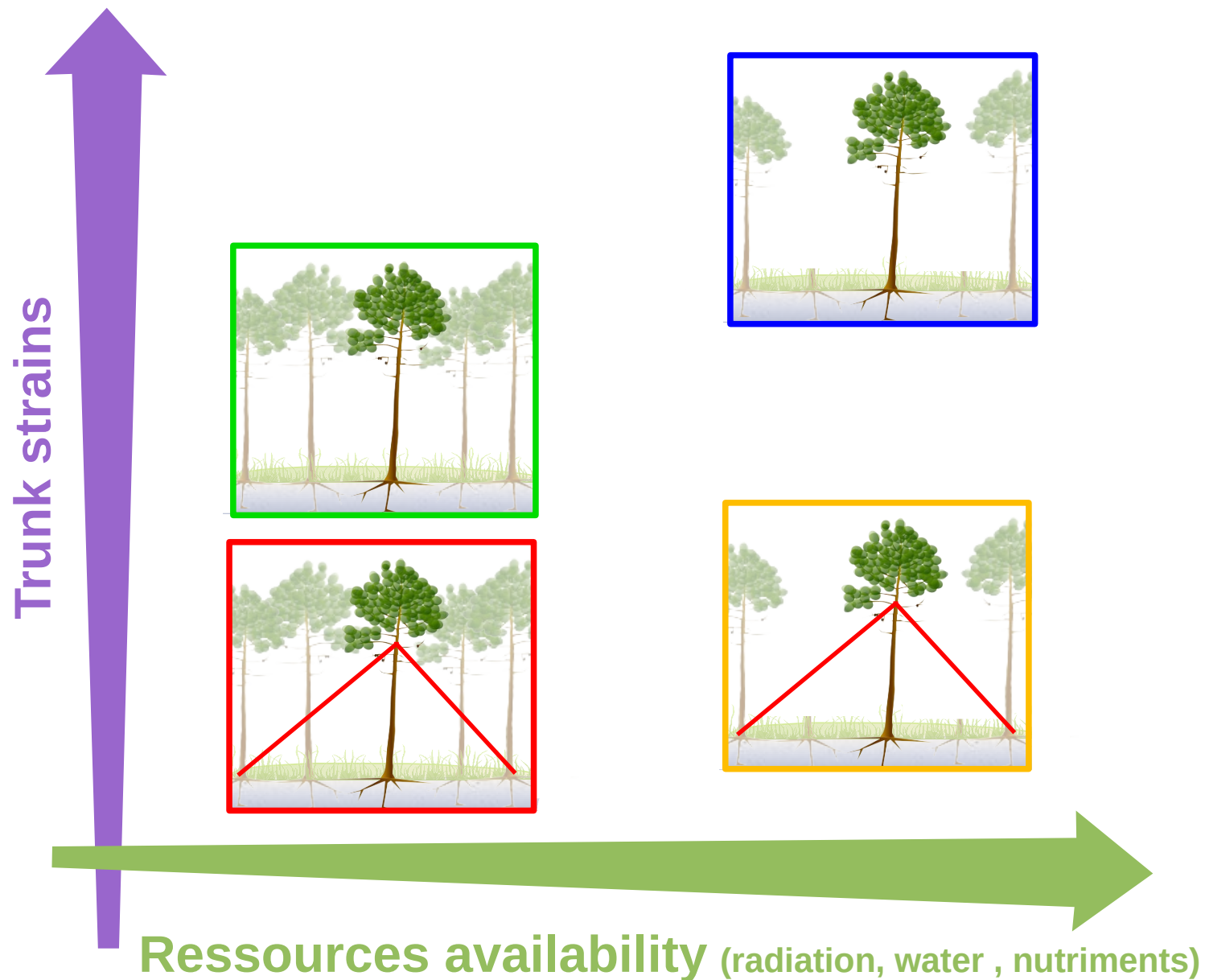
## Suivi de la croissance des troncs

- 3 hauteurs (0.6, 1.6 & 4 m)
- ~ mesures bimensuelles effectuées par l'UE Pierroton

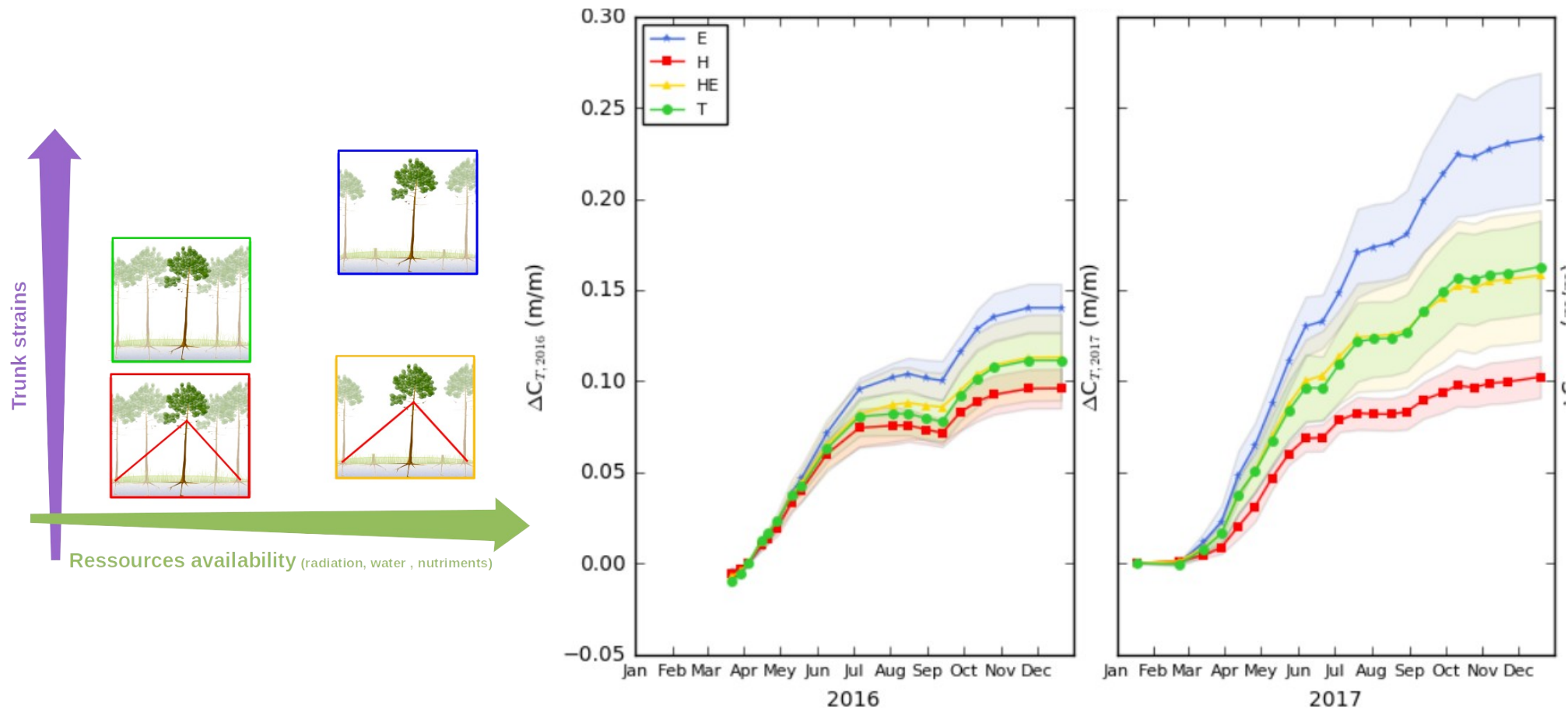


- 4-5 ans de suivi prévu

# Long term reaction of trees to a change of wind loading



# Long term reaction of trees to a change of wind loading

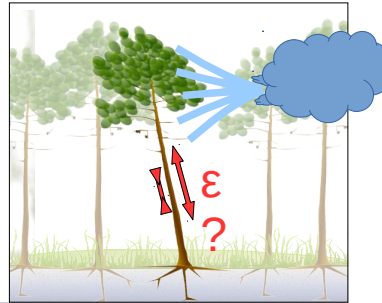


- Trees with neighbors removed, have their secondary growth increased.
- But this is not the case if they are guyed!

→ The rapid effect of thinning may not be due to the greater availability of resources (light, water, minerals) but to the greatest mechanical stress

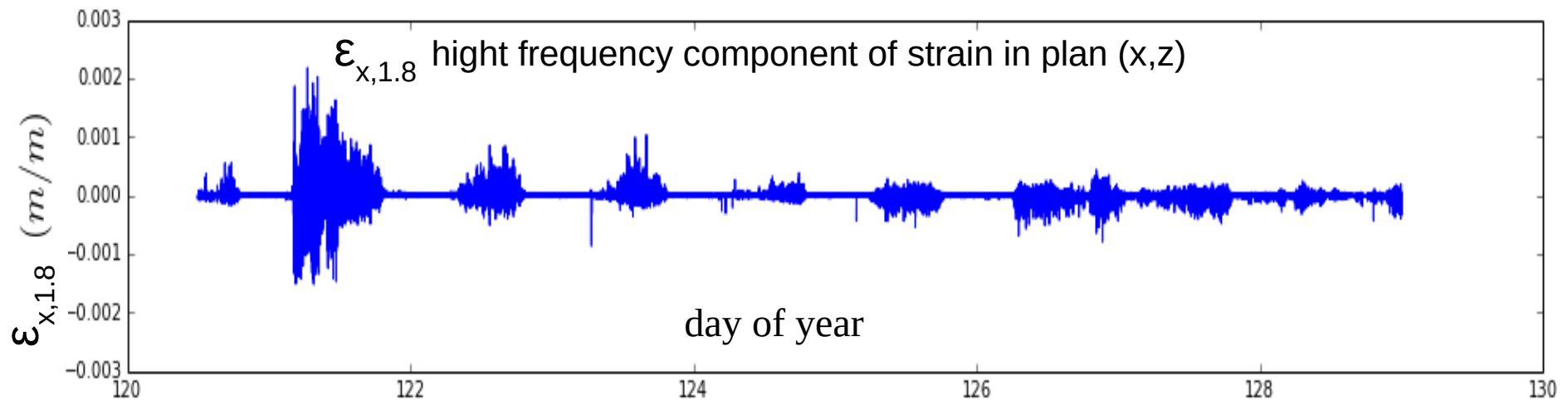


# Characterization of the range of deformations resulting from chronic winds



6 trees strains ( $\epsilon_x, \epsilon_y$ ) followed during 10 days

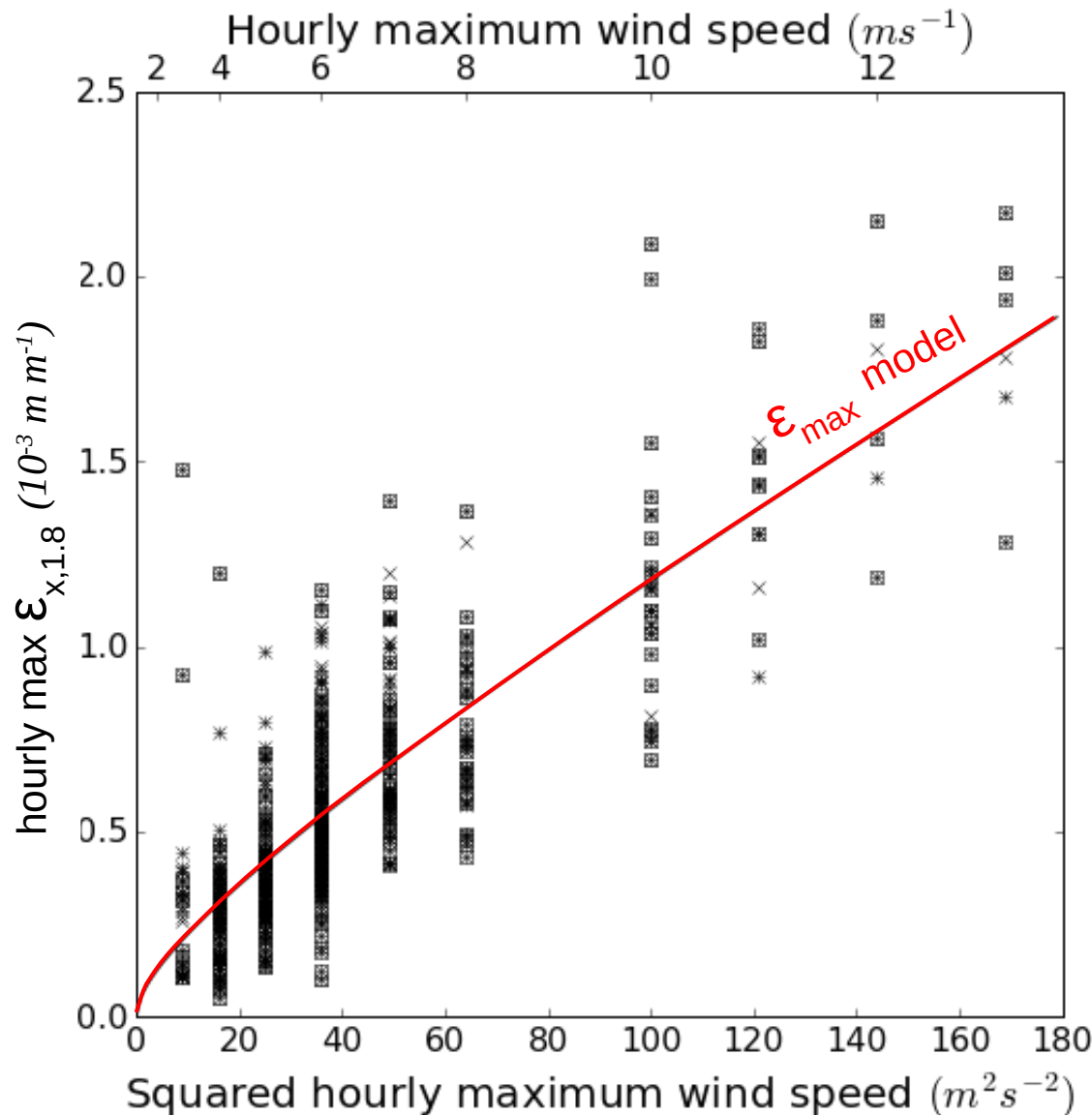
- strain sensors (based on Moore et al., 2005)
- set at height  $h = 1.8$  m



→ local strain flexion:  $\epsilon_{1.8} = \sqrt{\epsilon_{x,1.8}^2 + \epsilon_{y,1.8}^2}$



# Characterization of the range of deformations resulting from chronic winds



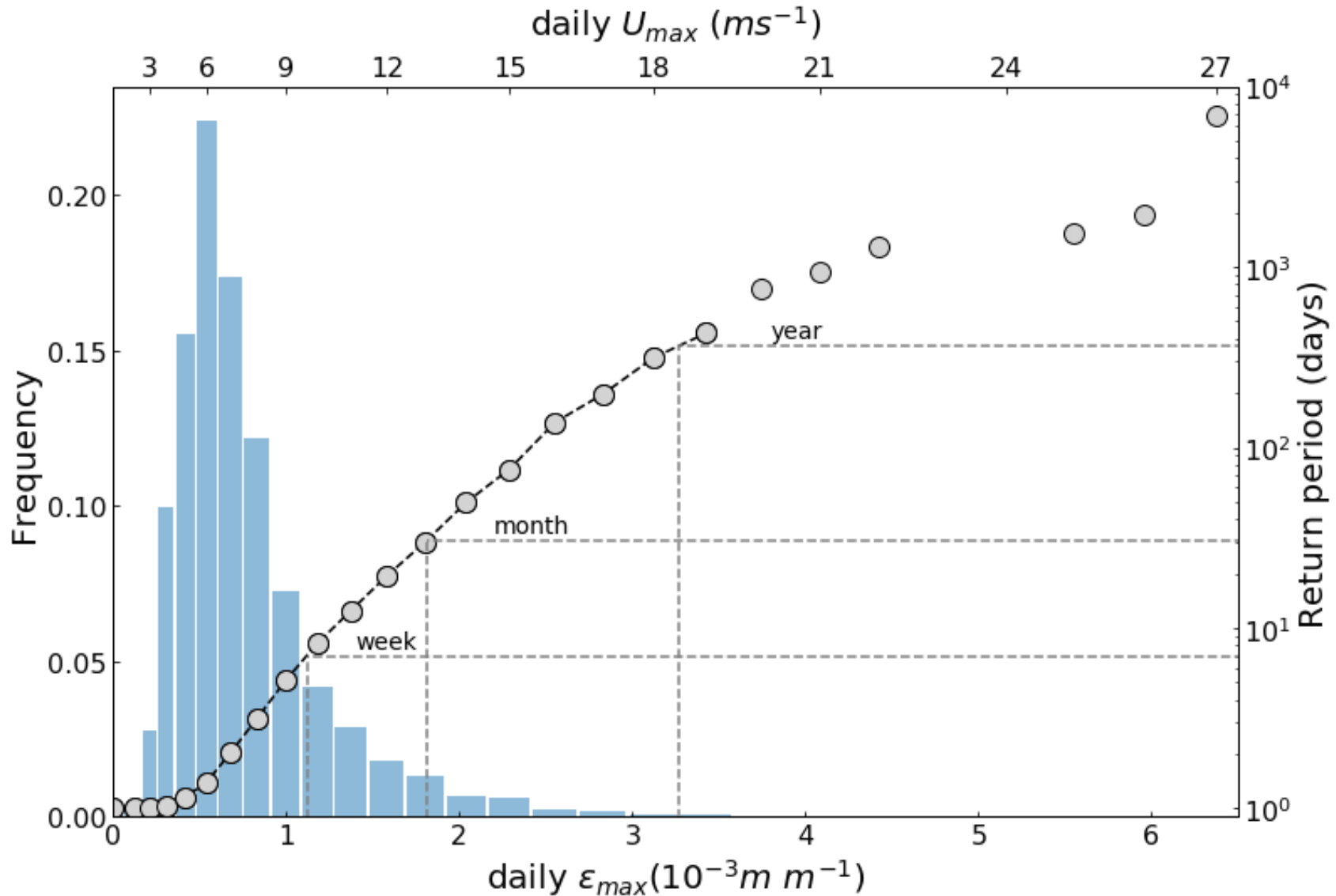
Trunk strain model at 1.8 m :

$$\epsilon_{1.8} = p_1 \cdot \underbrace{\left(1 + p_2 / U_{\text{max}}\right)}_{\text{evolution with } U_{\text{max}}} \cdot U_{\text{max}}^2$$

evolution with  $U_{\text{max}}$  probably due to crown reconfiguration and partial decorrelation between wind speed at meteorological station height (2 m) and at crown height (12 m)

# Trunk strain regime induced by wind

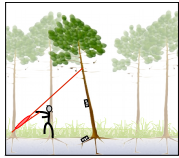
- trunk  $\varepsilon_{\max}$  simulated from chronic meteorological wind speed (1996-2015)



- We define the 'chronic strain range' as the strain with return time less than one year :  $\varepsilon_{1.8} < 3.25 \times 10^{-3} \text{ m.m}^{-1}$

# Wood growth reaction to mechanical strains: an experimental design to access a dose-response characterization

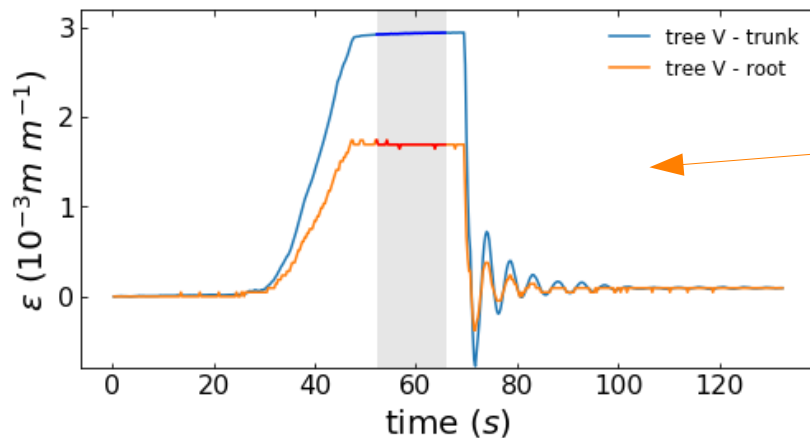
- Control : 6 trees
- Treatment : 18 trees pulled
  - artifically pulling
  - 3 times by week for 6 weeks
  - maintained for 20 secondes
- 1 flexion level by tree in the chronical range [0.6, 3.0‰]. Measured in the flexion direction by strain gage on :
  - the trunk (1.8 m heighth)
  - a anchorage root



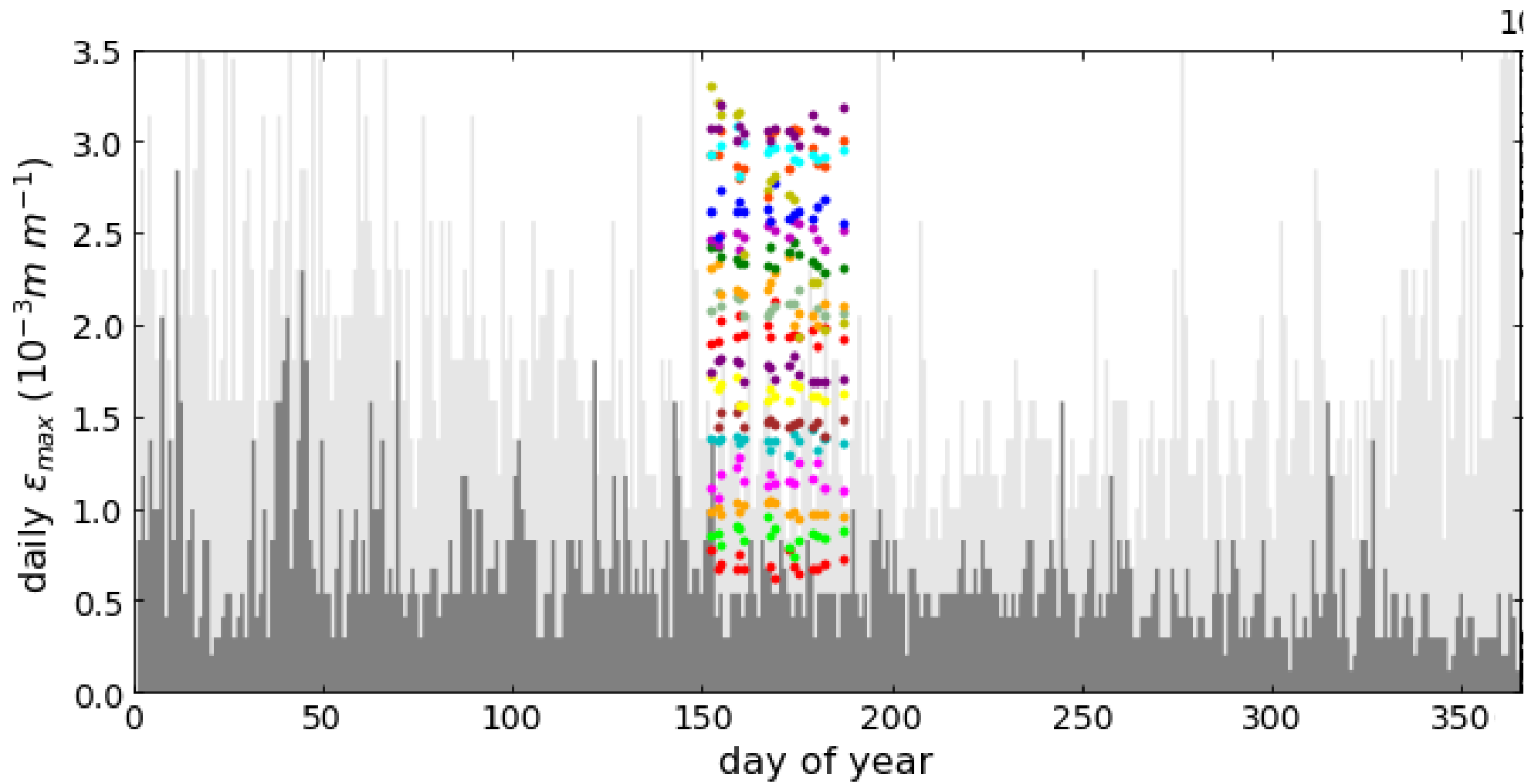
*A design inspired by those of Bonnesœur et al. (2016) on Fagus S.*



Example of trunk and root strains during a pull test

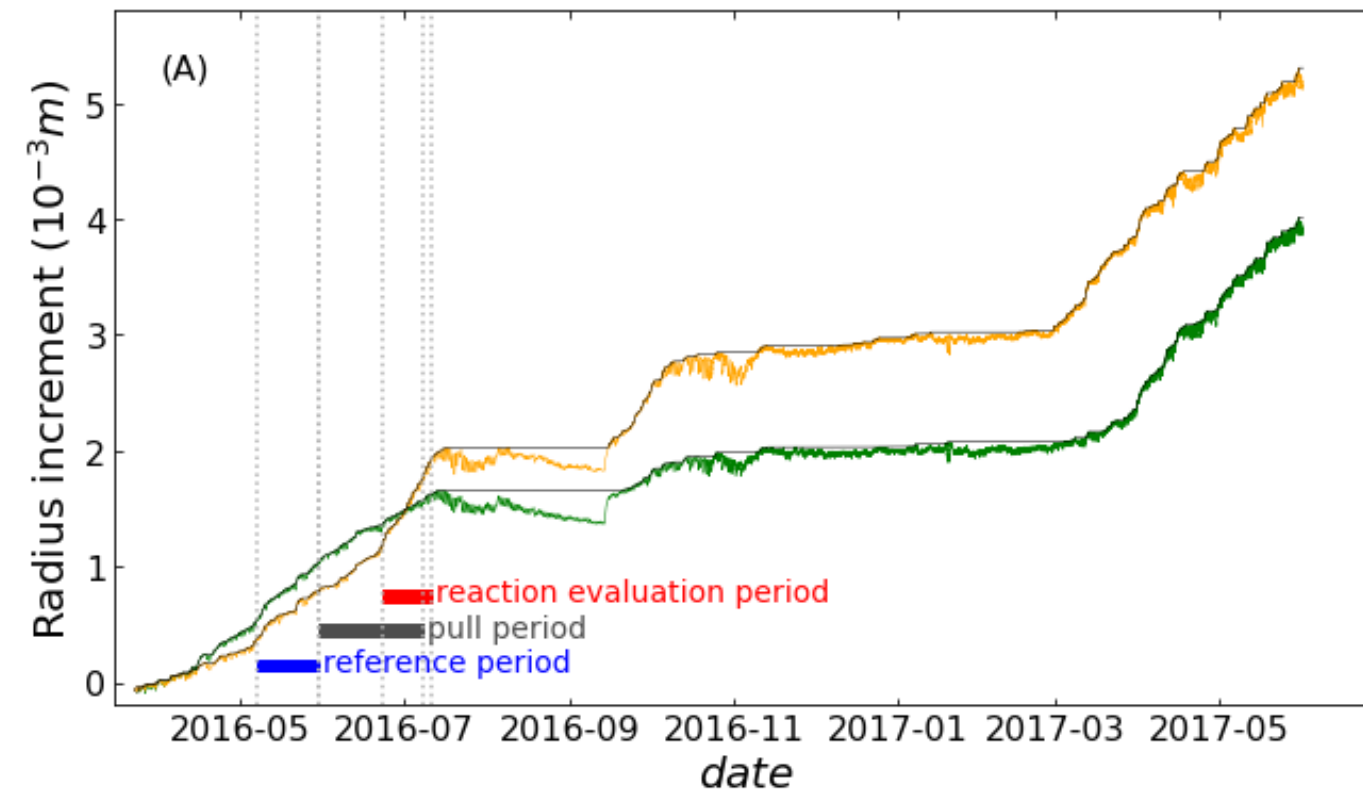


# Daily strains realised on each tree

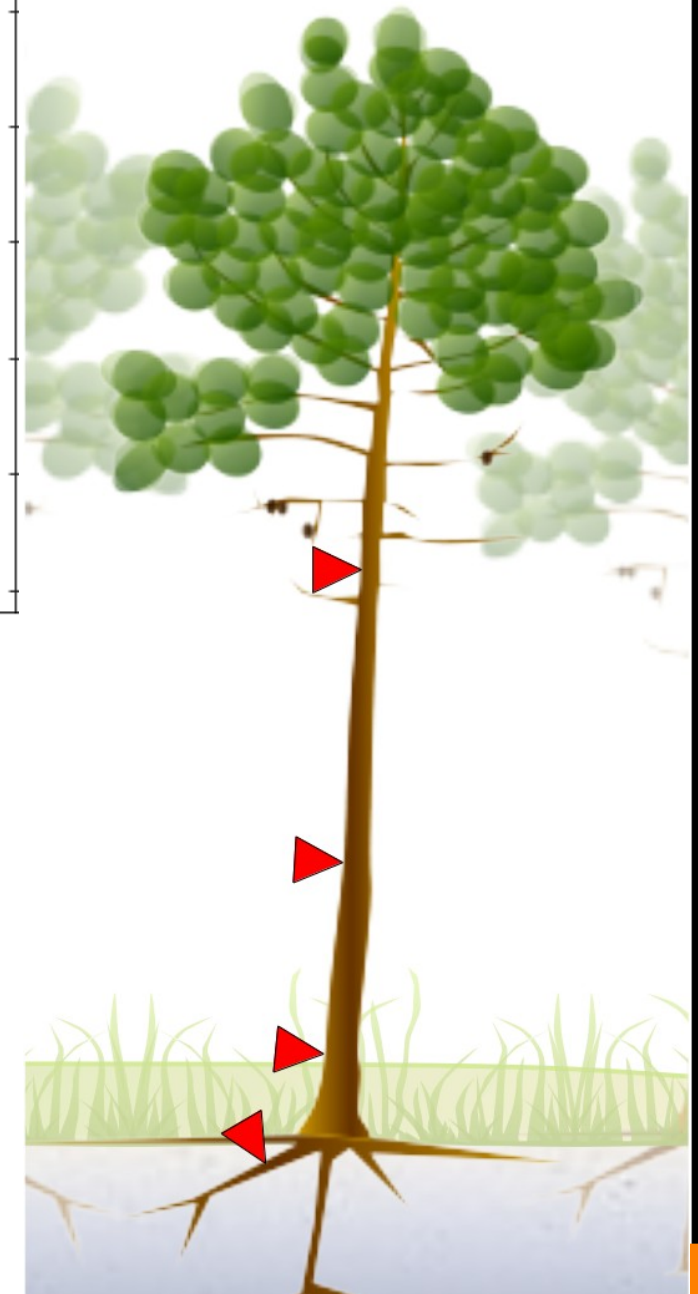




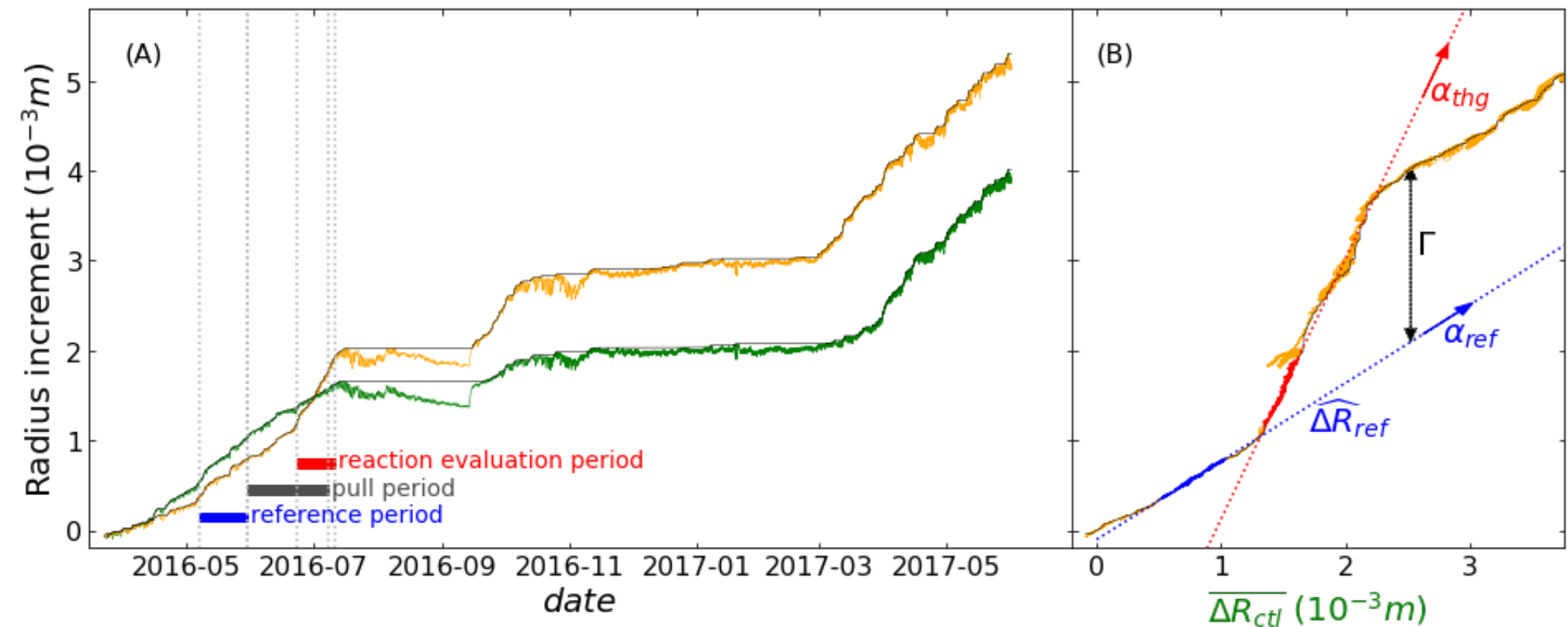
# Wood growth reaction monitoring



- 4 microdendendrometers (▶) per tree in the flexion direction
  - 3 on trunk under guying fixation point
  - 1 on an anchorage root
- Radial size measured at 1/2 hour time step
- Measures started 11 weeks before treatment and, continued until the end of 2017



# Thigmomorphogenic reaction characterization



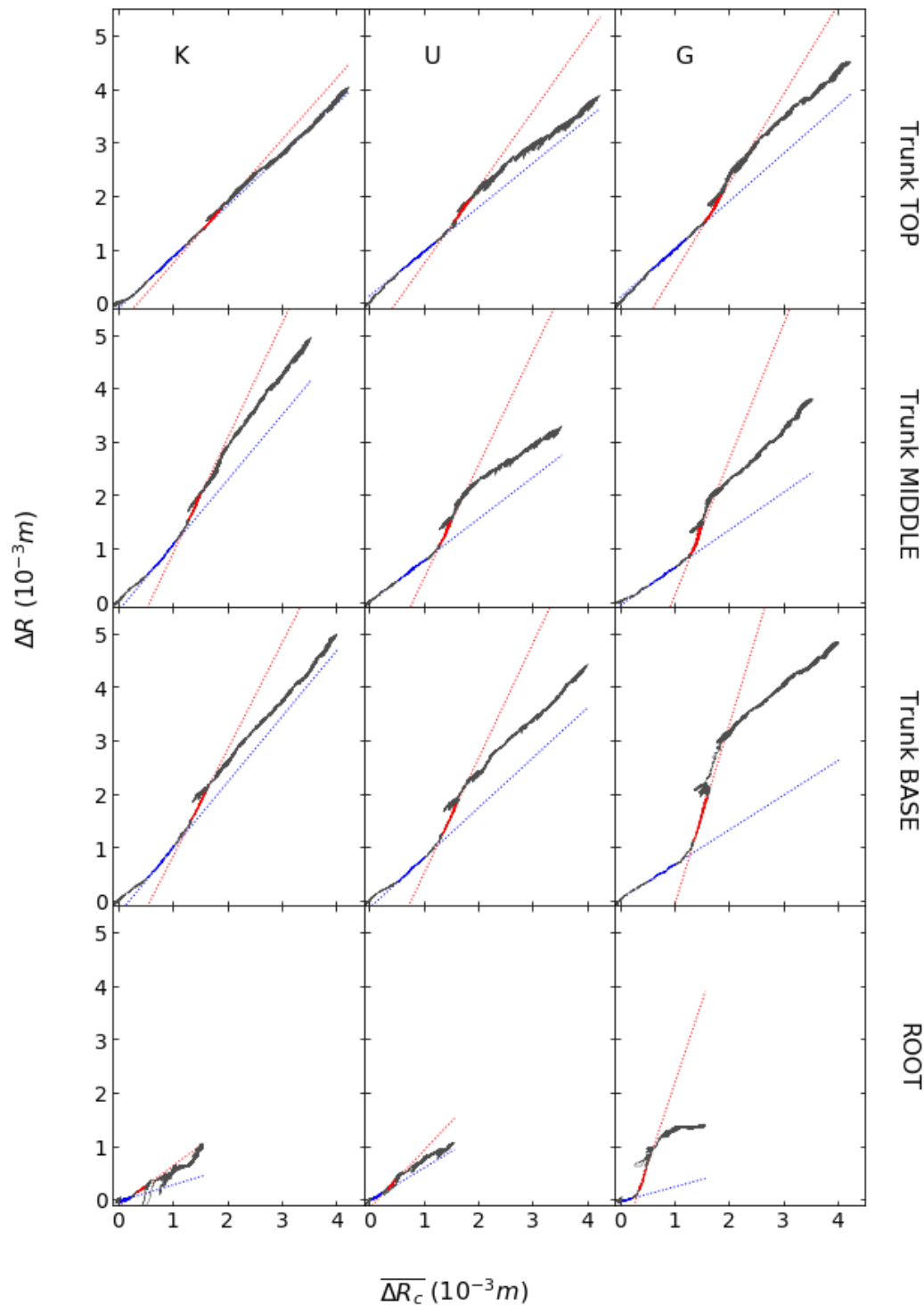
Radial growths of pulled trees are compared to those of the mean control tree to remove climatic effects.

$\widehat{\Delta R}_{ref}$  : reference wood radius increment

$\alpha_{thg} / \alpha_{ref}$  : initial growth gain

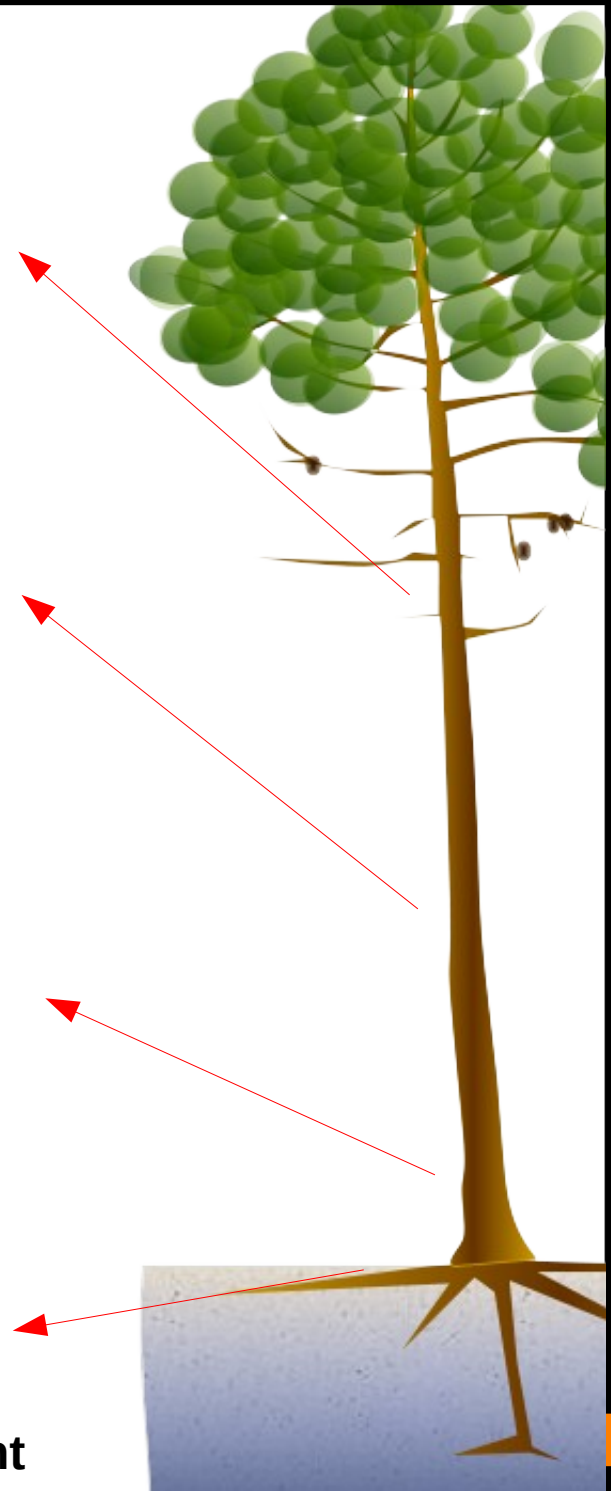
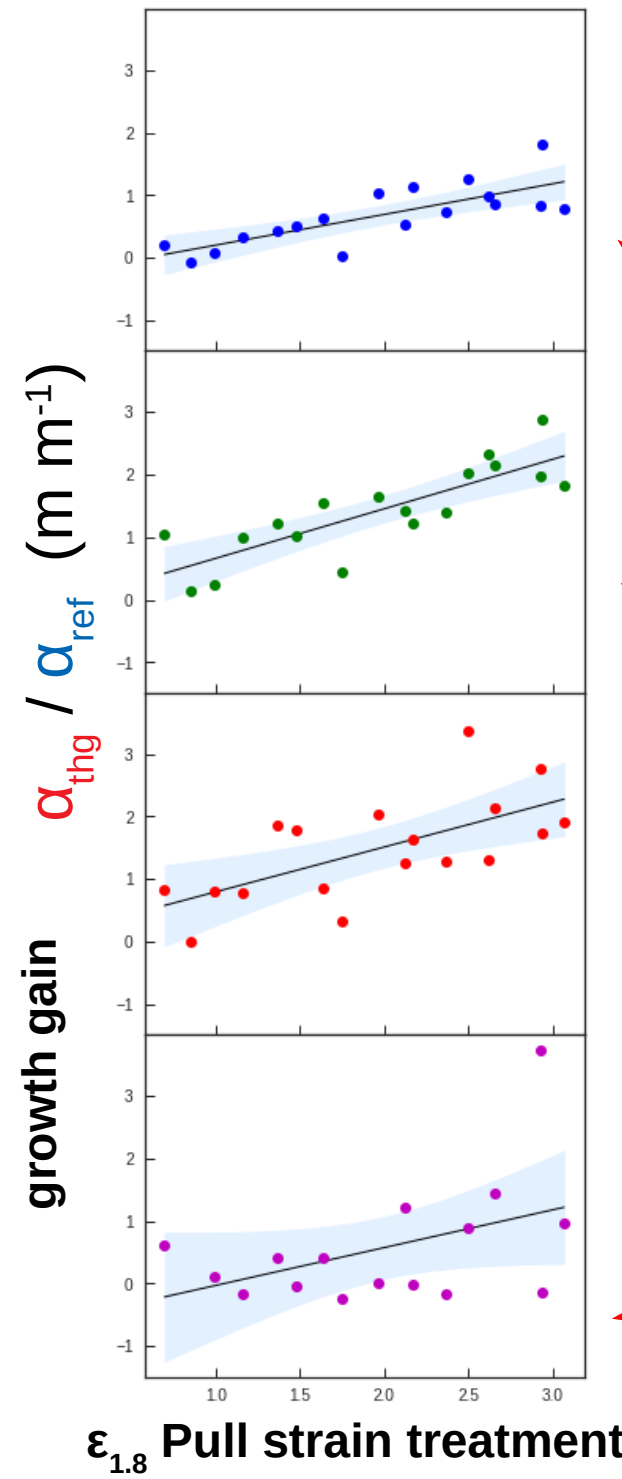
$\Gamma$  : total radius increment at end of thigmomorphogenic reaction

# Some examples of growth reaction to pull treatment



- For some roots, radial growth seems starts with pull treatment

# Initial growth gain - $\alpha_{\text{thg}} / \alpha_{\text{ref}}$ : Responses by level





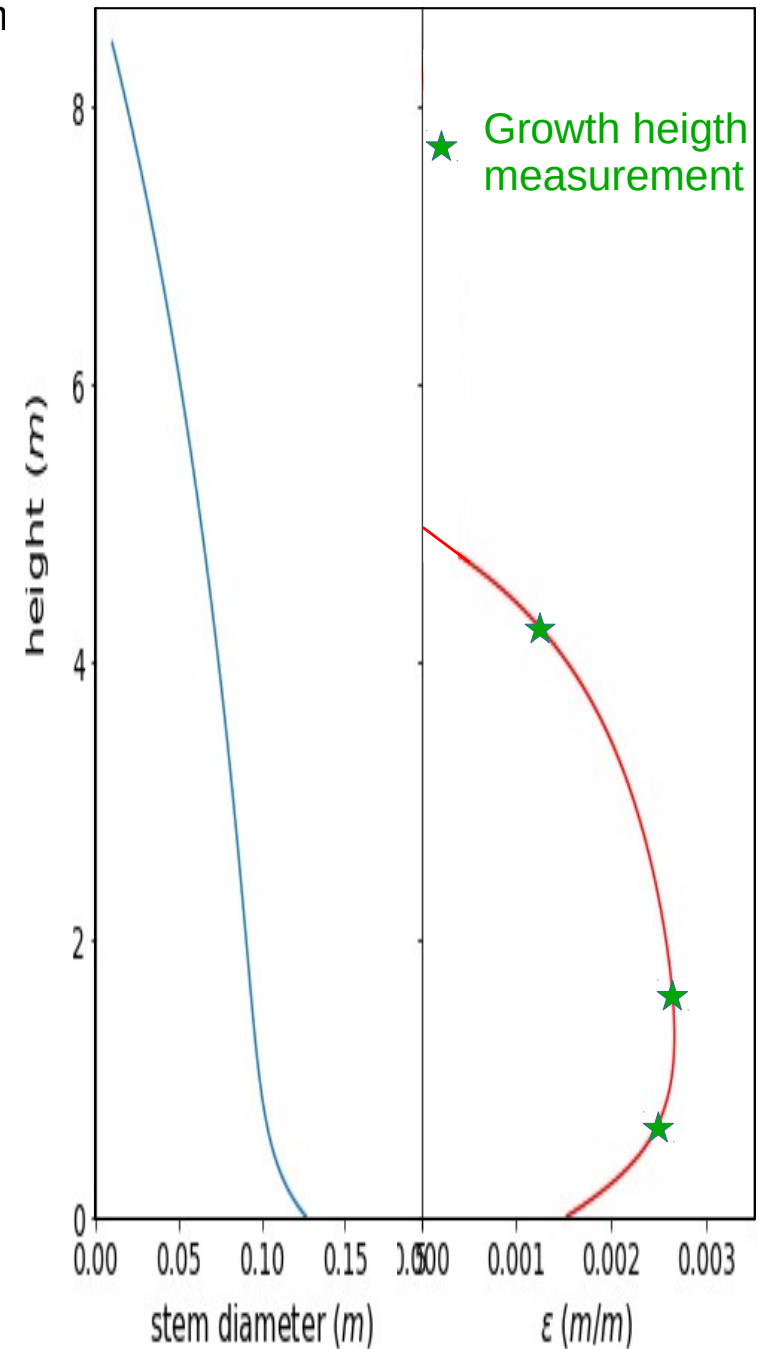
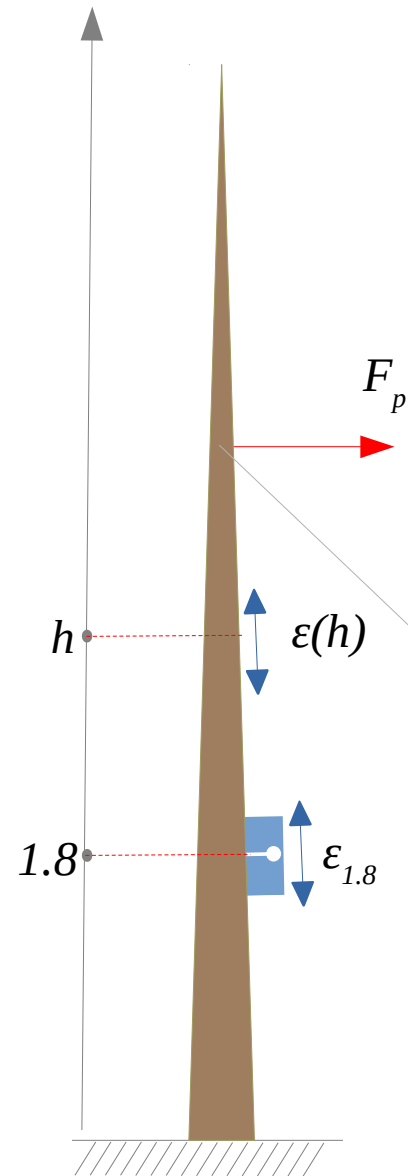
# $\varepsilon$ evaluation at point-dendrometer position

Local strain along the trunk could be express from that at at sensor strain fixed at 1.8 m height

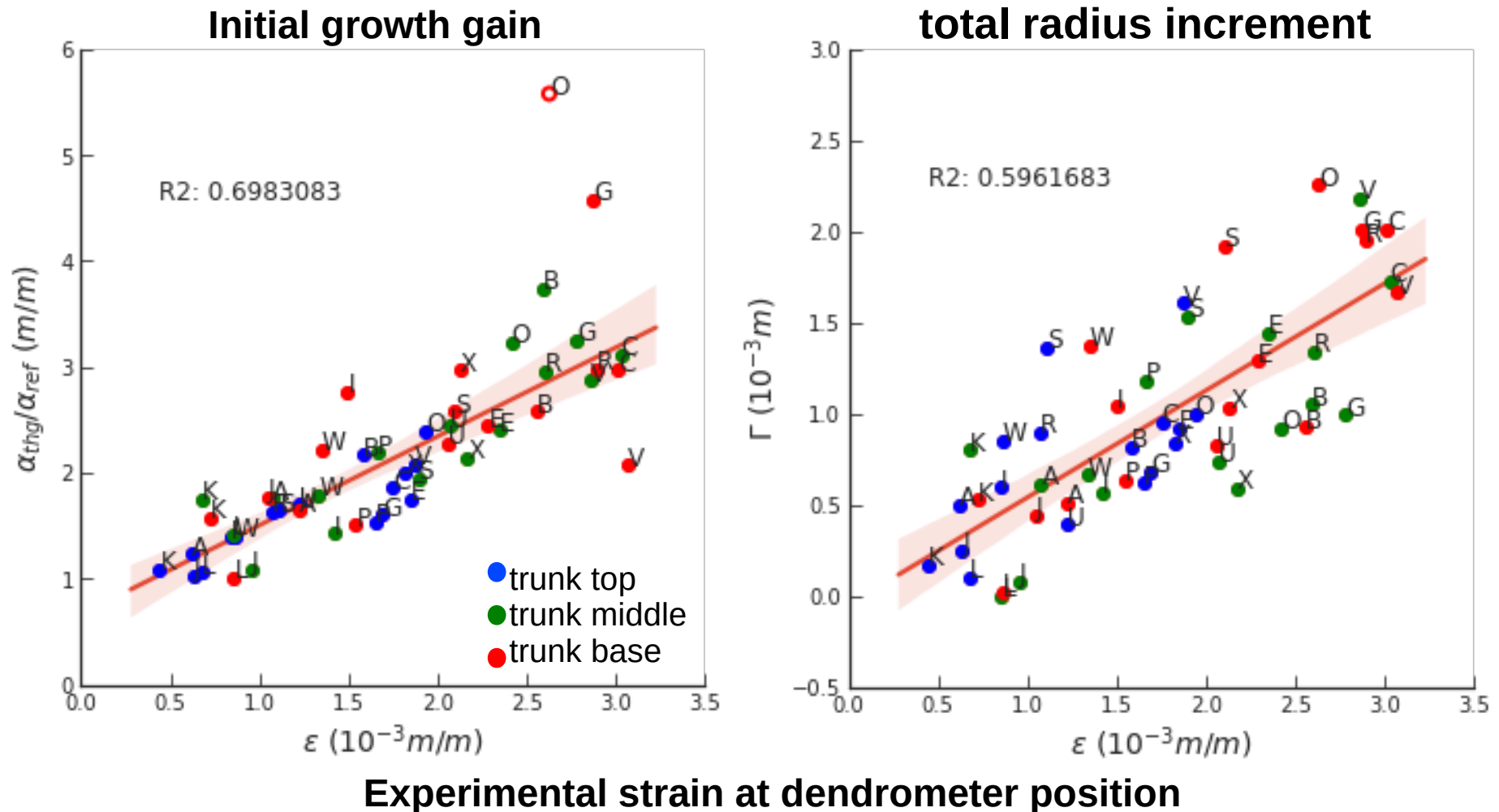
$$\left\{ \begin{array}{l} \varepsilon(h) = \frac{M(h)}{EI(h)} \cdot \frac{d(h)}{2} \\ M(h) = (h_p - h) \cdot F_p \\ I(h) = \frac{\pi d(h)^4}{64} \end{array} \right.$$

Local strain along the trunk could be express from that at at sensor strain fixed at 1.8 m height

$$\varepsilon(h) = \varepsilon_{1.8} \frac{h_p - 1.8}{h_p - h} \left( \frac{d_{1.8}}{d_h} \right)^3$$

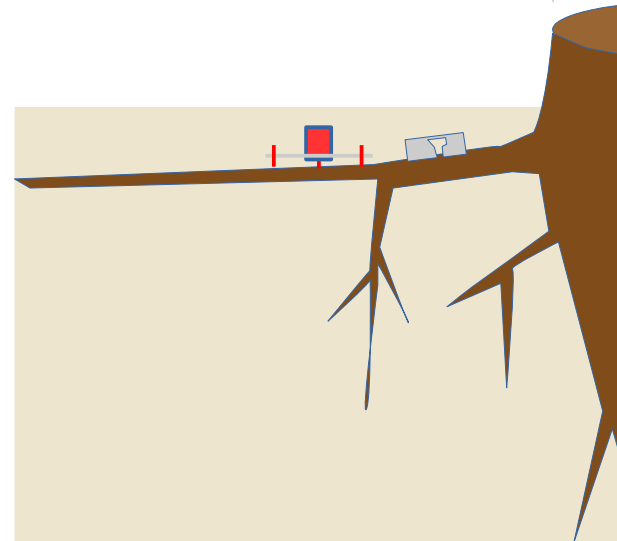
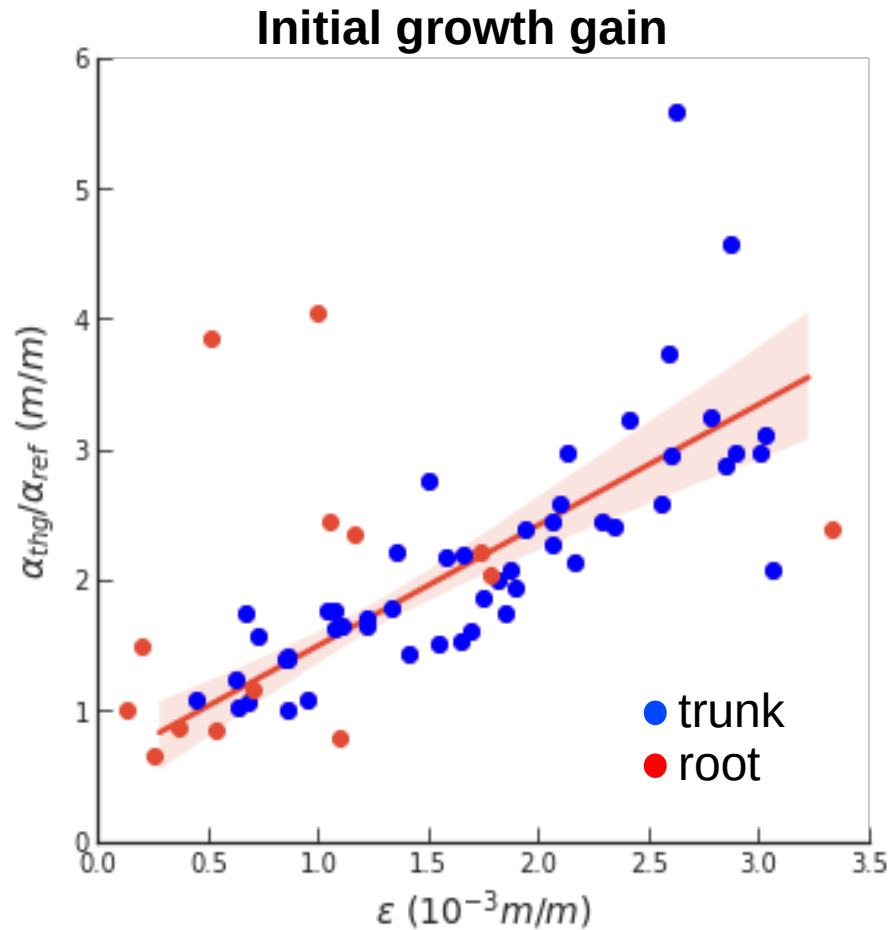


# A simple response of growth to tissue strain



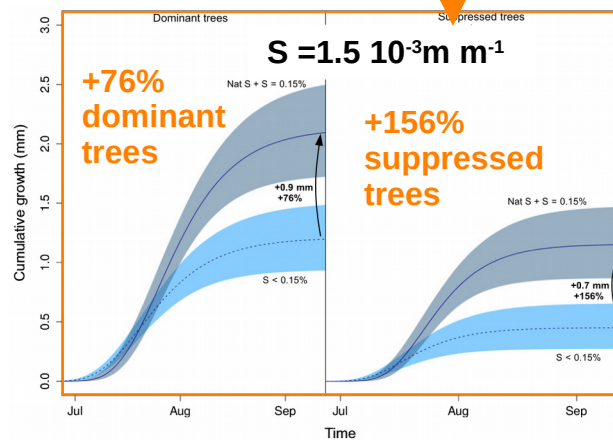
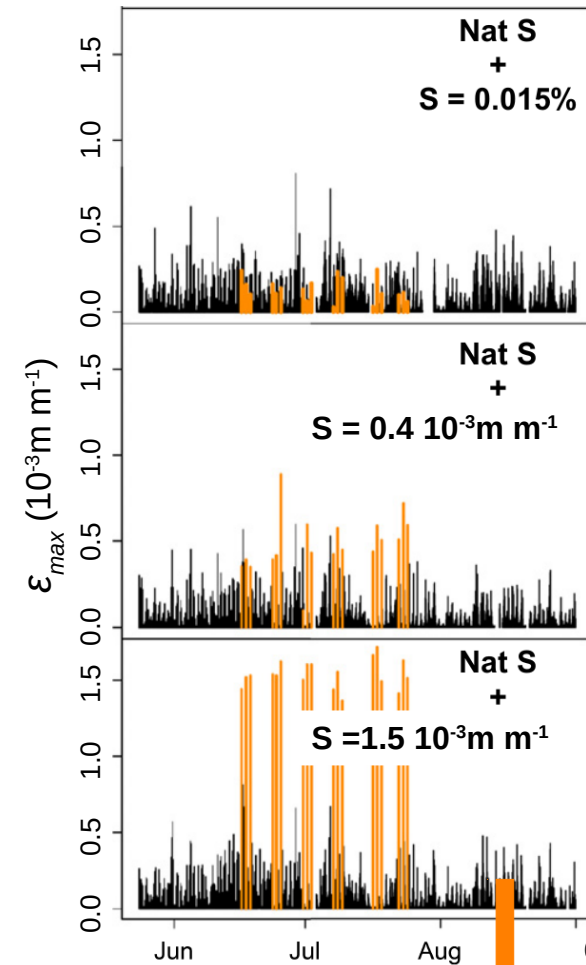
- A global homogeneity of the growth response to strain
  - Between trees and inside tree
  - Coherent with Sum of Strain-Sensing Model S3M (Coutand and Moulia, 2000; Moulia et al., 2011)
- A response that could be very large

# What about roots case ?

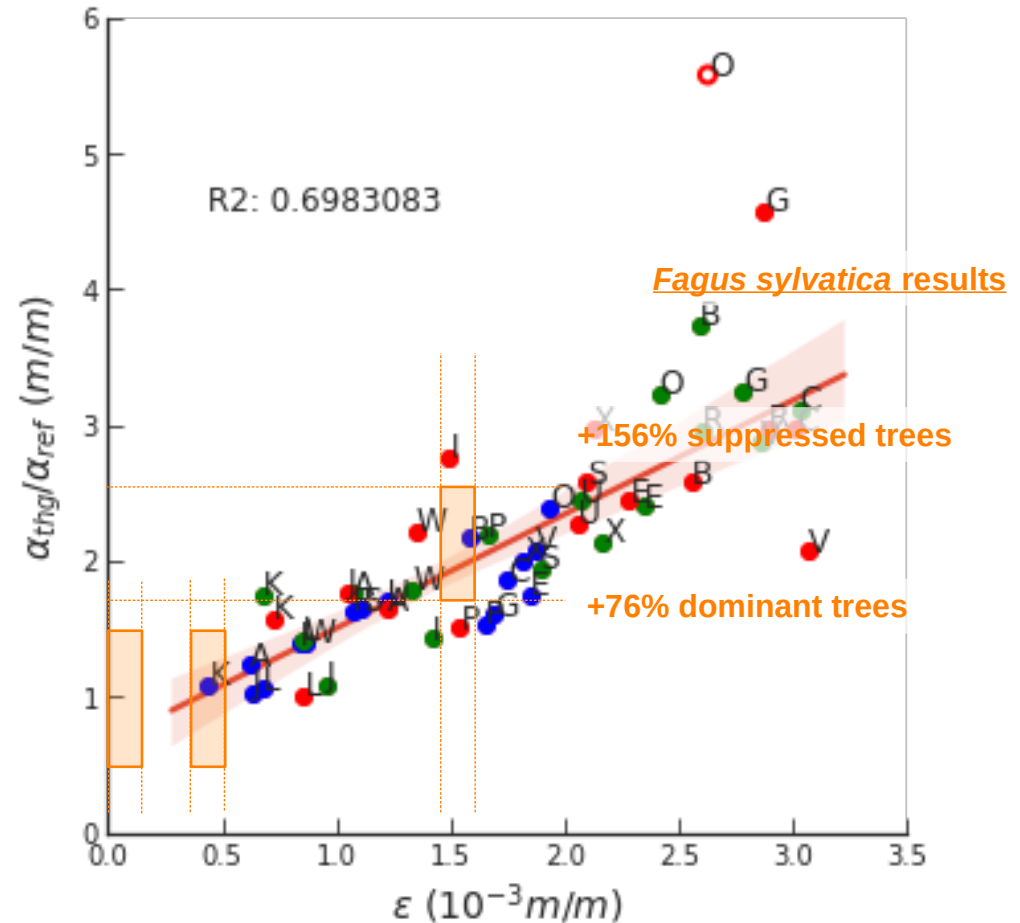


- A more important dispersion of relative growth increment. But ...
  - A clear reaction of a part of roots that don't have growth before pull treatment,
  - In some cases, the distance between strain and growth sensors (~20cm) could reflect contrasted tissue strains and be unsuitable to analyze the growth response.

# Comparison with Bonnesoeur et al. (2016) results on *Fagus s.*



Growth gain



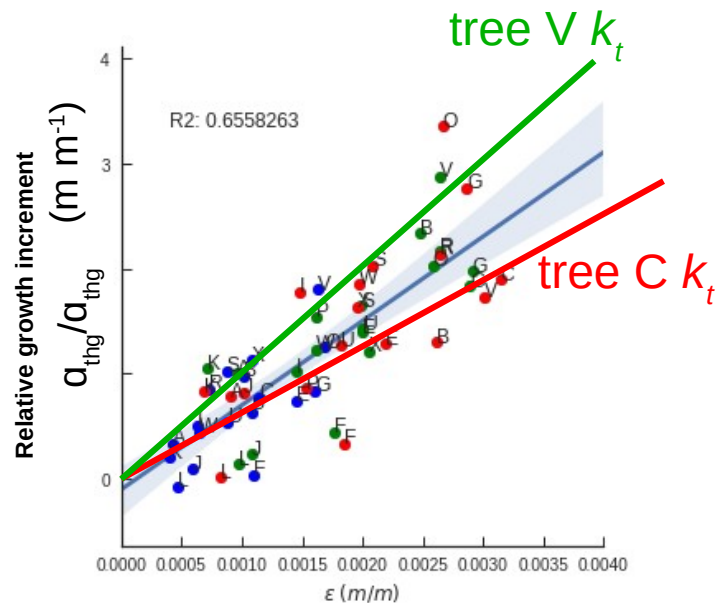
Experimental strain at dendrometer position



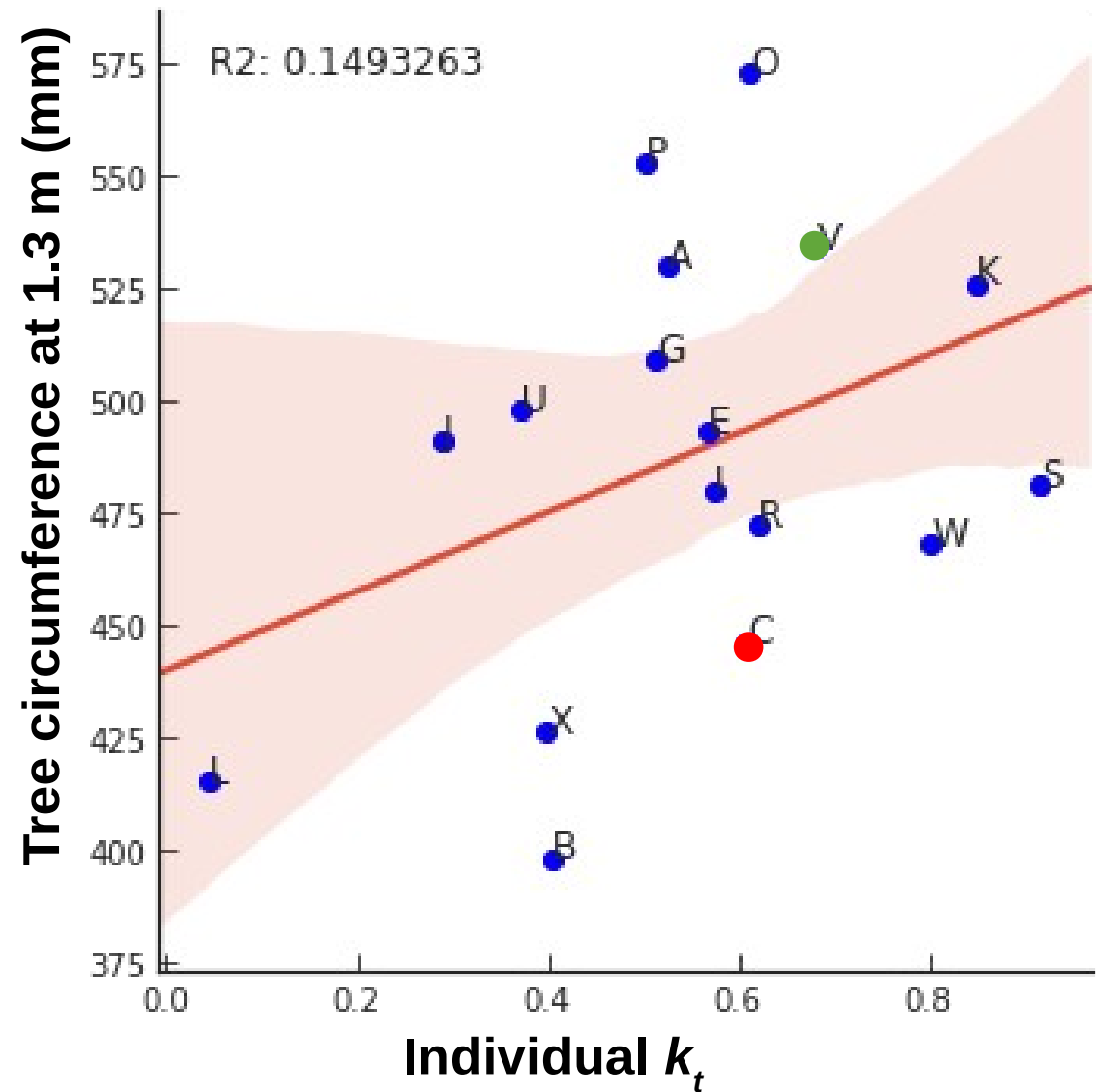
# A part of the secondary growth vigor is explained by thigmomorphogenesis reactivity

The profile of strain generated by pull experiment could be use to access an individual thigmomorphogenesis reactivity ( $k_t$ ) :

$$\alpha_{thg} / \alpha_{ref} = k_t \cdot \varepsilon$$

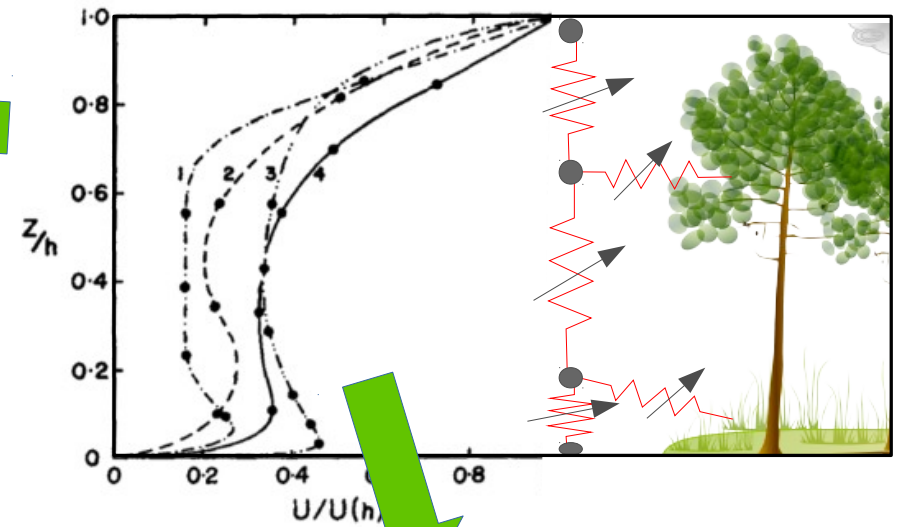
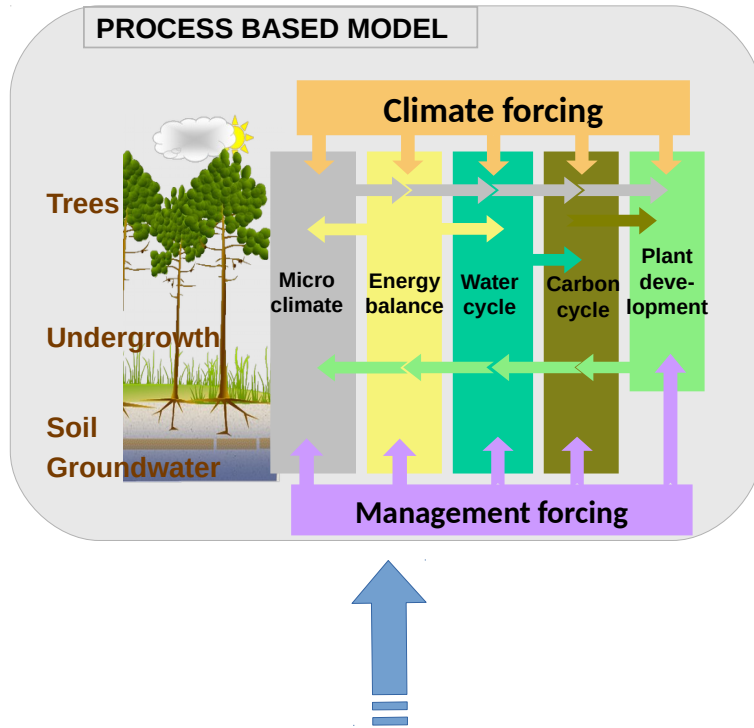


Experimental strain at microdendrometer position

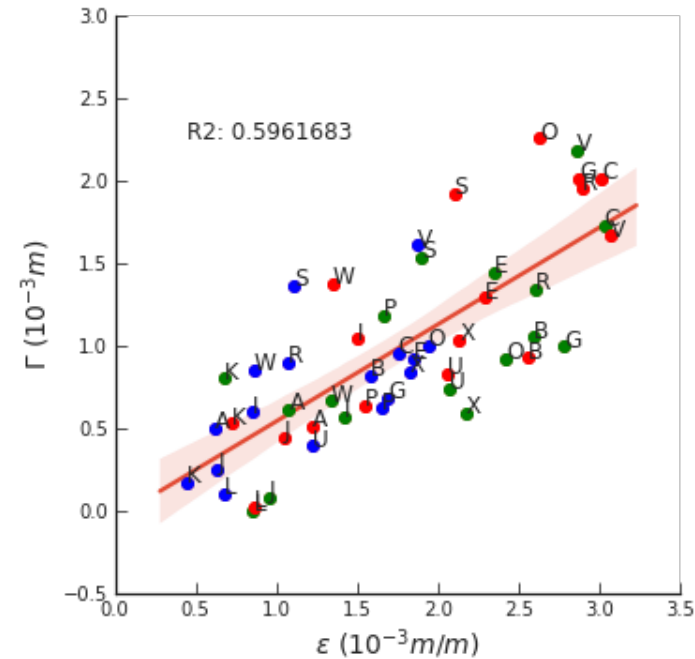


# So, what about wind in our forest process based model ?

## 1. Aerodynamic effects are modeled



## 3. Thigmomorphogenesis.



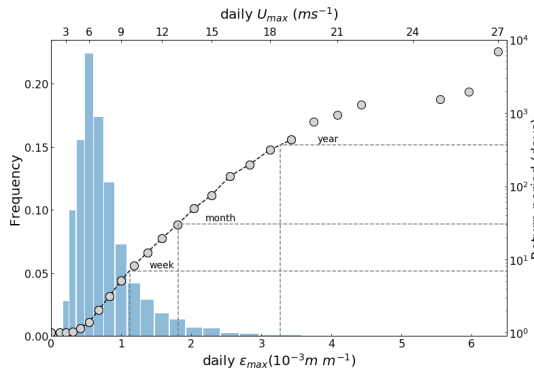
## 2. Vulnerability and stability



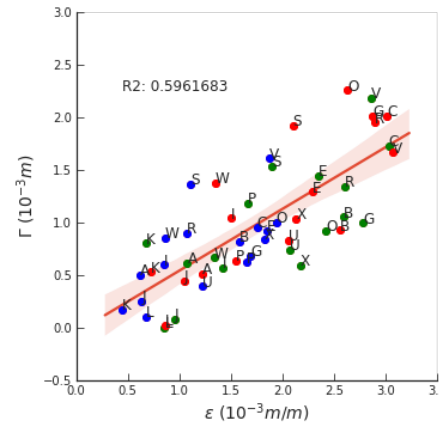
# Perspectives:

## 1 – test the role of different wind ranges on acclimation

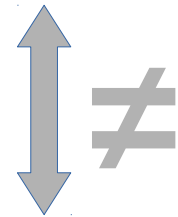
- What our results suggest



X



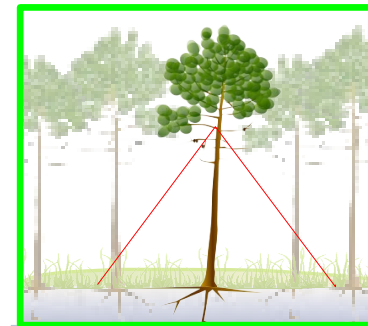
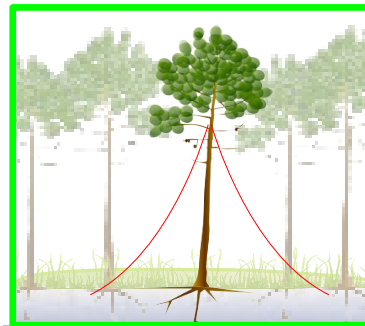
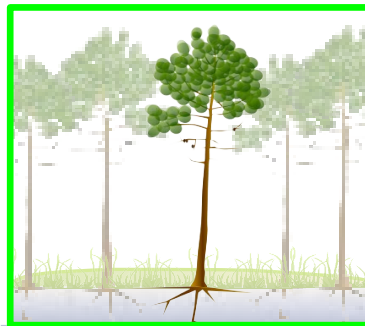
Main role of low winds on growth control



- Bonnesoeur et al (2016)

Forest trees filter chronic wind-signals to acclimate to high winds

- A design to filter different levels of high strains

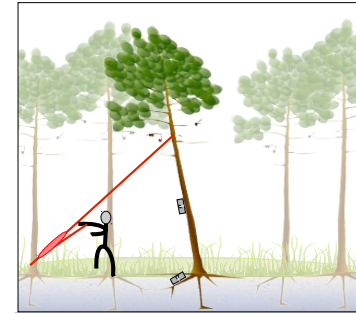


# Perspectives:

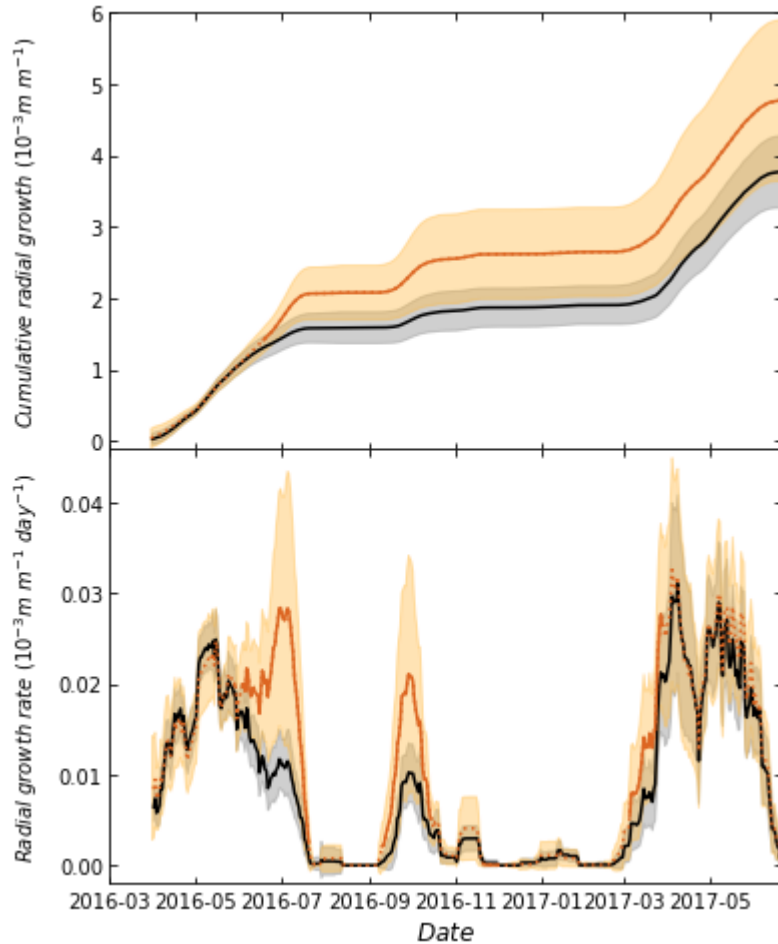
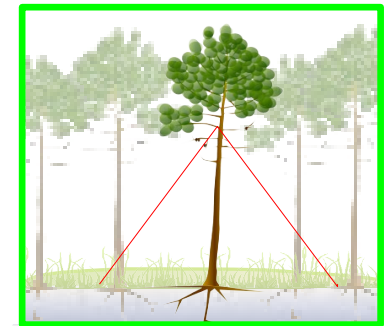
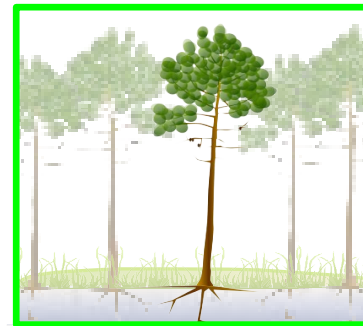
## 2 – Are all solicitation periods equivalent?

→ 2 designs envisaged

- Artificial bending at different seasons



- Seasonal filter of natural strains





- Experimental :
  - Thimomorphogenic effects of wind on primary growth in forest
  - Interaction of thigmomorphogenic effects and tree carbon cycle
  - ...
- Integration in process model
  - describe strain distribution inside the tree
  - Reconceptualisation of growth process between resources limitations and wood functions

# Conclusion

- Thigmomorphogenesis appears to be a process that control Pinus pinaster growth in the the range of the effects of chronic winds
- There is yet many lack of knowledge before a really integration in process based model
- Thimomorphogenesis could be study as an ecophysiological process but probably also as allometric modulation factor.

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*The story between the **wind and trees** is not limited to a game where the tree can die*

# Acknowledgments

- J.-M. Bonnefond, D. Garrigou, R. Kubath, S. Debesa
- Unité expérimentale de Pierroton
- Projet VENTPIN - Région Aquitaine