Light transmittance measurement as a tool to keep track of phenology and leaf development : a case study on oak

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Introduction

With ongoing climate change

Changes in tree phenology

ex : Increase in temperature => early budburst date (but not in some cases)

Changes in leaf quantity

ex : decrease of LAI after a drought

Introduction

⇒ Necessity to follow tree phenology on the long-term

To better assess the impact of climate change on ecosystem functioning, species distribution, …

⇒ Necessity to assess the evolution of LAI on the long-term

To better predict forest dynamics (including understorey vegetation)

Introduction

Direct methodologies, visual observations and leaf collections are time-consuming or cumbersome

⇒ Use of an indirect method: light transmittance measurements

Use of solar radiation sensors

Transmittance (T) = radiation below tree canopy / radiation above tree canopy

Beer-Lambert Law : T = exp(-k . LAI)

Introduction

Objectives and hypothesis

1) Transmittance can be used to keep track of oak leaf development during budburst period

=> *Model of transmittance and extraction of a set of parameters characterizing leaf unfolding*

2) It does exist a link between budburst stage and transmittance

=> *Explore links between visual observation of budburst stage and transmittance*

3) The method is independent of year and canopy structure (tree density)

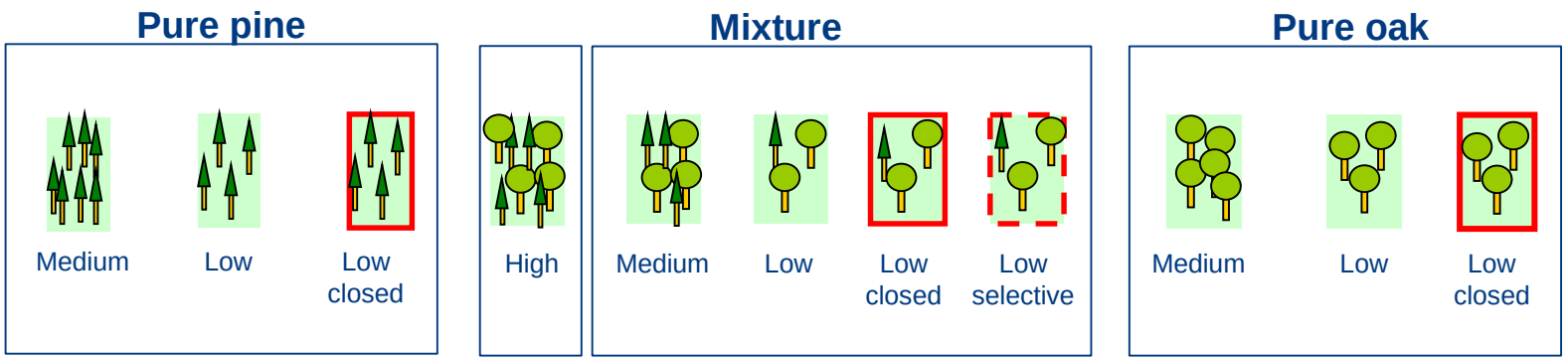
=> *Four consecutive years for two stand densities*

Study site

OPTMix
Oak Pine Tree Mixture

http://optmix.irstea.fr/

1 site = 11 plots ½ ha

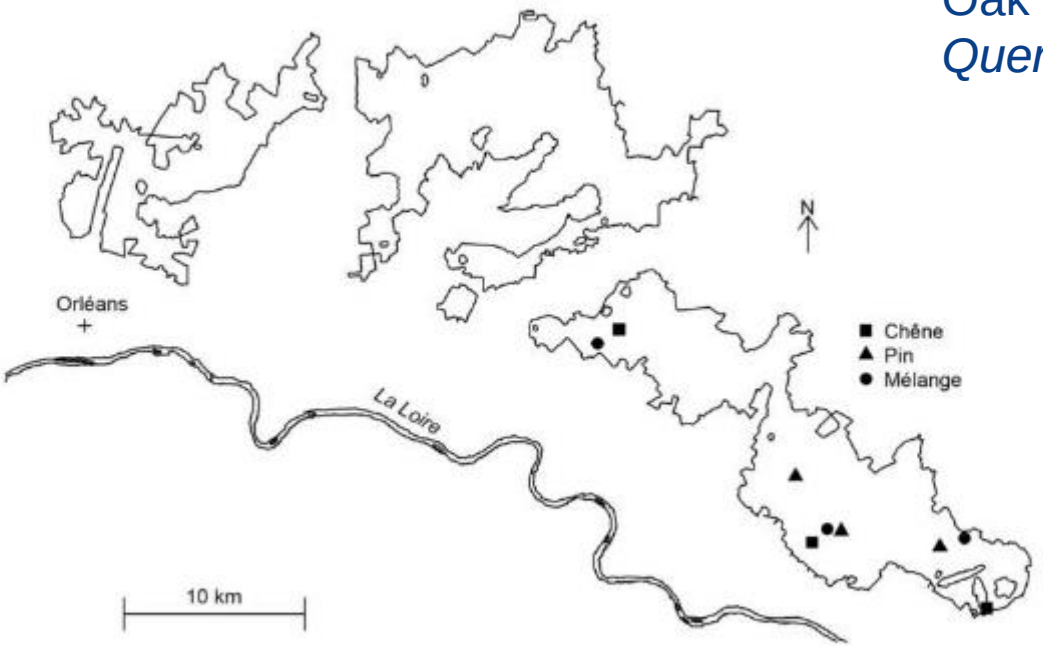


- 3 densities *low* *medium* *high*

Relative Density Index (N/Nmax) : *0.45* *0.7* *≅ 1*

Study site

Three replicates in the Orlean's forest



Oak
Quercus petraea

Pine
Pinus sylvestris

Mixture

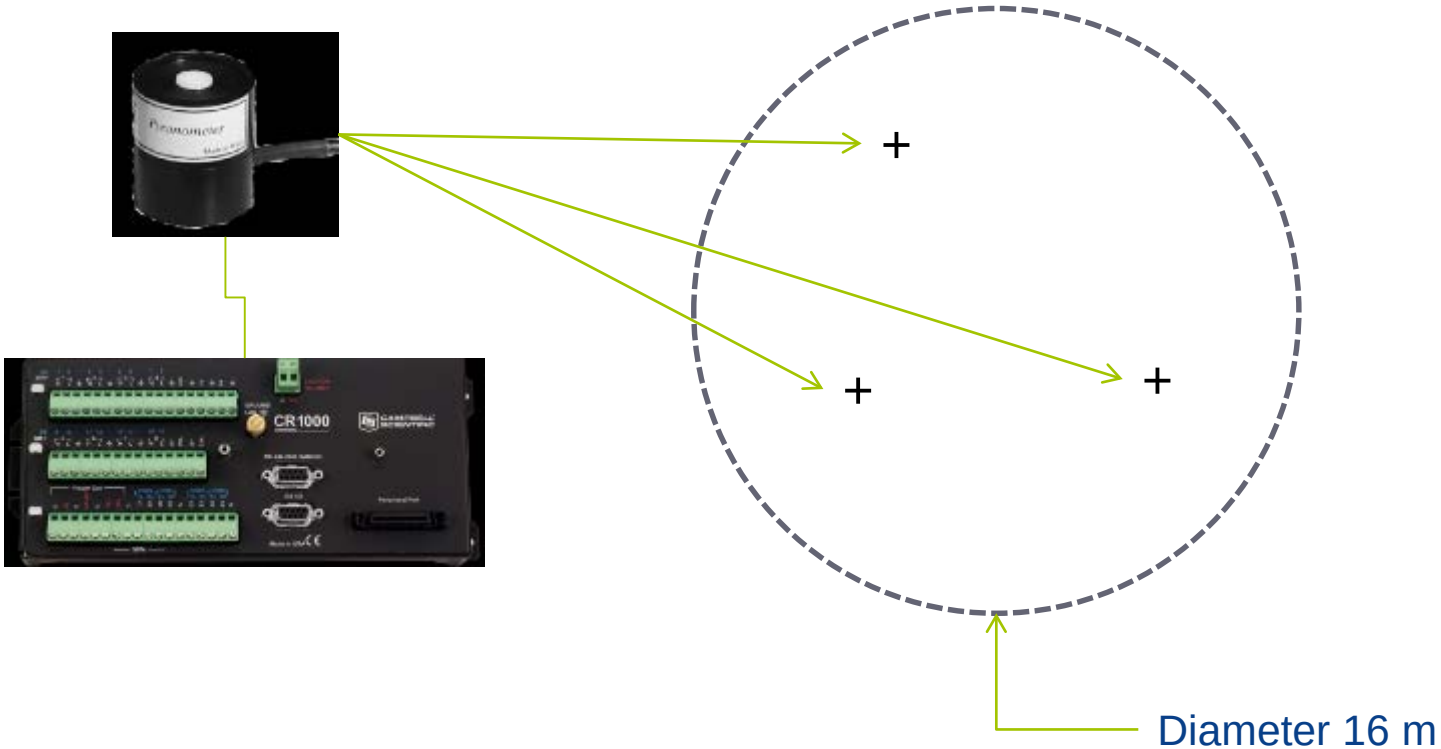
Sampling design

- All the plots with monospecific oak
- A thinning at the end of 2017 (mainly in the low density plots)

Stand name	Density	1st Thinning (year-month)	BA1 (m^2/ha)	Dg1 (cm)	2nd Thinning (year-month)	BA2 (m^2/ha)	Dg2 (cm)	Nb of points	Radiation years	Pheno. years
O12	low	2012-12	14.5	21.7	2017-09	12.8	23.6	3	2015 to 2018	2013 to 2018
O214	low	2013-01	14.7	22.5	2017-10	12.8	24.1	3	2015 to 2018	2013 to 2018
O593	low	2014-03	15.2	26.3	2017-11	12.6	28.9	3	2017 to 2018	2014 to 2018
O12	medium	2012-12	20.6	22.9	No	21.5	23.4	3	2015 to 2018	2013 to 2018
O214	medium	2013-01	19.3	19.9	No	19.9	20.5	3	2015 to 2017	2013 to 2018
O593	medium	2014-03	22.5	24.6	2017-11	21.9	25.6	3	2017 to 2018	2014 to 2018

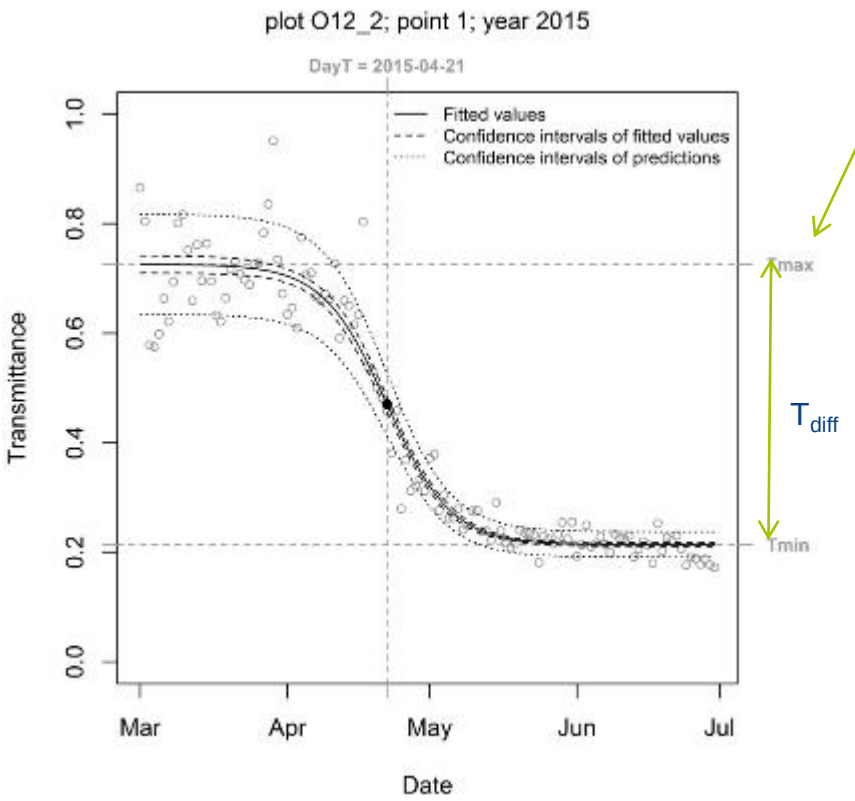
Light measurements

- Sensor of total solar radiations : SP1110 (Campbell scientific)
- 3 points on each plot => 18 points below canopy
- 1 point in open field
- A record every hours from 2015 to 2018



Model of transmittance during budburst period

- Sigmoid
- Fitting for each point and each year



Maximal transmittance (linked to WAI)

Minimal transmittance (linked to PAI = WAI + LAI)

Part of radiation intercepted by developing leaves

$$T = T_{min} + \frac{T_{diff}}{1 + e^{(c_T(Day - Day_T))}}$$

Date at the inflexion point

Rate of foliage development

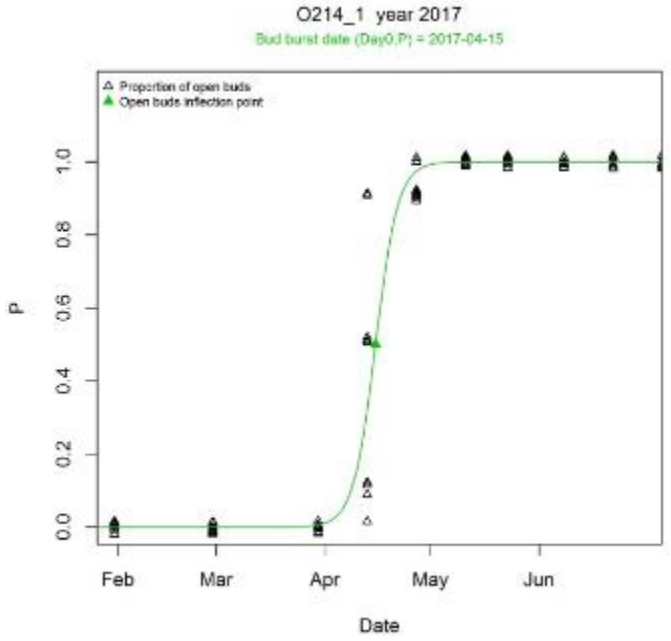
Visual observations of budburst stage

- Observations on 9 trees per plot from 2013 to 2018
- Note of the percentage of open buds every 15 days
- Fitting of a logistic per plot
- Budburst date = 50 % open buds

Target stage = open bud

[Stade 09]
Bout des feuilles sorti

Badeau *et al*. (2017)



Links between budburst date and transmittance

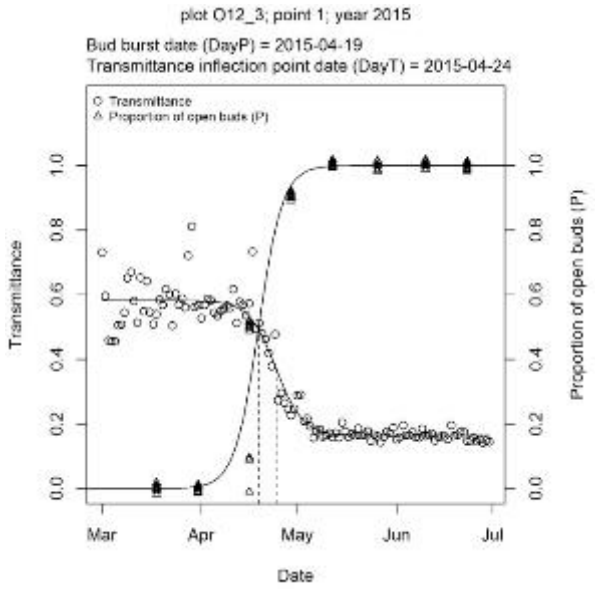
- Test of different indices to deduce budburst date

Ex1 : Difference between budburst date and transmittance inflexion date

Ex2 : Radiation part intercepted by leaves at the budburst date

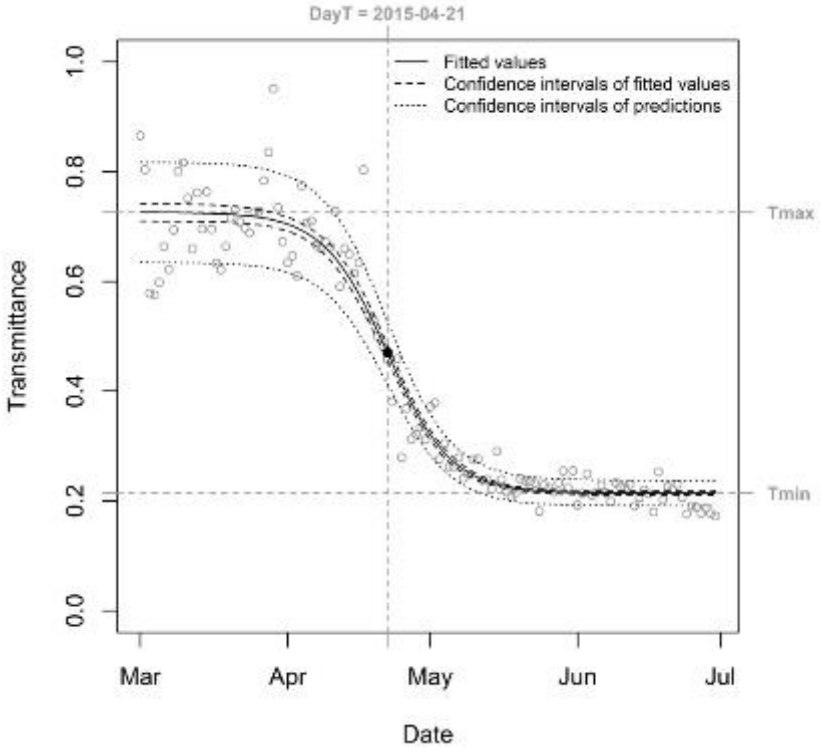
$RI_{openbuds}$ = Tmax – T(budburst date)

- Multiple regressions between budburst date and transmittance parameters

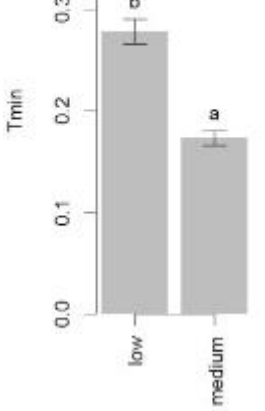


Results: Transmittance model

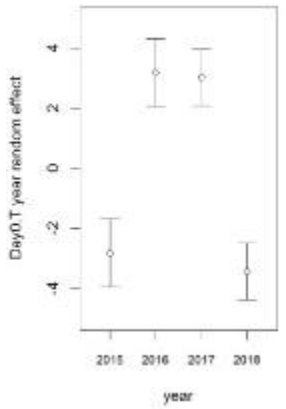
- Density effect on Tmin, Tmax and Tdiff
- Year effect on cT and DayT
- Year effect on Tmin at low density due to thinning



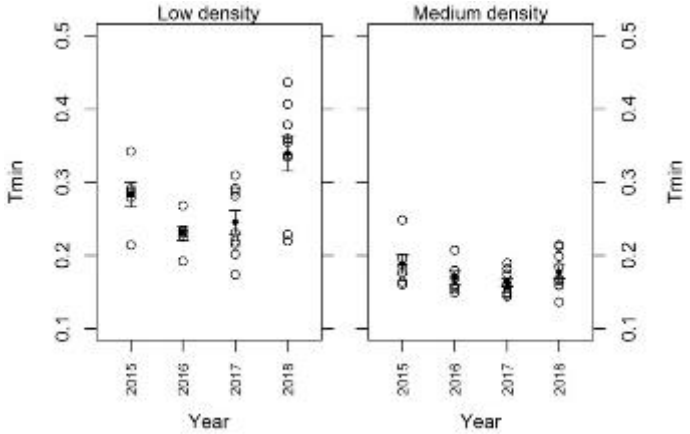
Density



Year

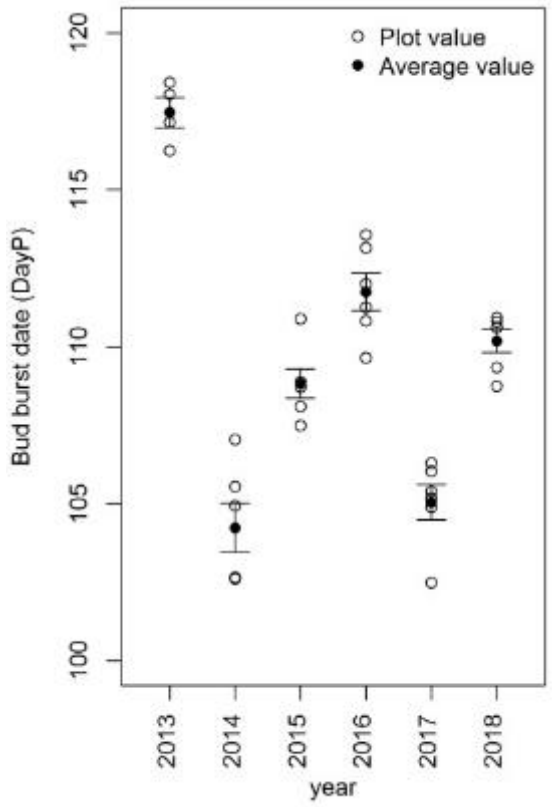


Thinning effect (end of 2017)



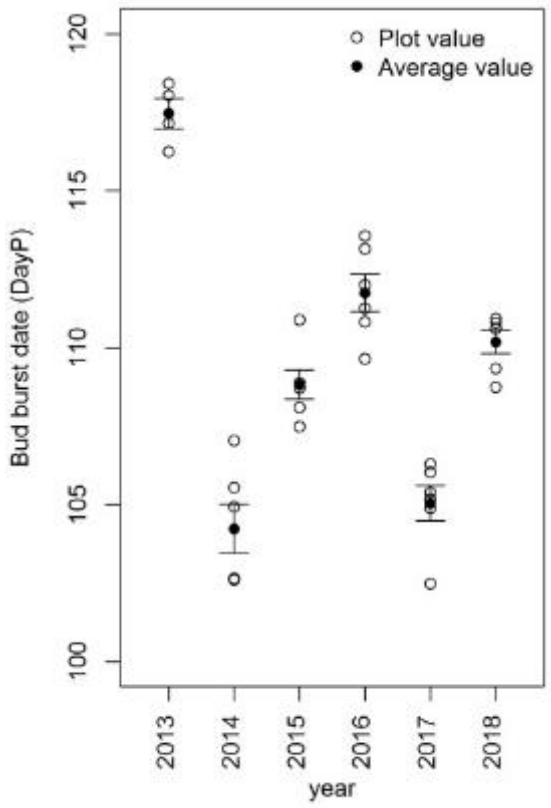
Results: Budburst dates

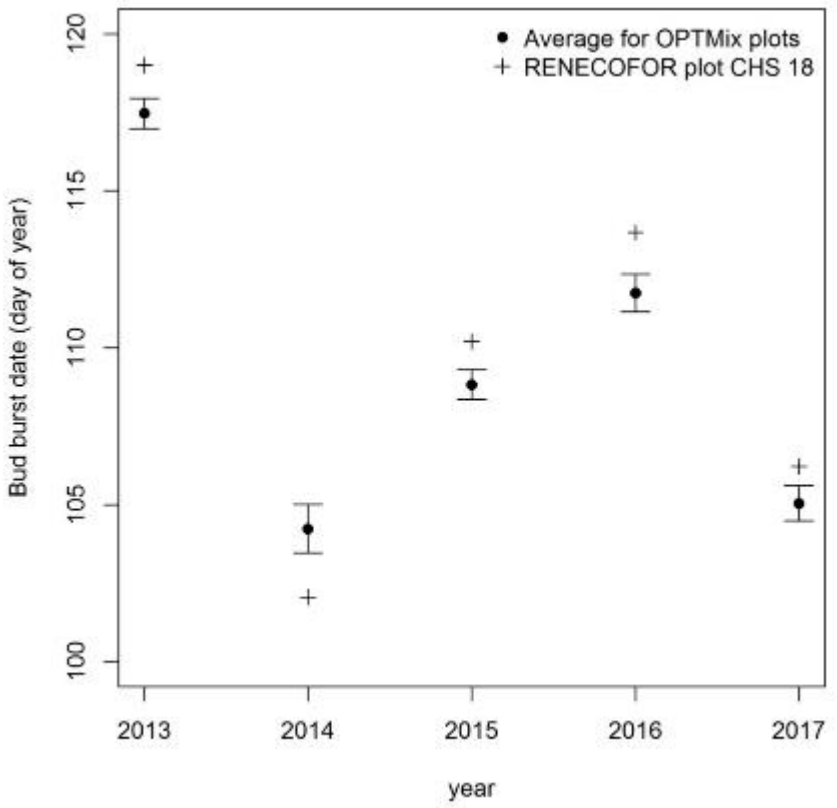
- Mean day = 117 (27th April), Standard error (year effect) = 4.8 days
- Maximal difference between 2013 and 2018 : 13 days



Results: Budburst dates

Comparison of budburst dates with the RENECOFOR Network (Vierzon's forest)



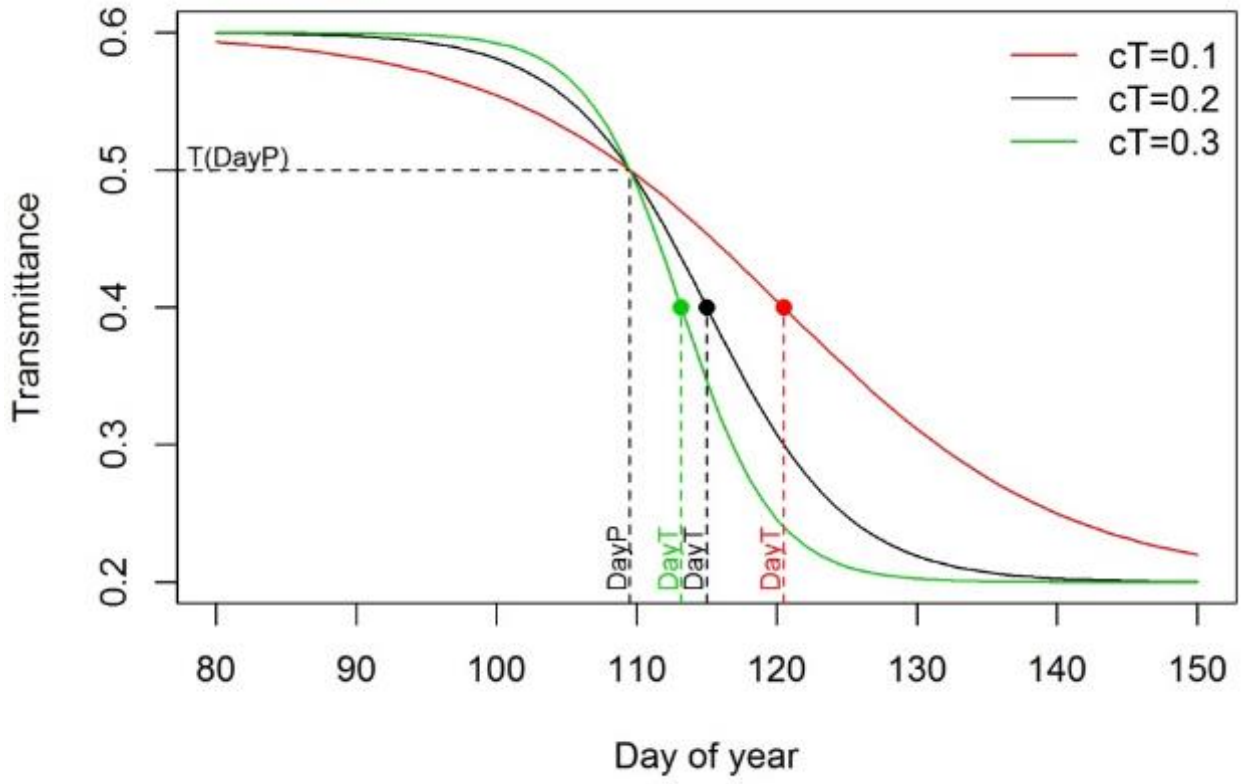


Results: Budburst dates and transmittance

- No direct link between budburst date and DayT (date at the inflexion point)

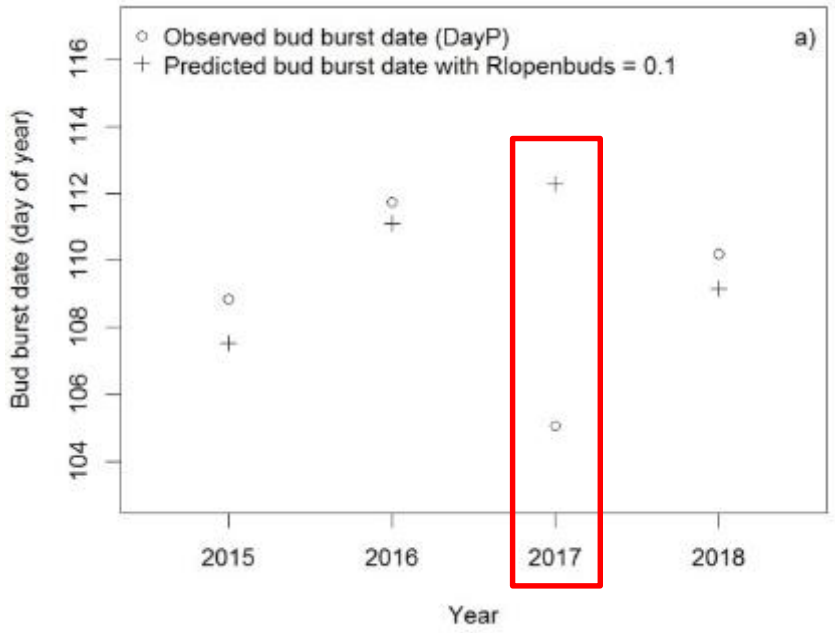
⇒ Because of leaf development rates different from a year to another

⇒ As a function of meteorological conditions after budburst date (temperature)



Results: Budburst dates and transmittance

- Radiation part intercepted by leaves at the budburst date : mean $RI_{openbuds}$ = 0.1
- Significant density and year effects

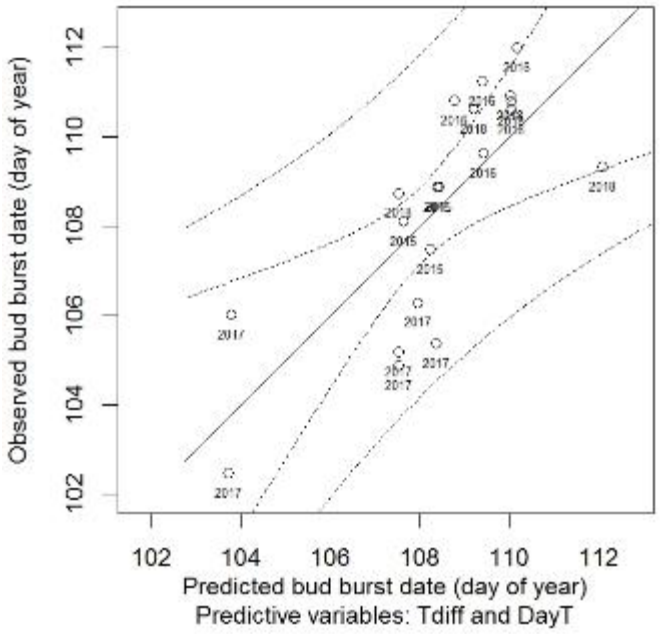


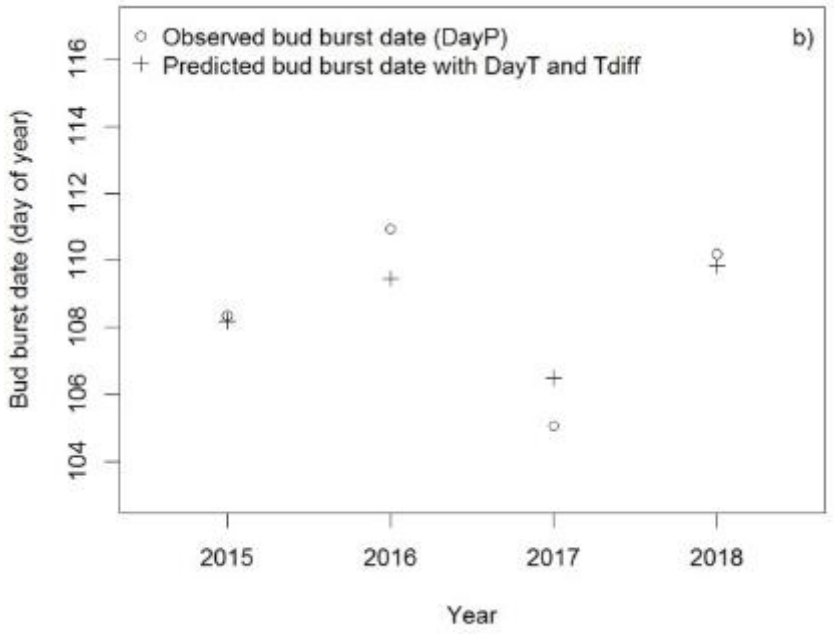
Budburst date poorly estimated in 2017

Linked to late frost ?

Results: Budburst dates and transmittance

- Regression between budburst dates and some parameters of the transmittance model : DayP = f(DayT , Tdiff) ; R^2 = 57%





Conclusion

- Modelling transmittance during leaf unfolding :

=> A set of parameters characterizing leaf development

- No simple relationship between budburst date and the parameters of the transmittance model

- But we can deduce an approximate budburst date (mean error of 2 days)

- It is possible to estimate LAI from Tmax linked to WAI and Tmin linked to PAI, data not shown, a next time!

Thanks!


Quentin Guitard
Jean-Pierre Hamard
Nathalie Korboulewsky
Sandrine Perret
Patrick Vallet
Philippe Balandier
Rachel Barrier
Marion Gosselin
Sonia Launay
Catherine Menuet
OPTMix
irstea
Yann Dumas
Vincent Seigner
Agnès Rocquencourt
Anders Mårell
Yves Boscardin
Thomas Pérot

Link between cT and air temperature