How does climate influence the phenotypic variability of larch along an altitudinal gradient ?

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Larix decidua

Study Context

- <u>General objective :</u>

Determine biological adaptive potential of larch population to climate change

- Several approaches possible: experimental trial, biogeographic gradient…

<u>We choose to study in natural population along an altitudinal gradient:</u>

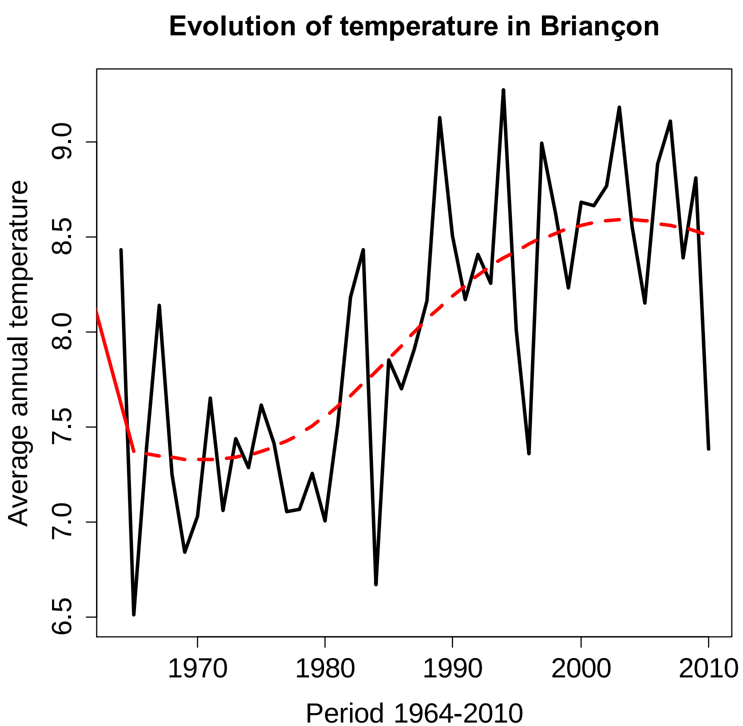
- Natural population in their own environment, old trees
- Strong environmental variations (mainly temperature), possible pressures of selection, adaptation ?
- Low geographic distance, same photoperiod, probable weak soil differences
- Other variables: competition, insect attack…
- Neutral evolutionary processes can influence phenotypic variability (as genetic drift)

2 axis of variation of temperature

Temperature fluctuates:

- In space (along altitudinal gradient)
- in time (between years)

→ can affect phenotypic variability



Microdensity approach

- Provide the information enclosed in the successive tree-rings
- Decode the phenotypic variability for each year as tree response to environmental change

increment core

Wood character may be related with **adaptive value :**

– **Ring width**

Highly integrative character. In certain conditions, an important growth may indicate a more favorable environment

– **Ring density**

Related to resistance to cavitation (Hacke et *al*, 2001, Dalla-Salda et *al*, 2011)

Objective of this study

Is there phenotypic variability for ring width along an altitudinal gradient of larch ?

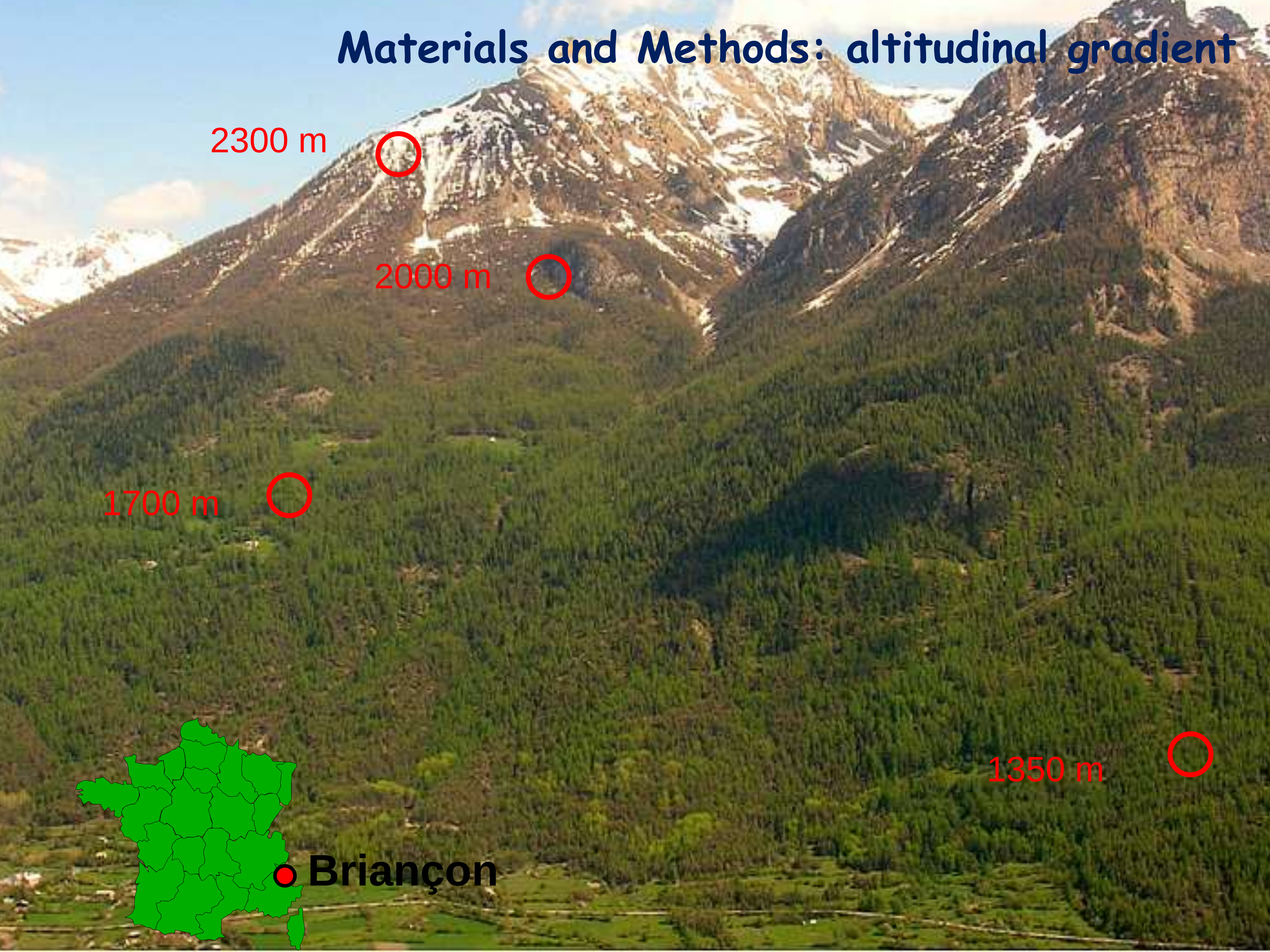
- Could nonselective evolutionary processes and/or selective pressures explain phenotypic variability along the altitudinal gradient ?

- Is there a more favorable altitude for larch ? If yes, where is this altitude ?

- How does it vary along years?

– Is the relationship observed along the gradient (space) consistent with the one observed along the years ?

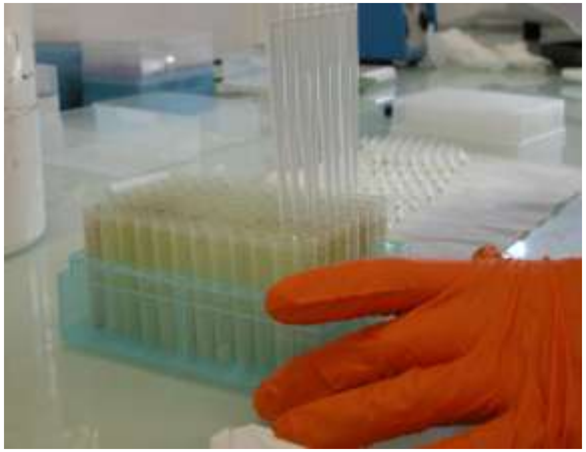
Materials and Methods: altitudinal gradient



Materials and Methods
Neutral evolutionary process

- <u>Neutral diversity :</u>
  - 11 microsatellites markers,

    788 trees (175 - 212 individuals per altitudinal levels)
  - Analyses :
    - Diversity index, Heterogeneity expected (He)
    - AMOVA (Excoffier, 1992)



Materials and Methods - Microdensity

- 1 - X-Ray radiography (Ploge 1966)
- 2 - Windendro 2008e Regent instruments Canada inc,
- 3 - Interdat,exe version 1.1, Jean-Luc Dupouey

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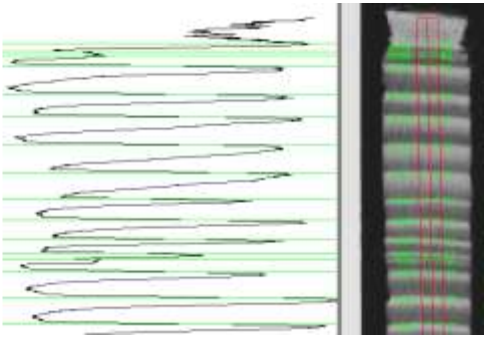

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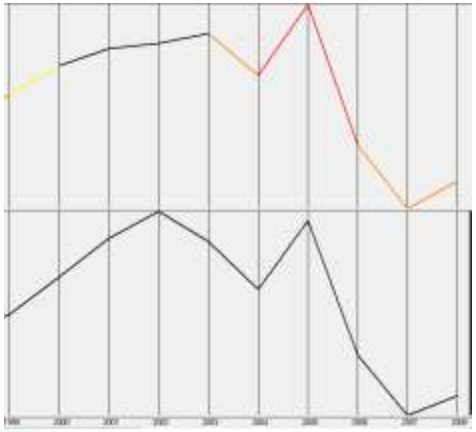


Ring analysis :

- 555 trees (130 -155 individuals for each altitudinal levels)
- 41 ring per tree (41 years →1967-2007)

Materials and Method - Others factors

- **Cambial age**
  - each ring have a distinct cambial age
- **Competition**
  - For each tree, we have associated a competition index
  - Here, competition index is derived by CI of Hegyi 1974:

Competition index i = Sum ((diameter j) / distance ij)

with only competitors with diameter upper the 0,8 * the diameter of the tree studied in the distance of 14 meters.

- **Insect attack**
  - years with insect attack are identified *(Zeiraphera diniana)*

→ adjusted data

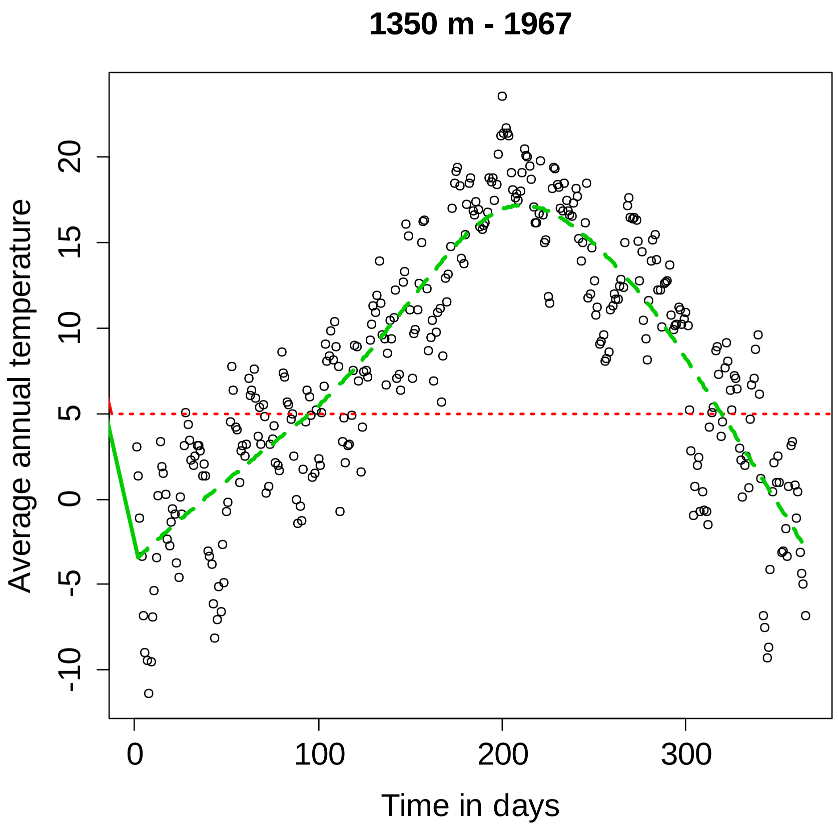
- **Soil difference + Solar radiation difference → Observed but no adjusted**

Materials and Methods : definition of growing season (GS)

For conifers in cold climate, xylogenesis begins at temperature above 5°C (Rossi et *al*, 2008)

Definition of the growing season: Temperature above 5°C

	1350m	1700m	2000m	2300m
T°C	12.13	11.36	10.25	9.19
length of GS	218	197	168	145
Beginning of GS	96	110	128	143
End of GS	314	307	297	288



Adjustment of other factors

- We test the effect of each variable, successively

	F value	significance	R2	improvement	significance
Cambial age (AC)	2723,948	***	0,089	-	-
Competition index (CI)	2491,457	***	0,170	2199	***
Insect attack (IA)	1389,690	***	0,261	1377,4	***
AC.CI	69,138	***	0,263	68,733	***
AC.IA	27,930	***	0,265	27,833	***
CI.IA	40,002	***	0,268	40,002	***

ANOVA Model:

- $Yijkl = \mu + ACi + CIj + IAk + (AC,CI)ij + (AC,IA)ik + (CI,IA)jk + \mathrm{E}ijkl$

Results: Influence of neutral evolutionary process

Results:

- High genetic diversity
- Low difference in diversity between altitudinal levels
- Very low differentiation (Fst General = 0,0152 ***, AMOVA)

Altitude	Ho	He
2300 m	0,741 (SE : 0,034)	0,739 (SE : 0,029)
2000 m	0,740 (SE : 0,038)	0,757 (SE : 0,033)
1700 m	0,739 (SE : 0,029)	0,761 (SE : 0,027)
1350 m	0,742 (SE : 0,016)	0,751 (SE : 0,015)
total	0,742 (SE : 0,031)	**0,761** (SE : 0,029)

Conclusions:

- Drift and mutations do not influence phenotypic variability / important gene flow
- Hypothesis "adaptive phenotypic variability along the gradient resulting from selection pressure" can not be rejected

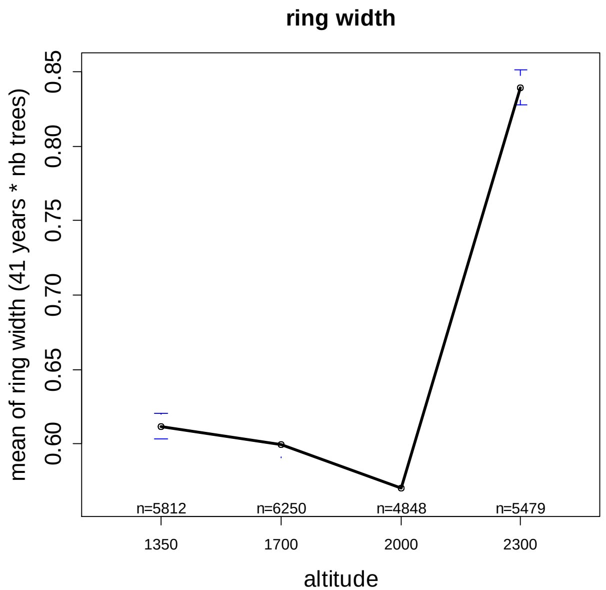
Results: ring width and spatial variability

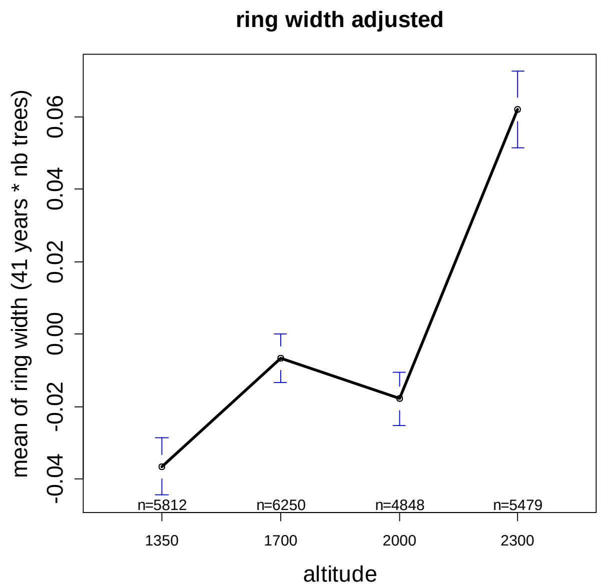
ANOVA to test phenotypic variability

(Ring_width)ij = *μ* + (*altitudinal_levels)i* + Eij

Ring width	F_value	p_value
raw	895,8	< 2,2e-16 ***
adjusted	231,43	< 2,2e-16 ***

- Existence of phenotypic variability along this gradient
- In general, altitude most favorable to larch is at the highest altitude (2300m)

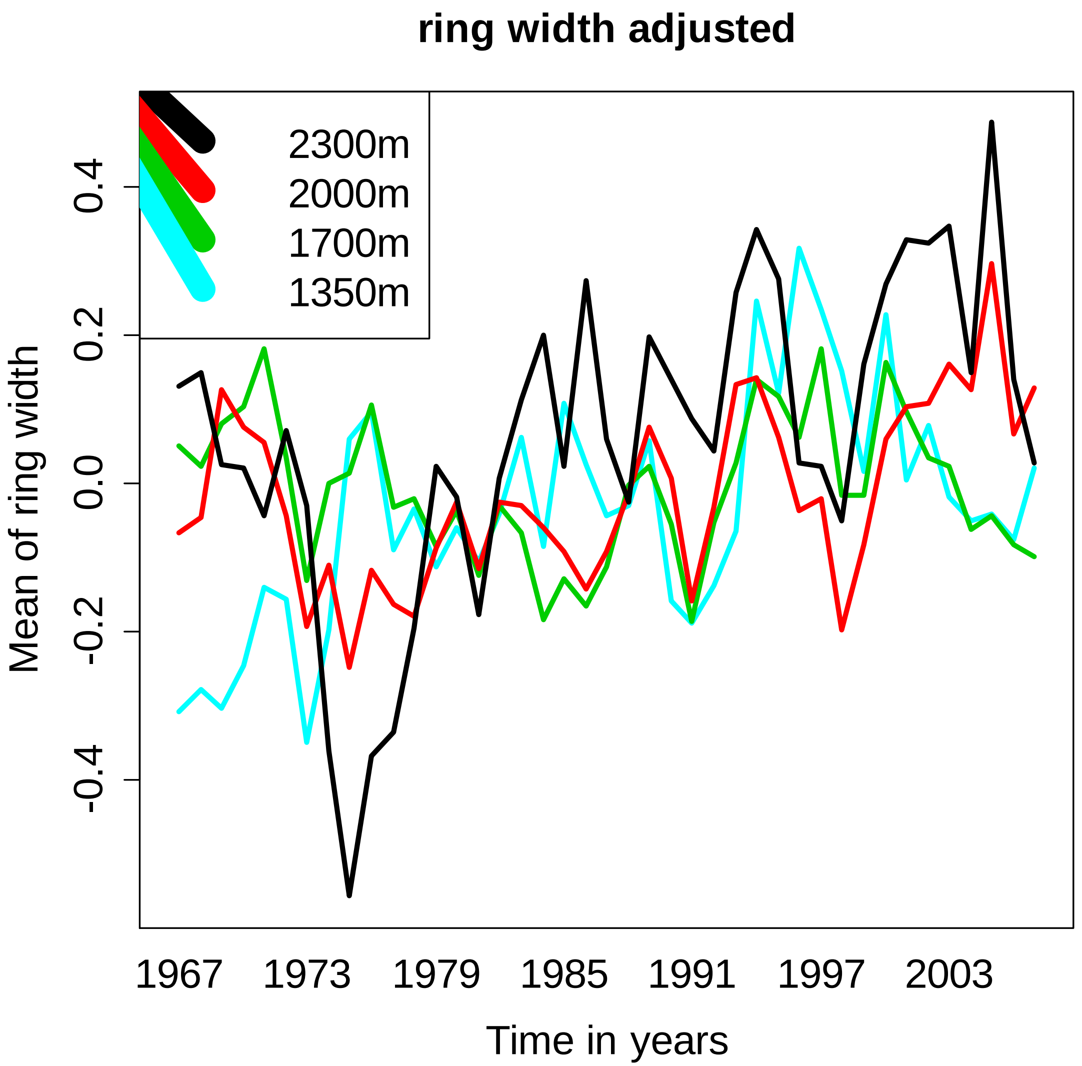




Spatial * temporal variability

- optimum of growth can be modified between years
- Confirmation of optimal growth à 2300m

optimum_growth	number_years
2300	**20**
1700_1350	5
No optimum	4
1350	3
Others	< 3



Effect of climate in temporal phenotypic variability

	temperature	precipitation
2300m	0,40 (0.01 *)	-0.07 (0.66 ns.)
2000m	0.27 (0.08 ns.)	-0.26 (0.10 ns.)
1700m	-0.12 (0.45 ns.)	-0.004 (0.98ns.)
1350m	0.15 (0.33 ns.)	0.10 (0.52 ns.)
All levels	-	-

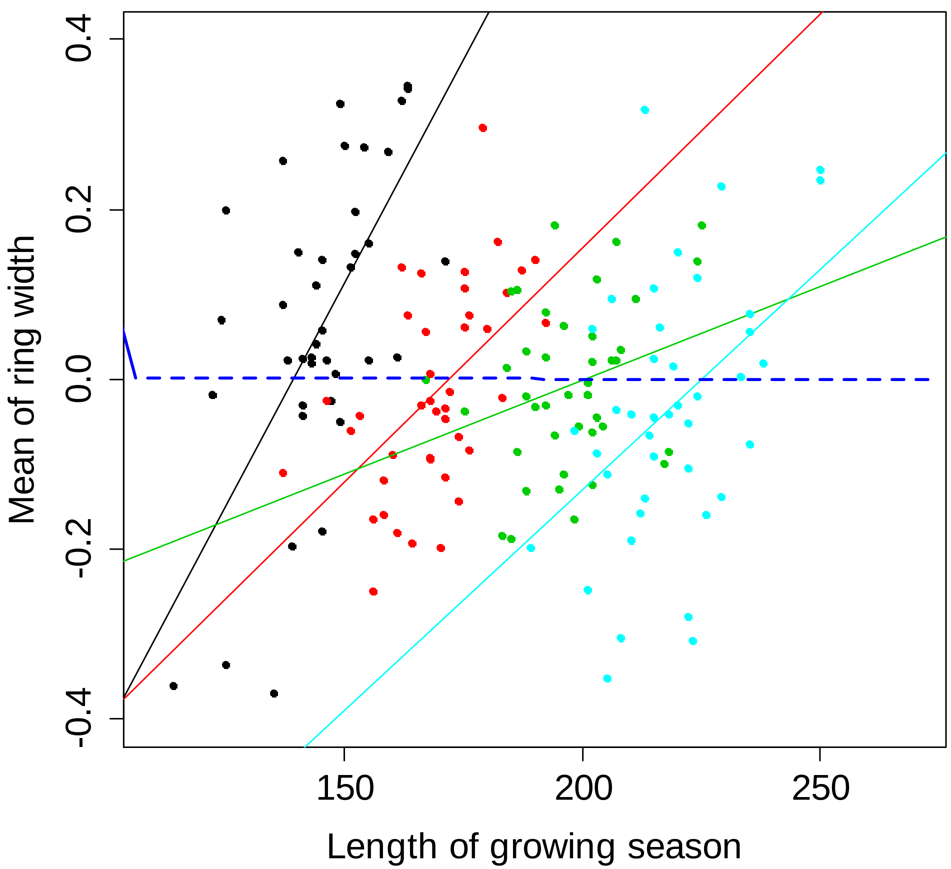
- Temperature and precipitation are low explicative factor

Effect of climate in phenotypic variability

	Length growing season
2300m	0.61 (2.6e-05 ***)
2000m	0.53 (0.0003 ***)
1700m	0.27 (0.08 ns.)
1350m	0.44 (0.004 **)
All levels	-0,002 (0,98 ns.)

- Length of the growing season is the most explicative factor
- Positive and significant relationship within altitudinal levels VS no relationship for all levels

ring width / growing season relationship



Discussion

- Strong relationship ring width / length of growing season observed within altitudinal levels, with stronger relationship for populations of high altitude
  - This is an expected result, because the temperature is more limiting in altitude
- High altitude appears as the most favorable environment despite lower temperature and shorter growing season
  - surprising result...

→ The relation ring width / temperature observed through space and time are inconsistent. Why ?

Discussion

→ The relation ring width / temperature observed through space and time are inconsistent. Why ?

- Insufficient adjustment or omission of a factor?
  - Younger trees on the highest plot. need to confirm the validity of adjustments (created age groups ....)
- The differences of temperature along this gradient does not play a role in phenotypic variability ?
  - tree height
  - Ring density (for the coherence time / space)
- Transplantation experiment could confirm or refute this trend

Thanks for you attention…

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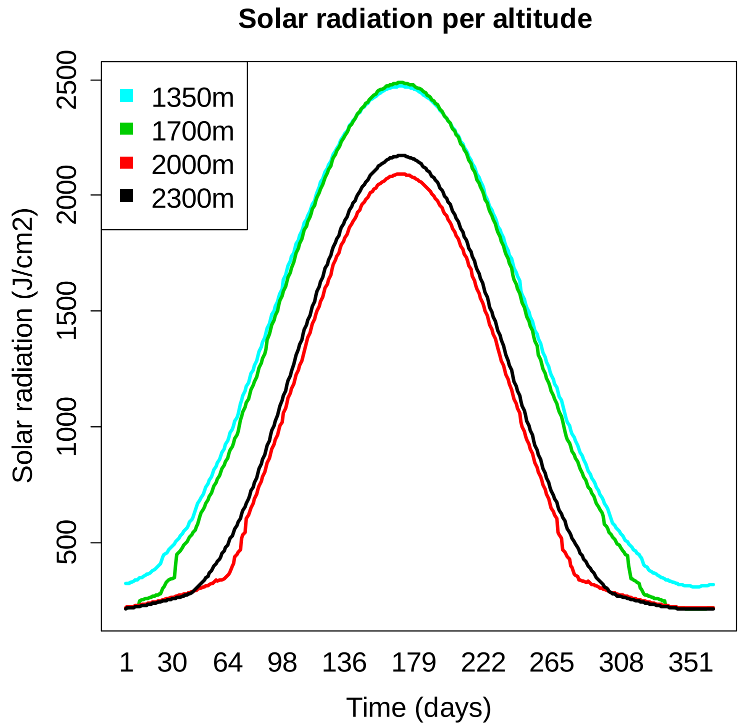
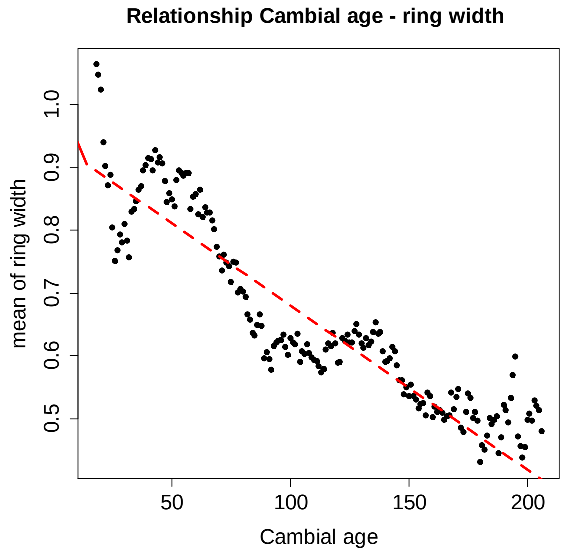
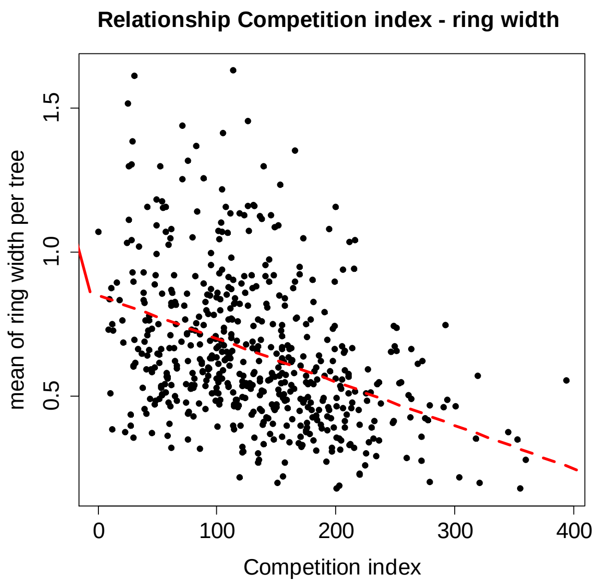
- Région Centre

Others factors

Altitude	profundity (cm)	% fine soil	chemical fertility
2300m	55	48,3	9,1
2000m	60	49,1	9,6
1700m	60	48,9	13
1350m	35	55	7,8







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