Ecological trends in wood production dynamics of coniferous forest

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Outline of the Presentation

1. Introduction

2. Material & Method

- GloboXylo Dataset presentation
- Elaborated data computation
- Basic model of wood production dynamics

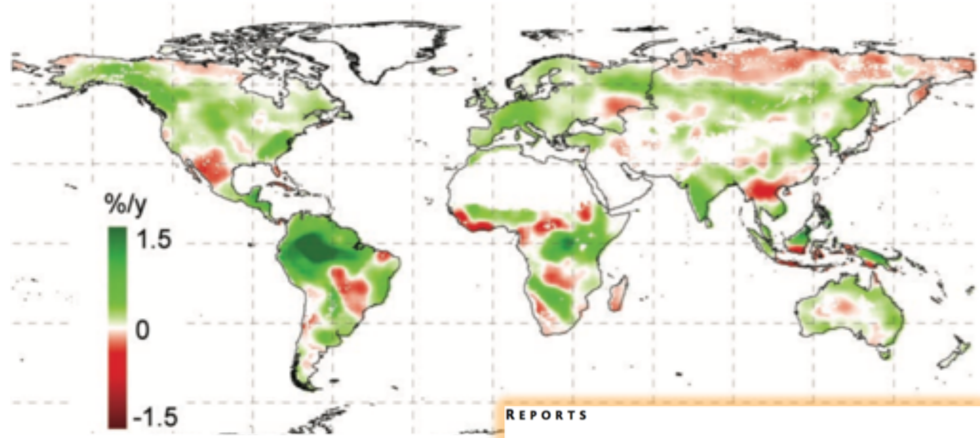
3. Results

- Biogeographic patterns
- Dynamics vs. phenology of growth
- Biome and species strategies
- Influence of environmental factors

4. Discussion & Perspectives

EARTH GREENING AND GLOBAL CHANGE?

- **Recent global change induced an increase in:**
  - Tree growth
  - Forest ecosystem NPP
  - Terrestrial biosphere carbon up-take
  - Forests are one of the largest C sink on earth
- **These changes are attributed to rising temperatures by**
  - Remote sensing
  - Direct observations
  - Eco-physiological models
- **Scientific Questions:**
  - Duration vs. rate of growth?
  - Effect of climatic factors



REPORTS

Climate-Driven Increases in Global Terrestrial Net Primary Production from 1982 to 1999

Ramakrishna R. Nemani,[1*†] Charles D. Keeling,[2] Hirofumi Hashimoto,[1,3] William M. Jolly,[1] Stephen C. Piper,[2] Compton J. Tucker,[4] Ranga B. Myneni,[5] Steven W. Running[1]

Table 1 | Change of the characteristics of 75-year-old forest stands 2000 in relation to 1960.

Forest stand attribute	Change from 1960-2000 in %	
	N. spruce	**E. beech**
Dominant tree height, *ho*	**+6**	**+9**
Mean tree diameter, *dq*	**+9**	**+14**
Mean tree volume, $\bar{v}$	**+34**	**+20**
Stand volume growth, PAIV	**+10**	**+30**
Standing volume stock, *V*	**+6**	**+7**
Tree number, *N*	**−17**	**−21**
Mortality rate, MORT	NS	−17
Mean tree volume increment $\overline{iv}$	**+32**	**+77**
Shift of $\overline{iv}-\bar{v}$-allometry	**+25**	**+57**
Shift of $N-\bar{v}$-allometry	NS	NS

E. beech, European beech; N. spruce, Norway spruce; *PAIV*, periodic annual increment of volume.
Comparative changes between 2000 and 1960 determined from our fitted linear mixed models (LMMs). We only report changes based on significant calendar year effects; bold numbers: $P<0.05$ (LMM); normal number: $P<0.10$ (LMM). Sample sizes for Norway spruce: $n=157$ (*ho*, *dq*, $\bar{v}$, *V*, *N*, $N-\bar{v}$-allometry), $n=141$ (PAIV, $\overline{iv}$, $\overline{iv}-\bar{v}$-allometry), $n=90$ (MORT). Sample sizes for European beech: $n=225$ (*ho*, *dq*, $\bar{v}$, *V*, *N*, $N-\bar{v}$-allometry), $n=217$ (PAIV, $\overline{iv}$, $\overline{iv}-\bar{v}$-allometry), $n=119$ (MORT). The crucial calendar year effects for a given forest stand attribute might result from one or two significant parameter estimates.

nature COMMUNICATIONS

ARTICLE
Received 7 Mar 2014 | Accepted 12 Aug 2014 | Published 12 Sep 2014 DOI: 10.1038/ncomms5967 OPEN

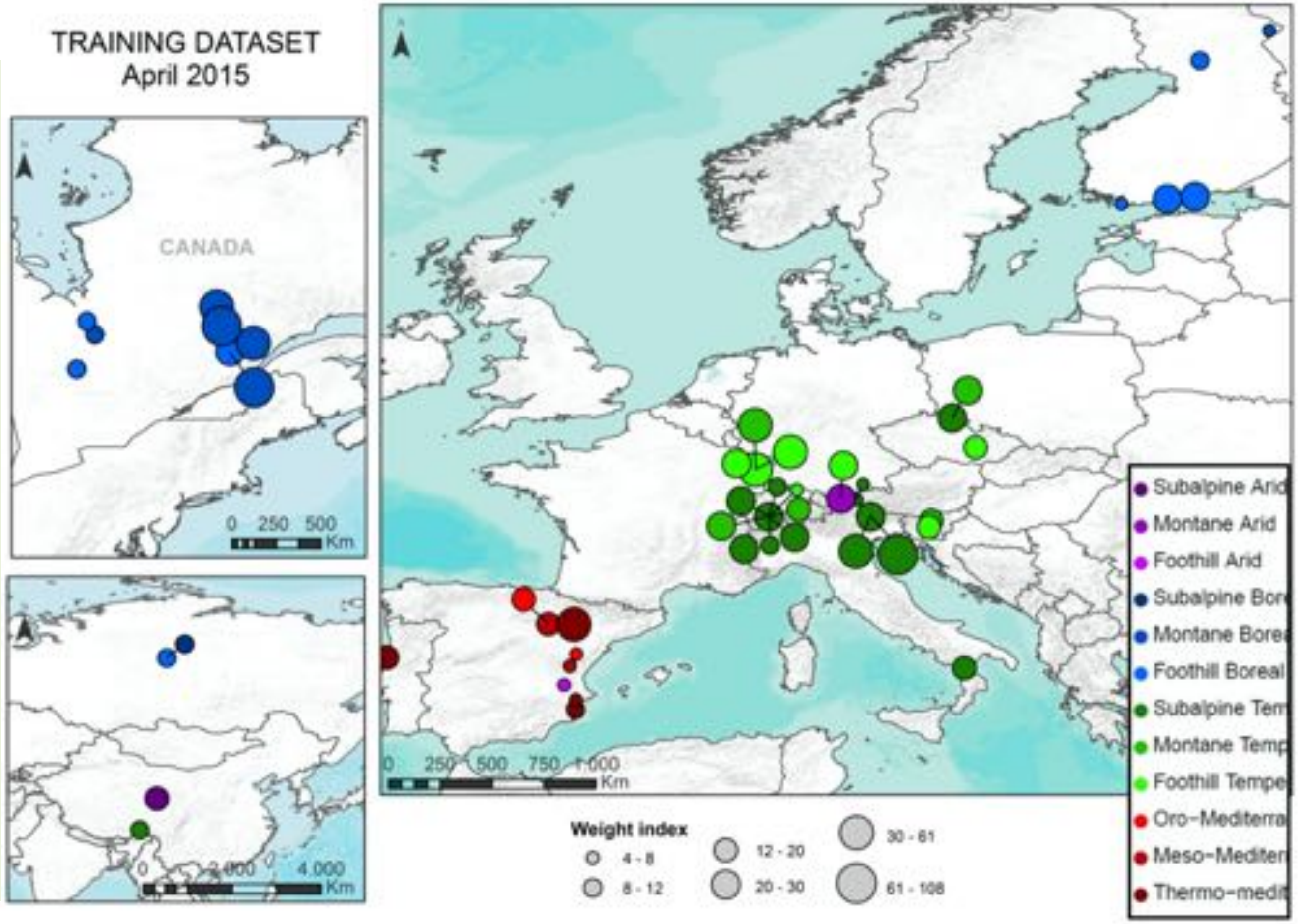
Forest stand growth dynamics in Central Europe have accelerated since 1870

Hans Pretzsch[1], Peter Biber[1], Gerhard Schütze[1], Enno Uhl[1,2] & Thomas Rötzer[1]

GLOBOXYLO DATABASE PRESENTATION

Wood formation monitoring and meteorological data

- > 50 study sites
- 3 continents
  - America
  - Europe
  - Asia
- 4 biomes
  - Boreal
  - Temperate
  - Mediterranean
  - Arid
- 15 conifer species
- 700 trees in total



EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY
COST is supported by the EU Framework Programme Horizon 2020
FPS COST Action FP1106 STReESS - Studying Tree Responses to extreme Events: a SynthesiS

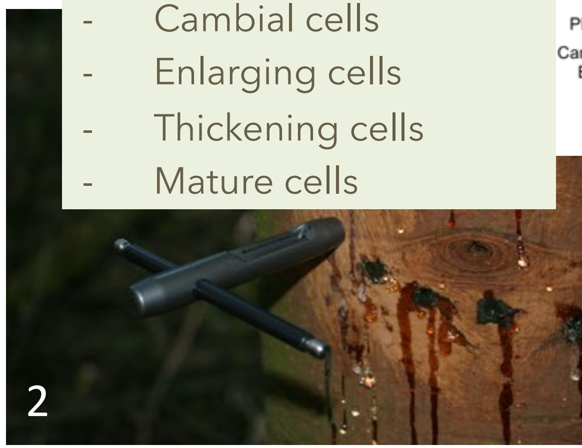
SAMPLING DESIGN AND ANATOMICAL

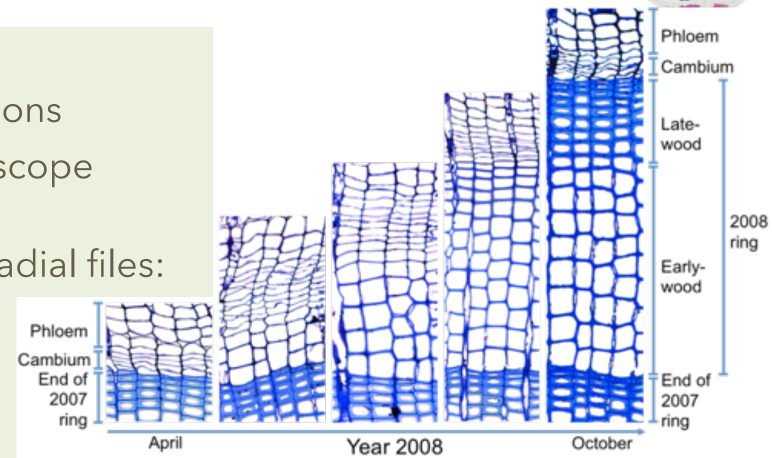
Wood sampling

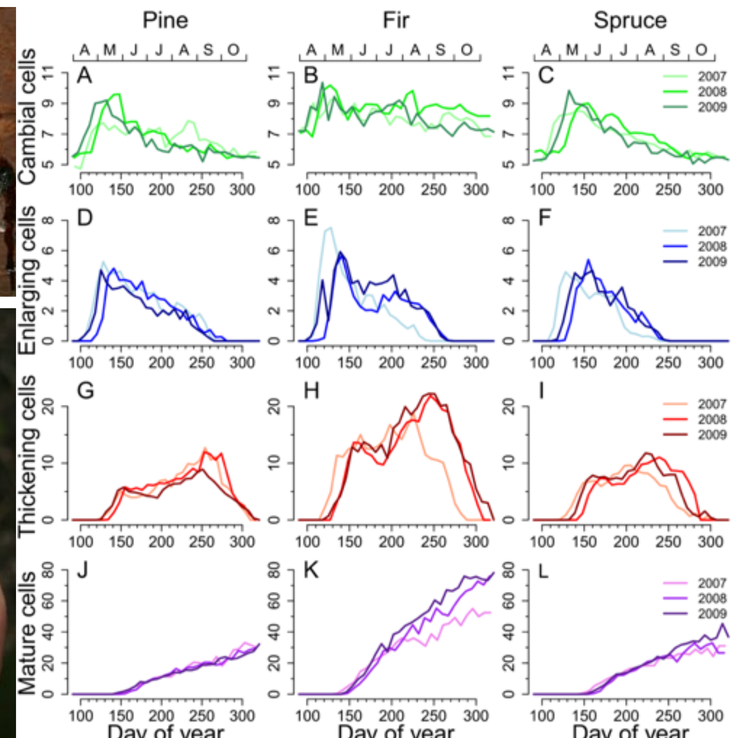
- 3-15 trees / sites
- ~ Weekly microcores

Developing xylem observations

- Preparation of anatomical sections
- Observation under light microscope
- Classification and counting of differentiating tracheid along radial files:
  - Cambial cells
  - Enlarging cells
  - Thickening cells
  - Mature cells

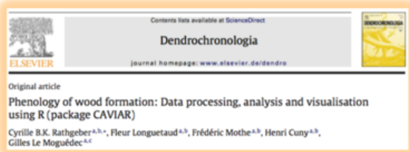




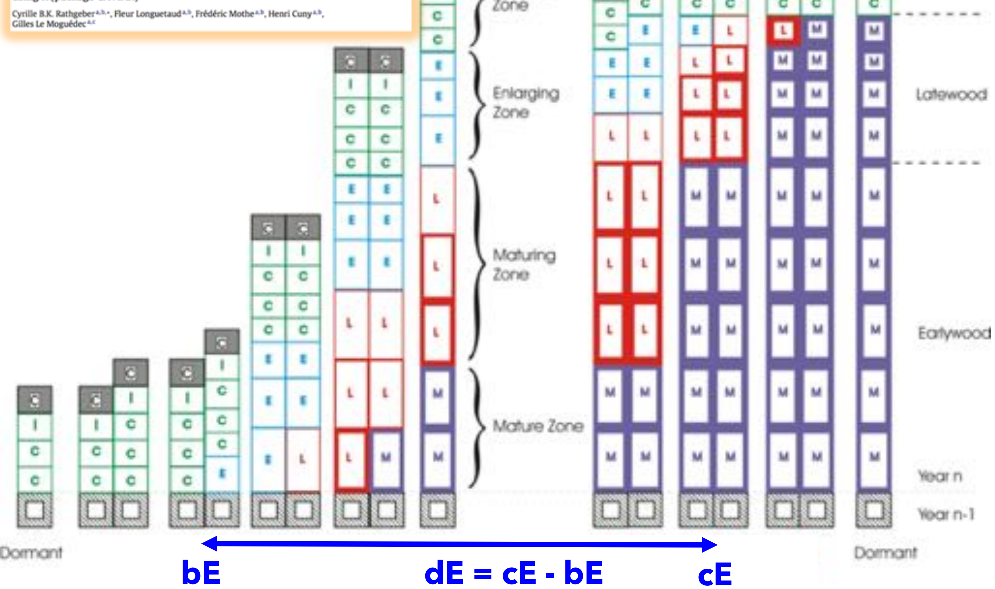


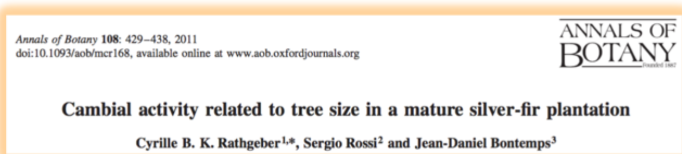
Xylogenesis Data Processing

MATERIAL

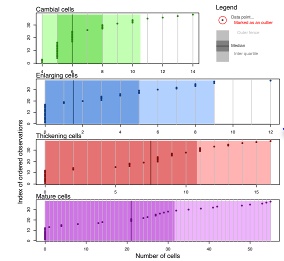

Contents lists available at ScienceDirect
Dendrochronologia
journal homepage: www.elsevier.de/dendro

Original article
Phenology of wood formation: Data processing, analysis and visualisation using R (package CAVIAR)
Cyrille B.K. Rathgeber[a,b,*], Fleur Longuetaud[a,b], Frédéric Mothe[a,b], Henri Cuny[a,b], Gilles Le Moguédec[a,c]

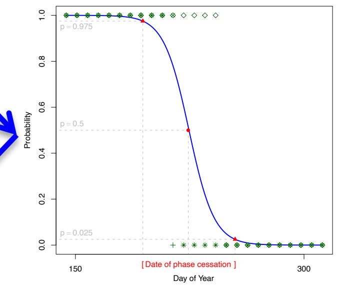



Annals of Botany 108: 429–438, 2011
doi:10.1093/aob/mcr168, available online at www.aob.oxfordjournals.org
ANNALS OF BOTANY
Cambial activity related to tree size in a mature silver-fir plantation
Cyrille B. K. Rathgeber[1,*], Sergio Rossi[2] and Jean-Daniel Bontemps[3]

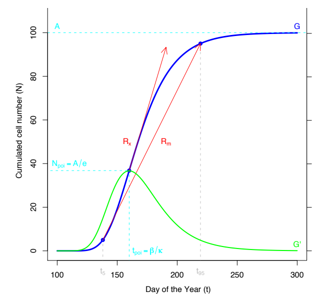
Check & format wood formation monitoring data



Assess xylem phenology (dE)

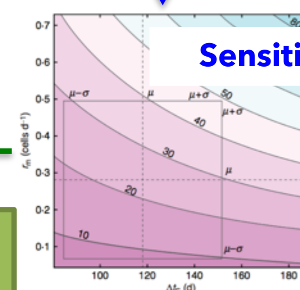


Assess xylem dynamics (r90)



Basic Physical model: RCN = dE x r90

Sensitivity analysis



What are the contributions of timings and rates?

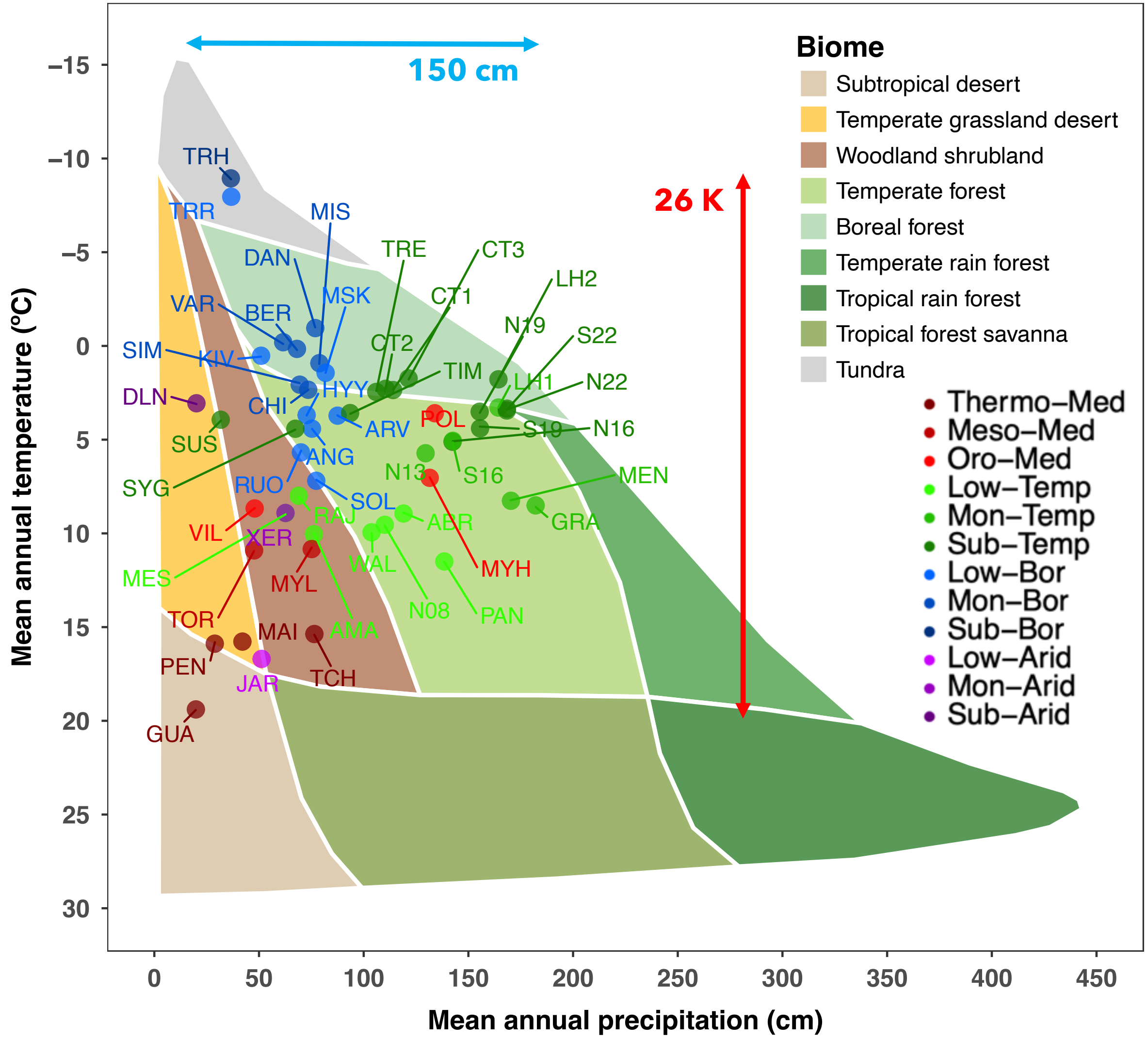
Mixed model analysis

What are the influences of climatic factors?

RANGE OF VARIATION OF THE CLIMATIC

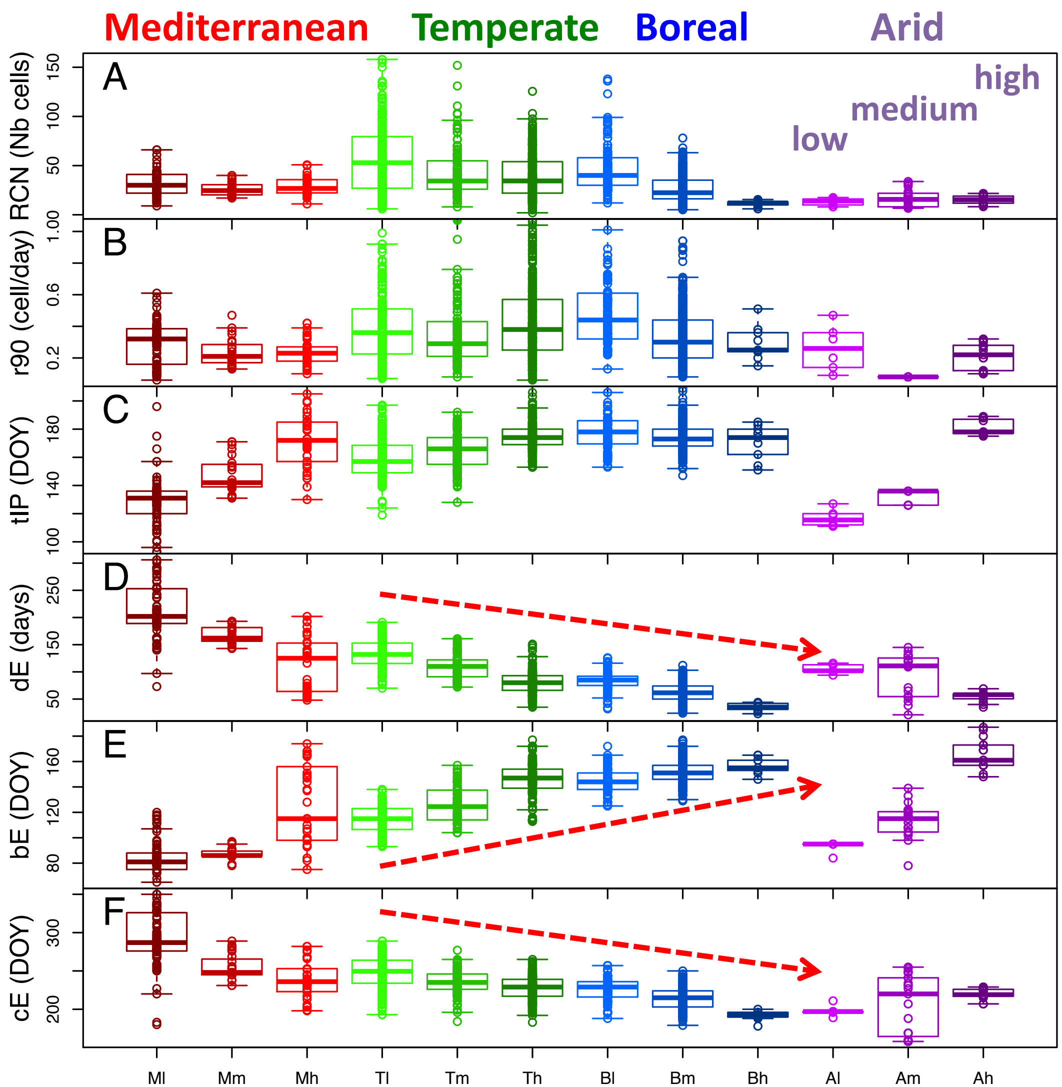
Huge range of climatic conditions

- Mean Annual Temperature:
  - From -8 °C in Siberia
  - To 18 °C in Spain
- Total annual precipitation:
  - From 30 cm in Tibet and Spain
  - To 180 cm in France and Slovenia



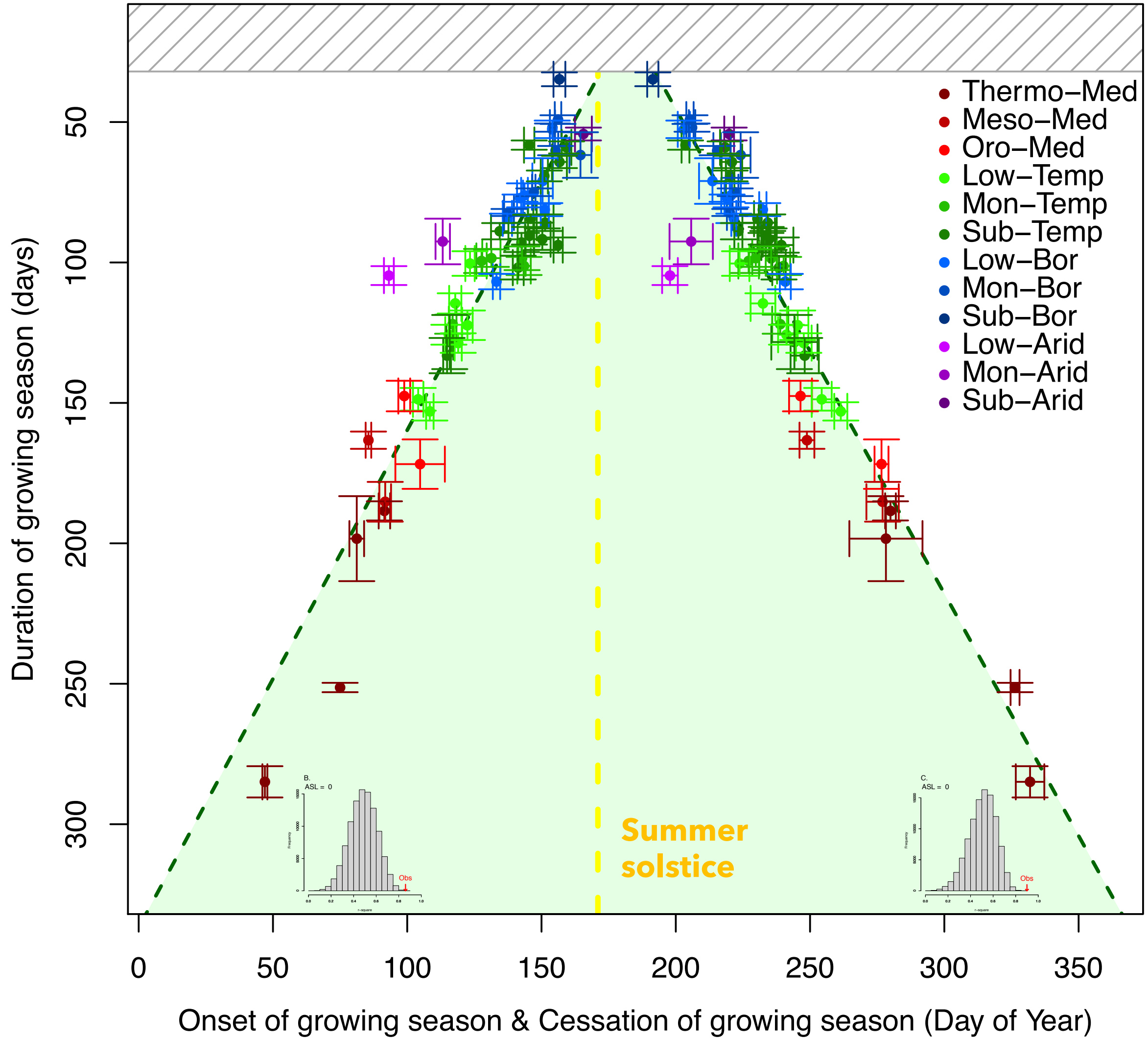
RANGE OF VARIATION OF THE VARIABLES OF INTEREST

- **Four bioclimatic zones**
  - Mediterranean forests (M)
  - Temperate forests (T)
  - Boreal forests (B)
  - Arid forests (A)
- **Three elevation zones**
  - Low elevation (l)
  - Medium elevation (m)
  - High elevation (h)
- RCN: from 3 to 150 cells
- r90: from 0.1 to 1 cell/day
- dE: from 1 to 10 months
- bE: from Feb. to Jun.
- cE: from Jul. to Dec.



LENGTH OF THE GROWING SEASON

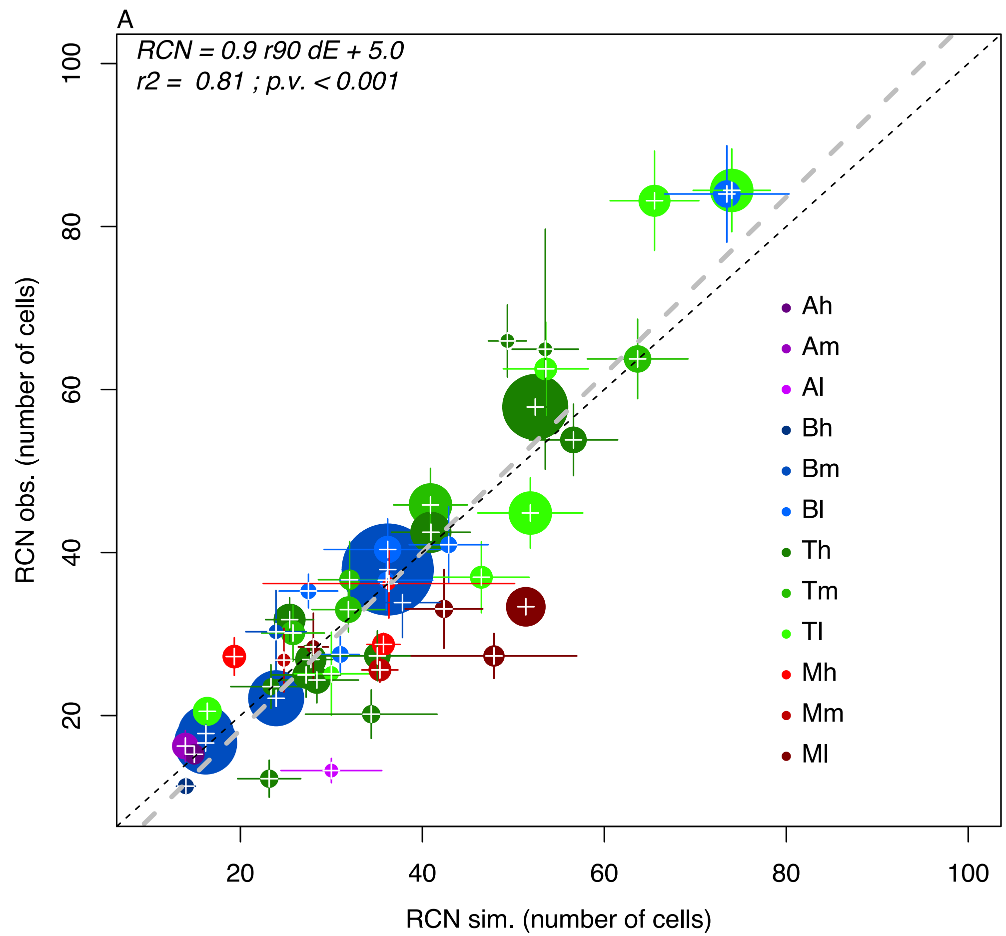
- **Clear biogeographic patterns**
  - Latitude
  - Elevation
  - Summer solstice
  - Upper limit at 40 days
  - No lower limit
- **Relationships between onset and cessation of cambial activity**
  - Similar range of variations
  - Similar contribution to dE
  - Similar importance



VALIDATION OF THE BASIC PHYSICAL MODEL

- **The basic physical model** *(RCN = dE x r90)*
  - Explains 80 % of the variance
  - Exhibits no significant bias
  - Works also for Mediterranean and arid forests!

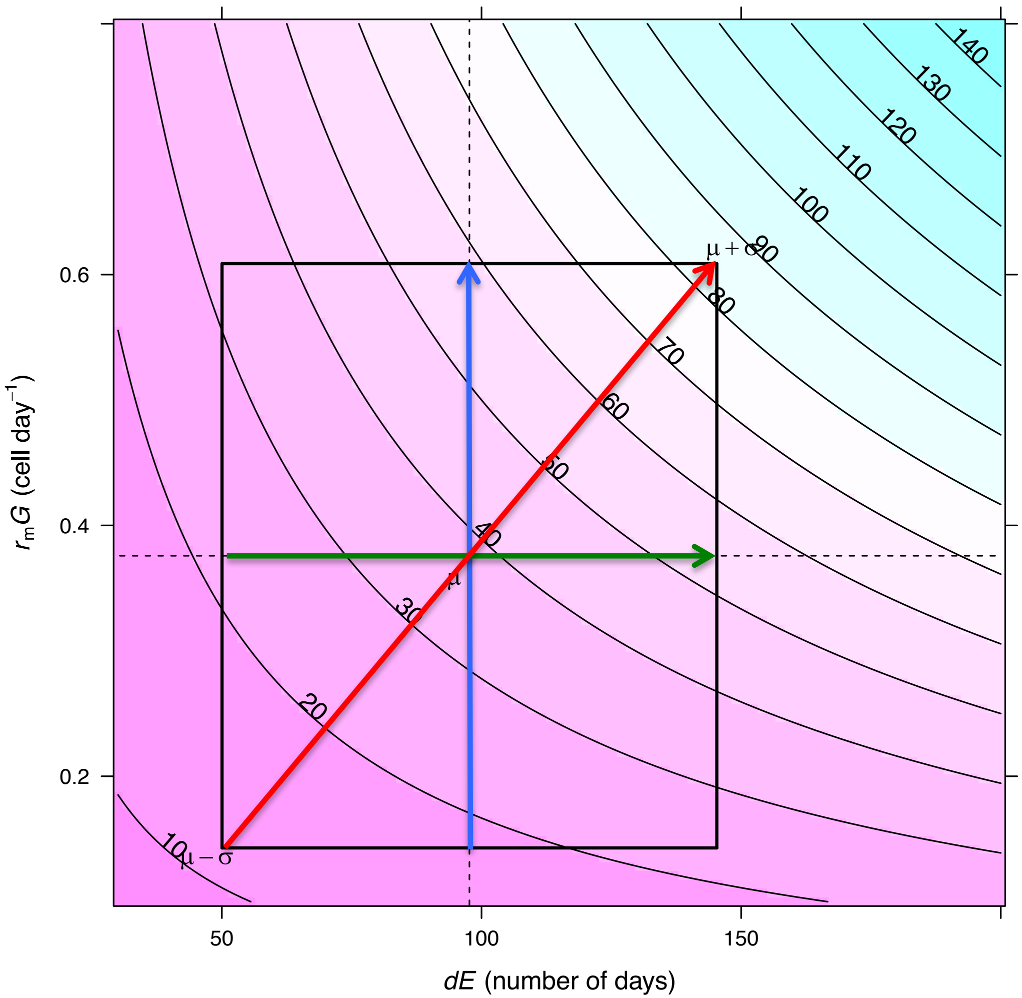
✓ **The model can be used for further investigations…**



CONTRIBUTION OF DURATION AND RATE TO TOTAL NUMBER OF XYLEM CELLS PRODUCED PER YEAR

Sensitivity analysis

- **r_mG varies, while dE is kept constant**
  - RCN: 18 → 59 (↗ 41 cells)
- **dE varies, while r_mG is kept constant**
  - RCN: 22 → 54 (↗ 32 cells)
- **Resulting contribution to total variation:**
  - r_mG : 55%
  - dE: 45%



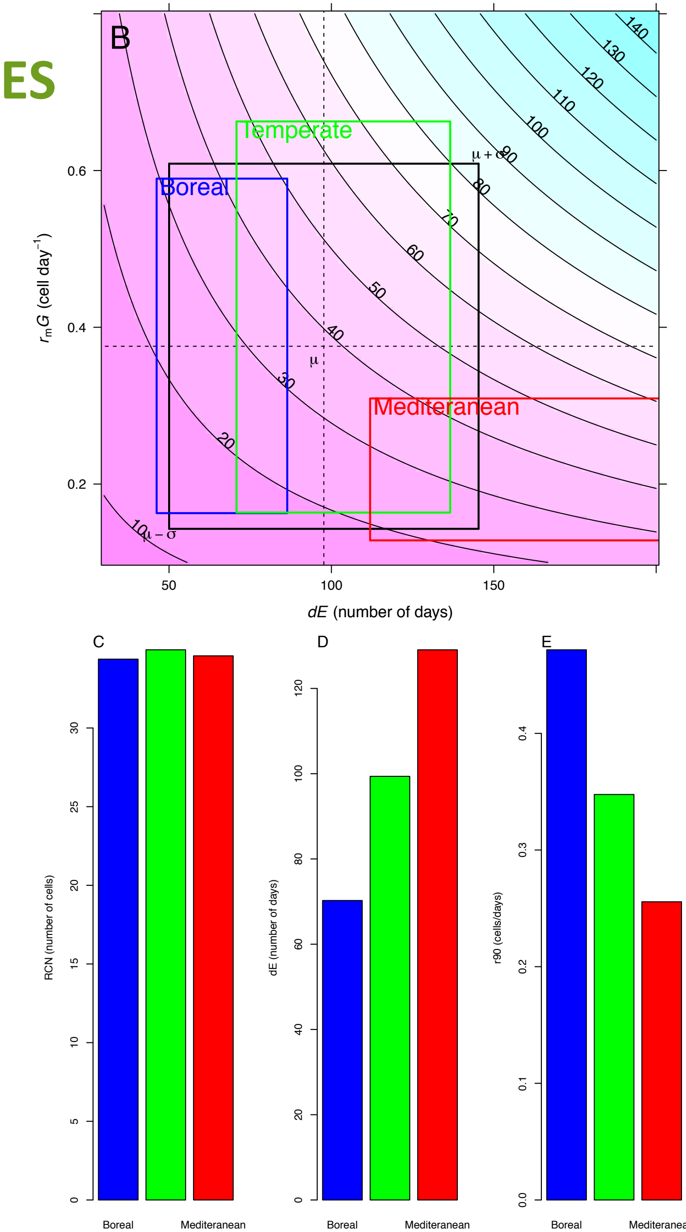
ECOLOGICAL TRENDS BETWEEN BIOMES

- **Boreal forests**
  - short growing seasons
  - high growth rates
  - r90 contributes to 65 %, dE to 35 %

- **Temperate forests**
  - Medium growing season
  - Variable growth rates
  - r90 contributes to 60 %, dE to 40 %

- **Mediterranean forests**
  - long growing seasons
  - low growth rates
  - r90 contributes to 55 %, dE to 45 %

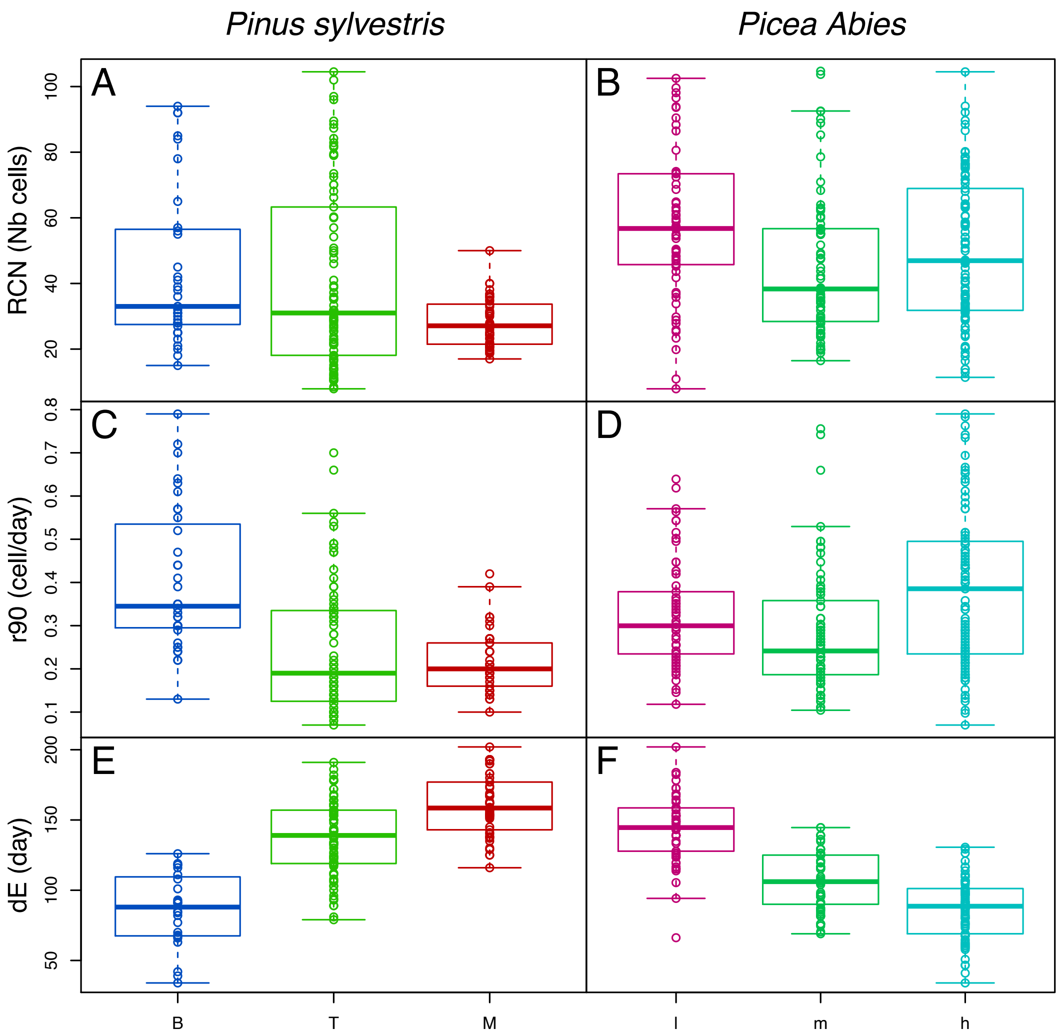
- **Standardised comparison (for 35 cells)**
  - Boreal: 70 days at 0.5 cells/day
  - Temperate: 100 days at 0.4 cells/day
  - Mediterranean: 130 days at 0.3 cells/day



SPECIES SPECIFIC STRATEGIES ?

- **Scots pine across bioclimatic zones**
  - Boreal (B), Temperate (T), Mediterranean (M)
  - 13 sites
  - 168 trees
  - Same as global trends:
    - RCN ⇢
    - R 90 ↓ from B to M
    - dE ↑ from B to M

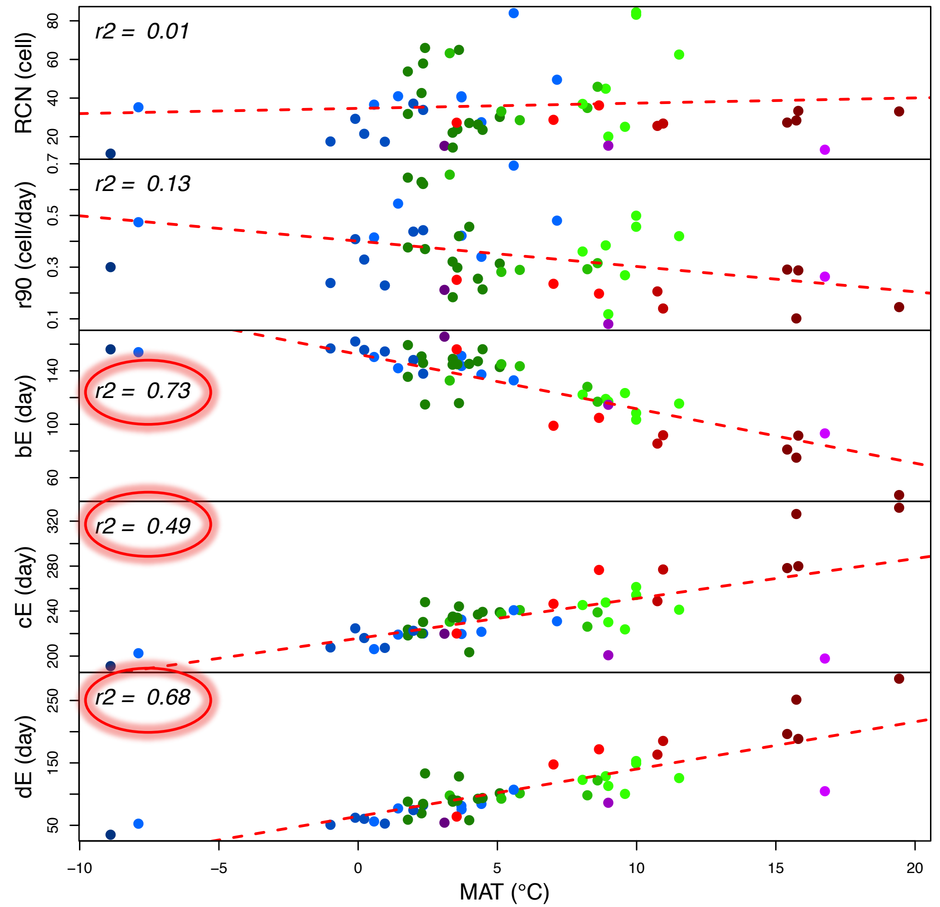
- **Norway spruce across altitudinal zones**
  - Low (l), Medium (m), High (h)
  - 17 sites
  - 246 trees
  - Same as general patterns
    - RCN ⇢
    - R 90 ↑ from B to M
    - dE ↓ from B to M



EFFECT OF TEMPERATURES ON WOOD FORMATION DYNAMICS

Effect of Mean Annual Temperatures on wood formation dynamics

- **Ring Cell Number (RCN)**
  - ➢ No effect
- **Mean cell production rate (r90)**
  - ➢ Small effect
- **Timings of enlargement (bE, cE, dE)**
  - ➢ Strong effect
- **Extend former results on cambium phenology**
  - ➢ Linear trend
  - ➢ Mediterranean area

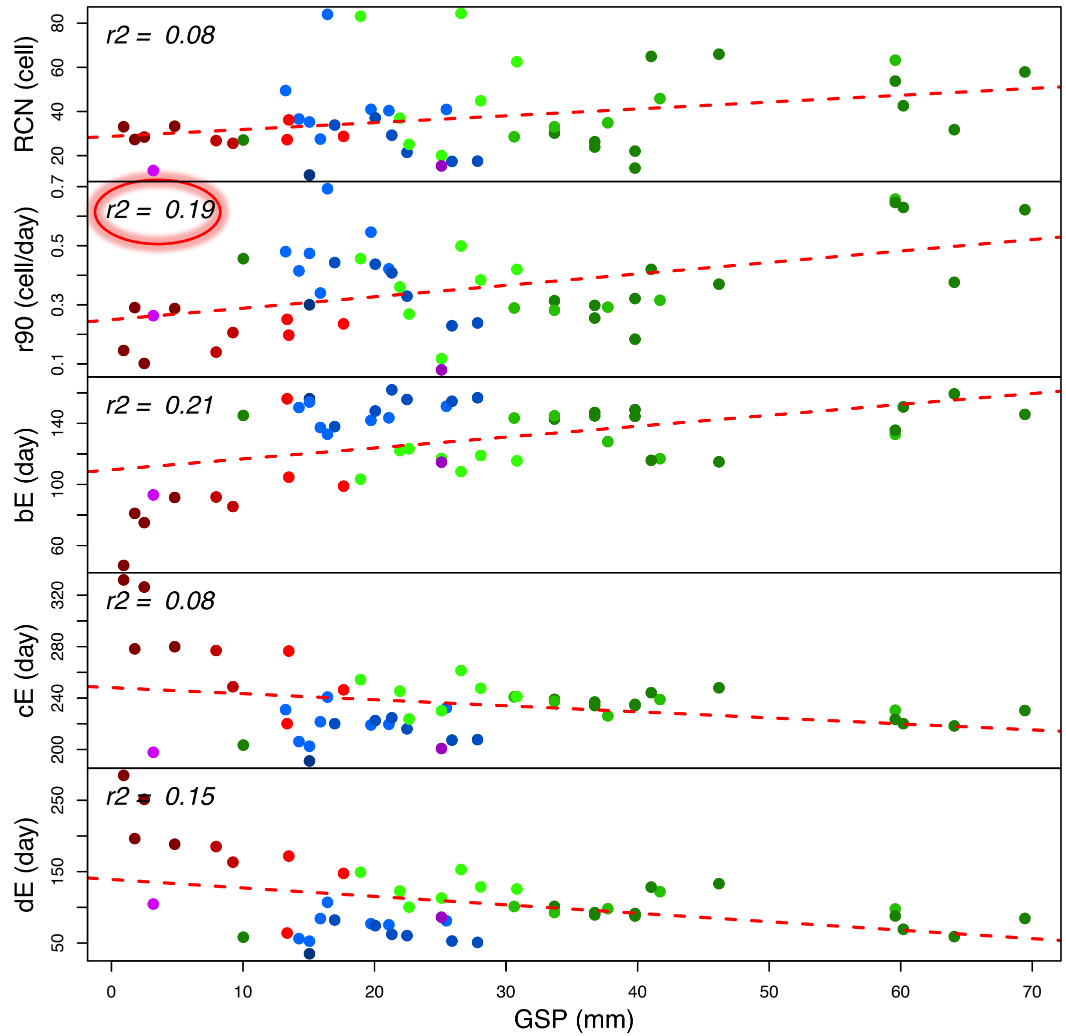


EFFECT OF WATER AVAILABILITY ON WOOD FORMATION DYNAMICS

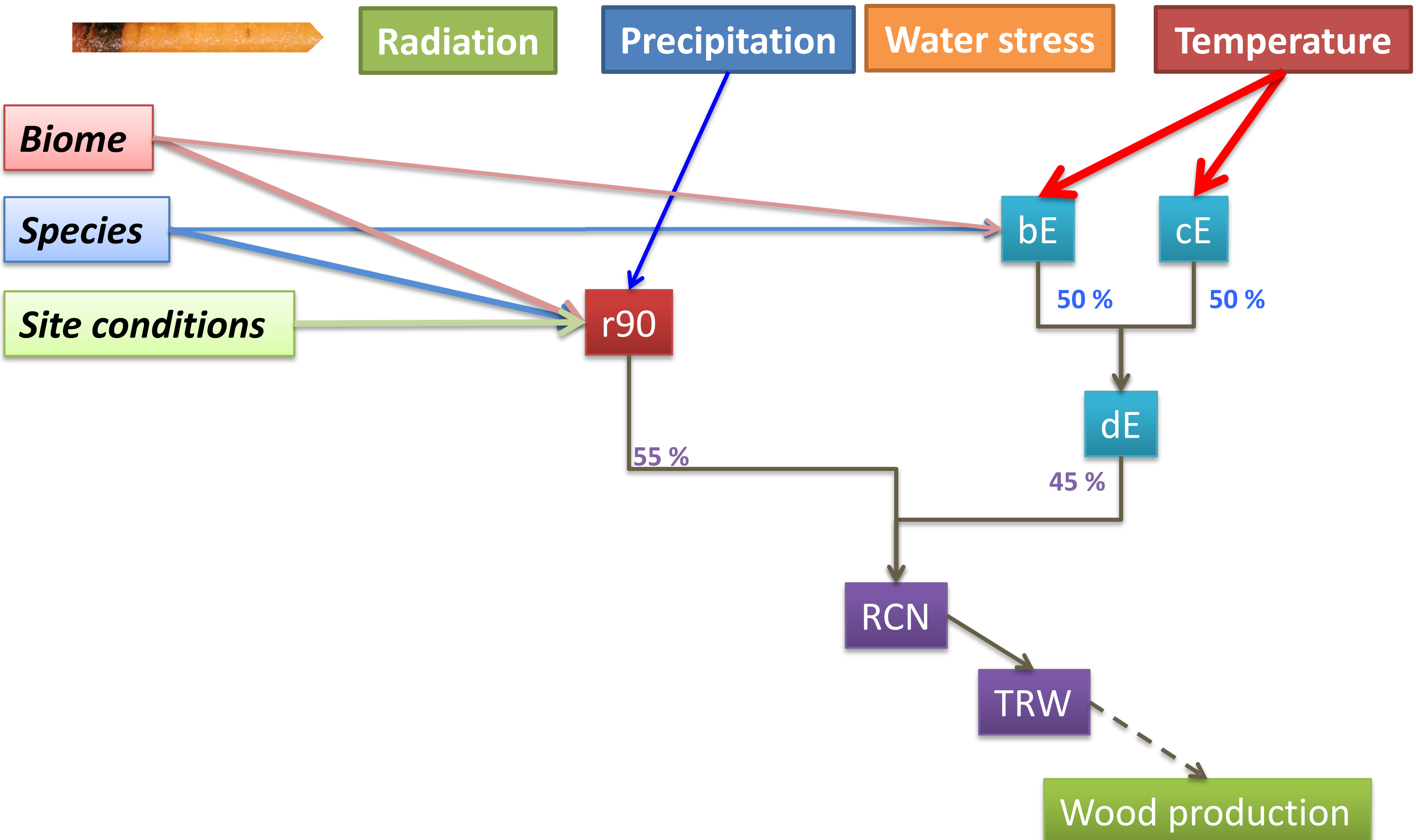
Effect of total Growing Season Precipitations (GPS) on wood formation dynamics

- **Ring Cell Number (RCN)**
  - ➢ No effect
- **Mean cell production rate (r90)**
  - ➢ Moderate effect
- **Timings of enlargement (bE, cE, dE)**
  - ➢ light effect

➢ **New result showing the influence of water stress on cell production at global scale**



SYNTHESIS


Radiation
Precipitation
Water stress
Temperature
Biome
Species
Site conditions
bE
cE
50 %
50 %
r90
dE
55 %
45 %
RCN
TRW
Wood production

Discussion and Perspectives

- **Global trends in wood production**
  - Contribution of **growth rate** > growing season duration
  - **Wood formation phenology** is mainly driven by temperature at global scale + species specific effect at local scale (global: 80 / local: 20)
  - **Wood formation dynamics** is under the control water balance + local conditions (global: 20 / local: 80)

- **Impact of global change**
  - Extension of the growing season even in Mediterranean zone…
  - …But strong modulation at site level…
  - …Very uncertain outcomes!

- **Future challenges**
  - Deciphering the effect of site conditions and environmental factors on growth rate

ACKNOWLEDGMENTS

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