Potential of adaptation to drought in Douglas-fir: twenty years of research efforts

Philippe Rozenberg, Alejandro Martinez Meier, Anne-Sophie Sergent, Guillermina Dalla Salda, Manuela Ruiz Diaz Britez, Thibaud Chauvin

Introduction, Breeding, Propagation and Deployment of Pacific Northwest Conifers Around the World: 70 years of Progress, Opportunities and Challenges

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Philippe Rozenberg

INRAE Orleans, France

"Potential of adaptation to drought in Douglas-fir: twenty years of research efforts"

RÉSEAU MiDi Milieux & Diversité Réseau thématique de recherche en Région Centre Val de Loire

IUFRO

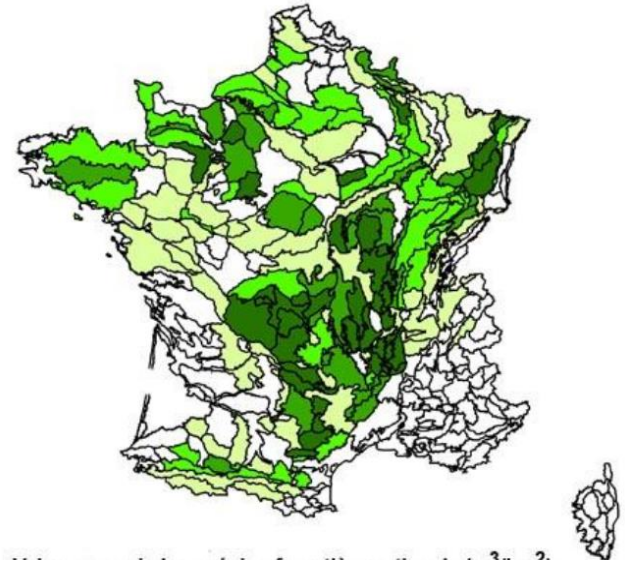
LE STUDIUM Loire Valley Institute for Advanced Studies

LIECO SUCCESSFUL AFFORESTATION

FGC Forest Genetics Council of British Columbia

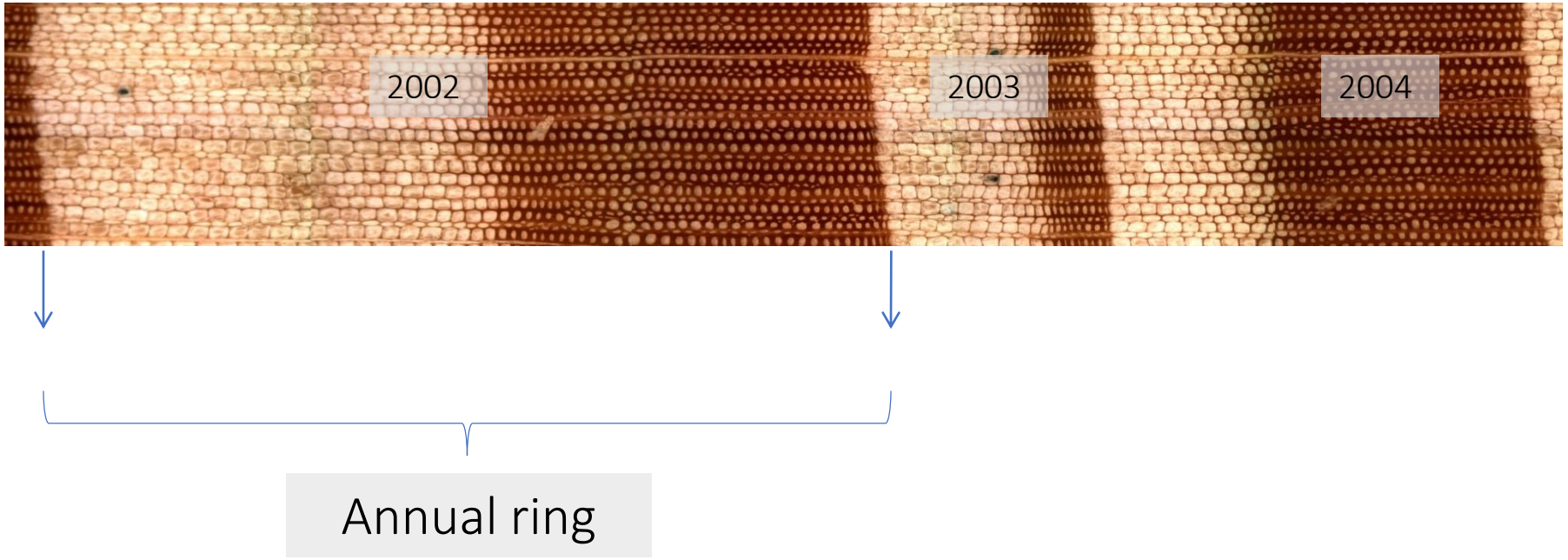
Context

- Douglas-fir suffered massive declines and diebacks during the 90's and 2000's in France
- Six successive PhD thesis investigated the adaptation of Douglas-fir to water stress



All based on wood, annual-ring features and sap conduction function

- Conduction > hydraulic > anatomy > cell wall proportion > density



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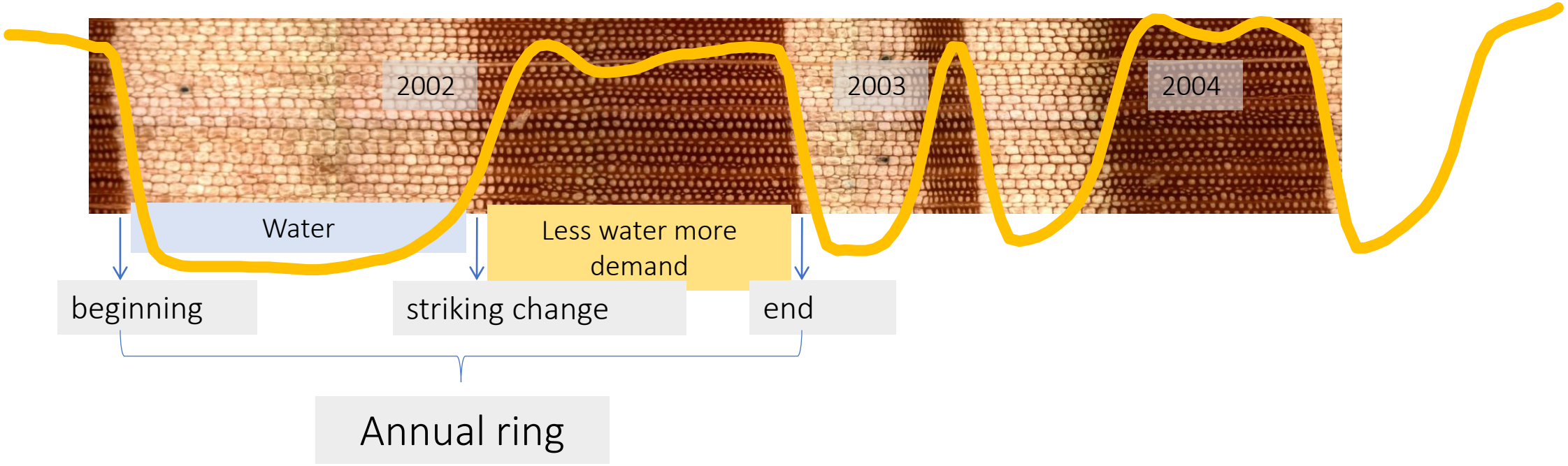
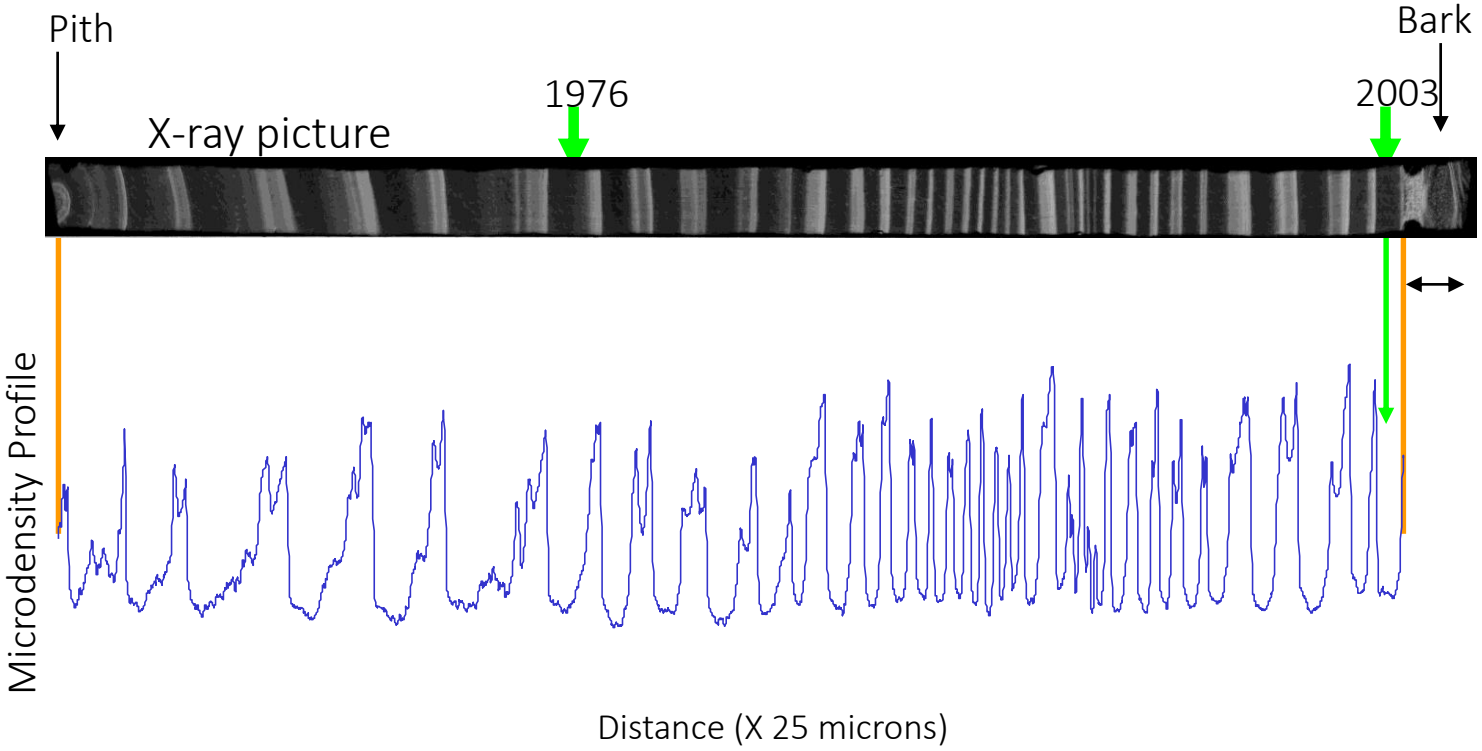
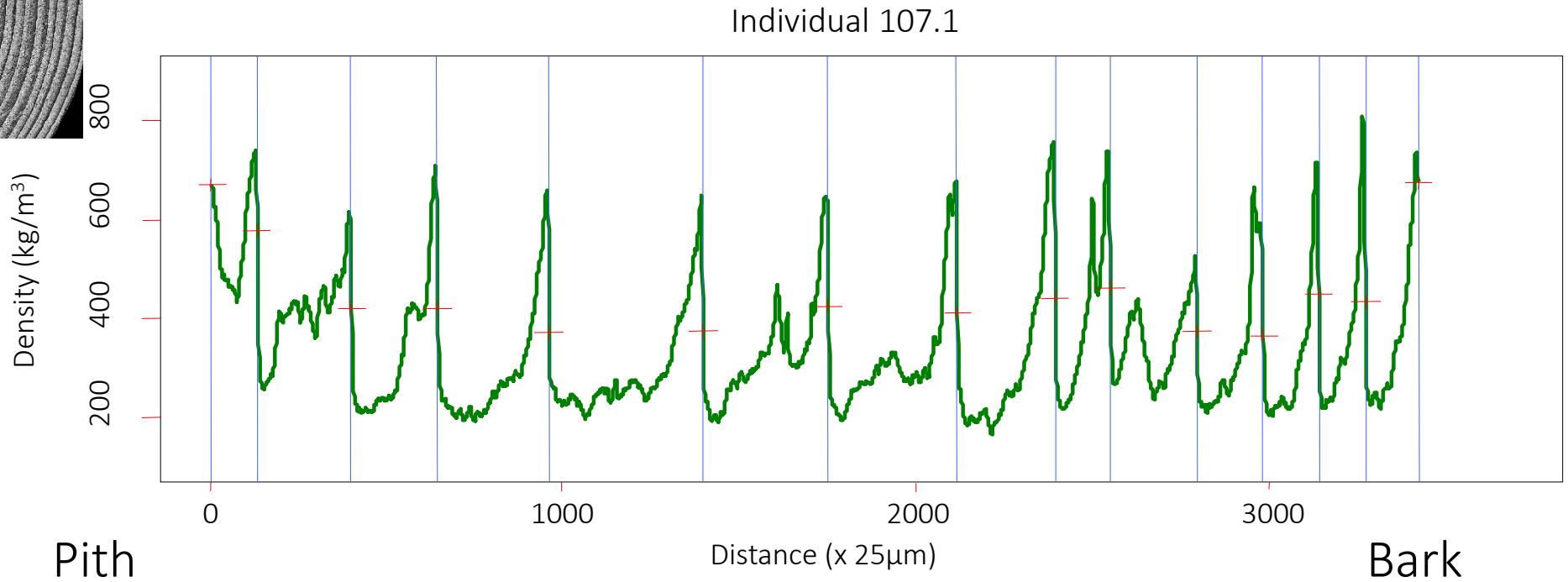


Microdensity profile



(1) 1998-2001: the relevance of wood and tree-ring studies

Annual-ring studies of the genetic and environmental determinism of tree response to biotic and abiotic stressors



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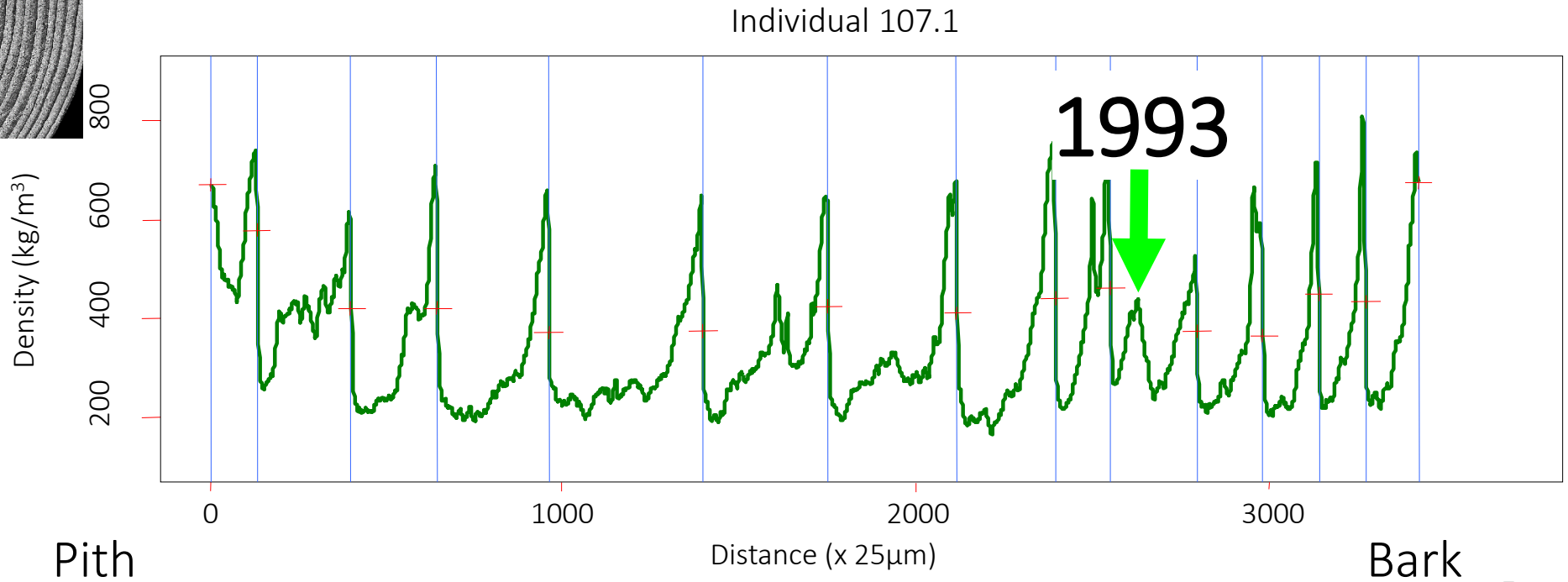
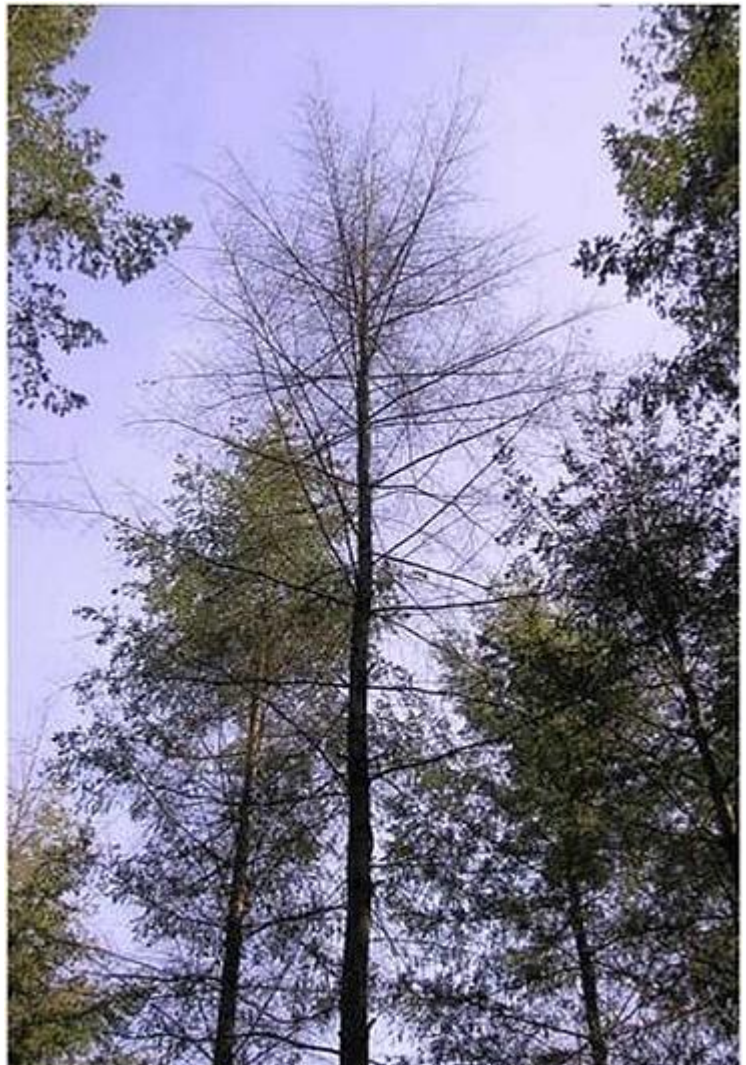


(2) 2005-2009: ring density records of adaptive response to drought



- Comparison of dead and surviving trees after a drought = relationship with the **survival component of *fitness***

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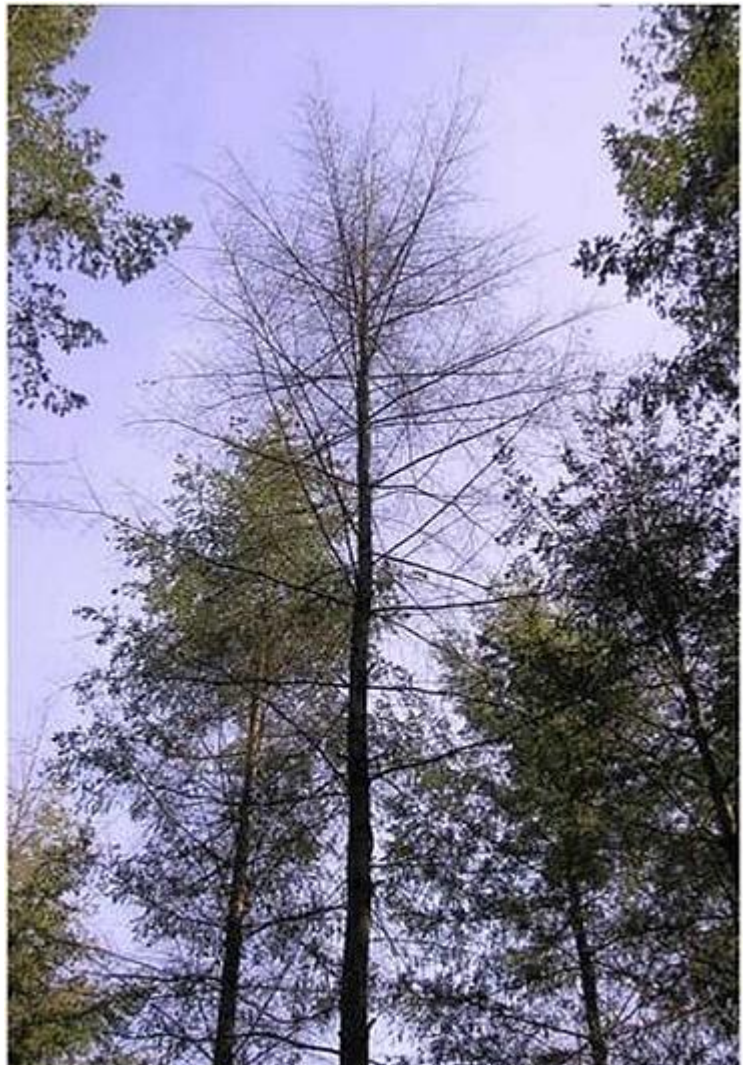


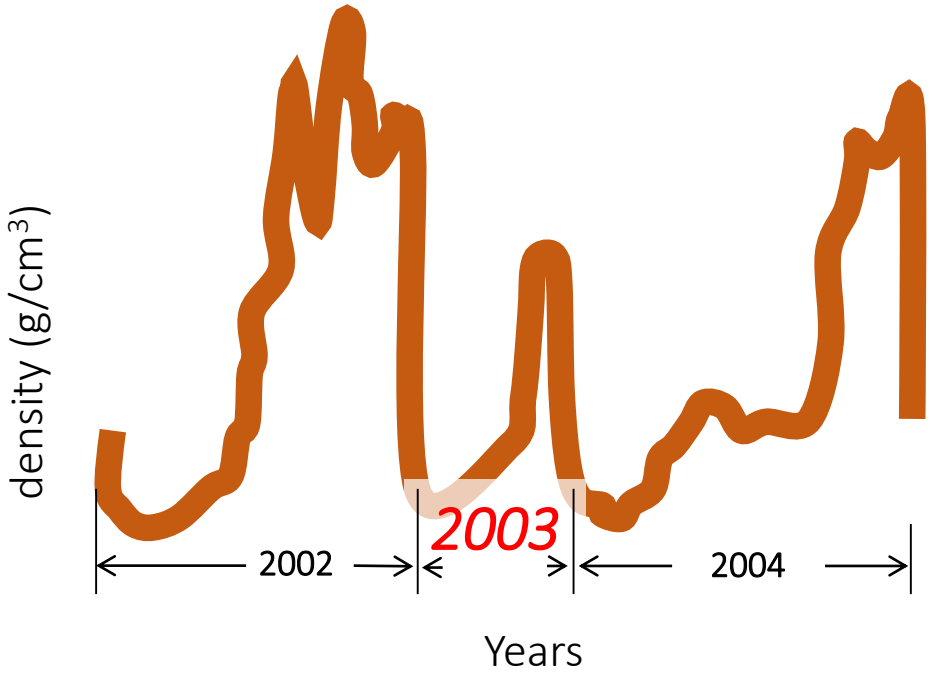
- Comparison of dead and surviving trees after a drought = relationship with the survival component of *fitness*

- **Density** (annual-ring microdensity) variables: (*proxies* of) ***adaptive*** traits for resistance to drought

- **Surviving** trees:
  - **Same** diameter
  - Significantly **denser**

(2) 2005-2009: ring density records of adaptive response to drought

- *2003* ring **significantly different** from the previous and the next one



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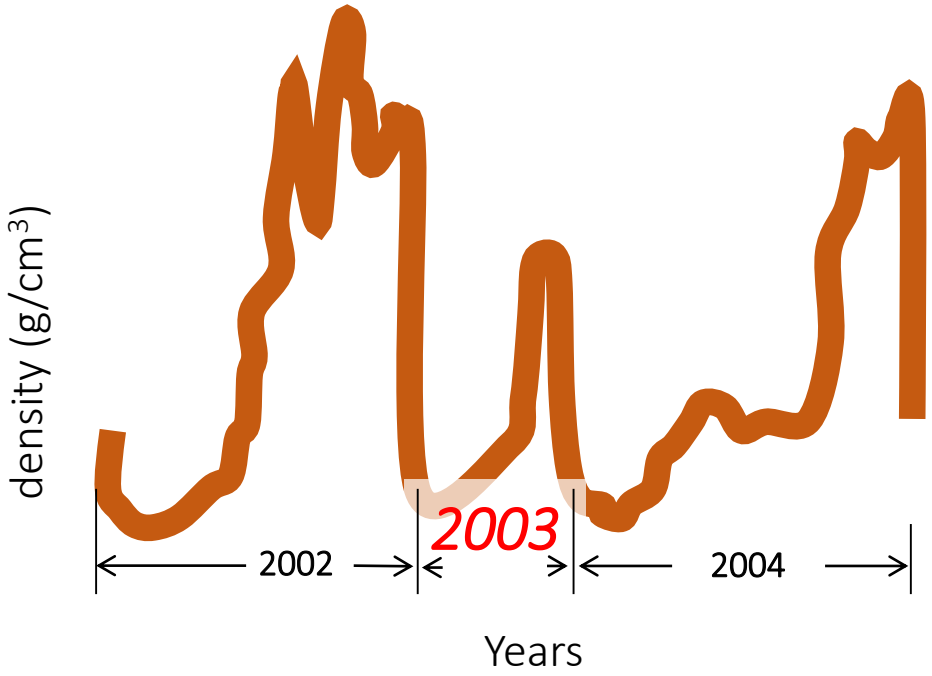
- 12 clones X 3 sites : the ring response to drought is **genetically determined**



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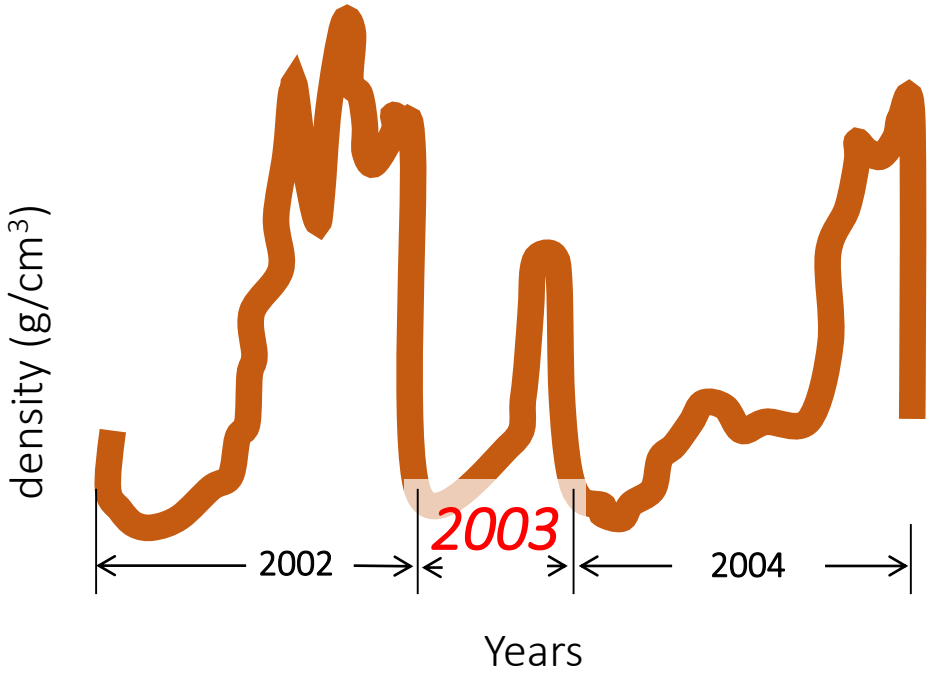
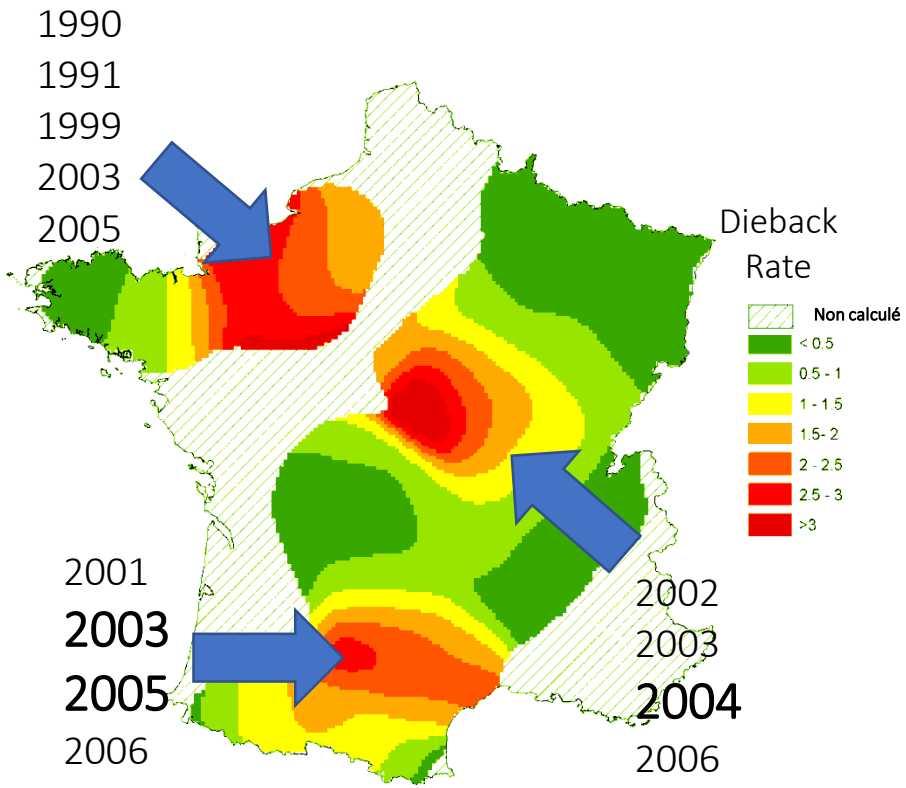


- High potential of tree-rings to estimate ***norms of reaction*** and **phenotypic plasticity**

(3) 2007-2011: drought-related diebacks and provenance variation of ring response to drought

Douglas-fir forest plots with variable dieback rates



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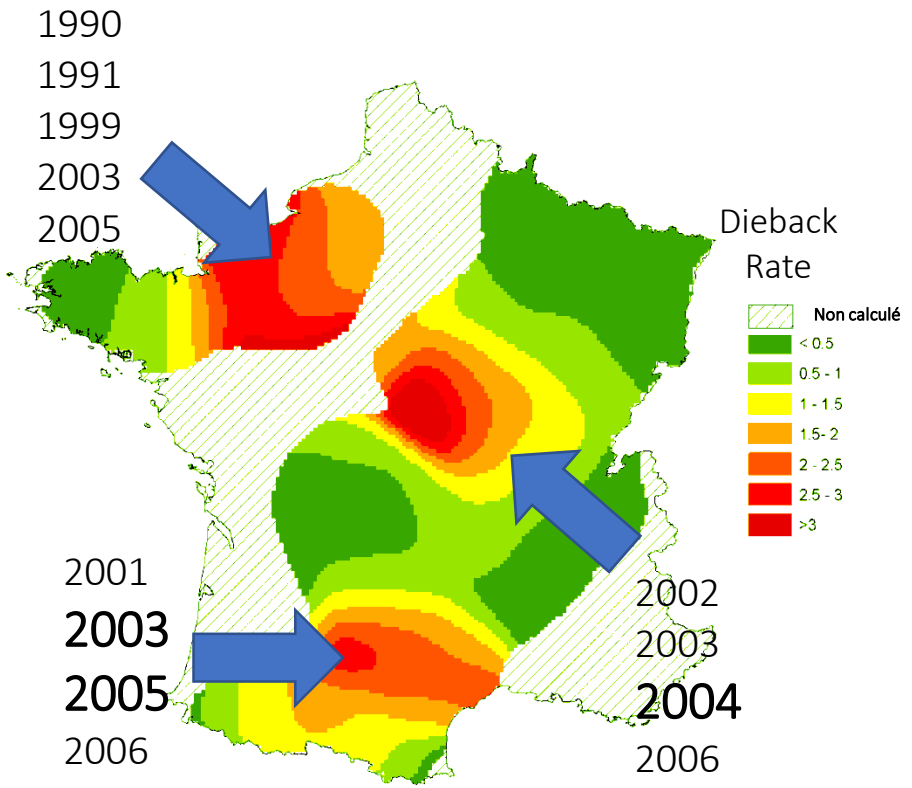

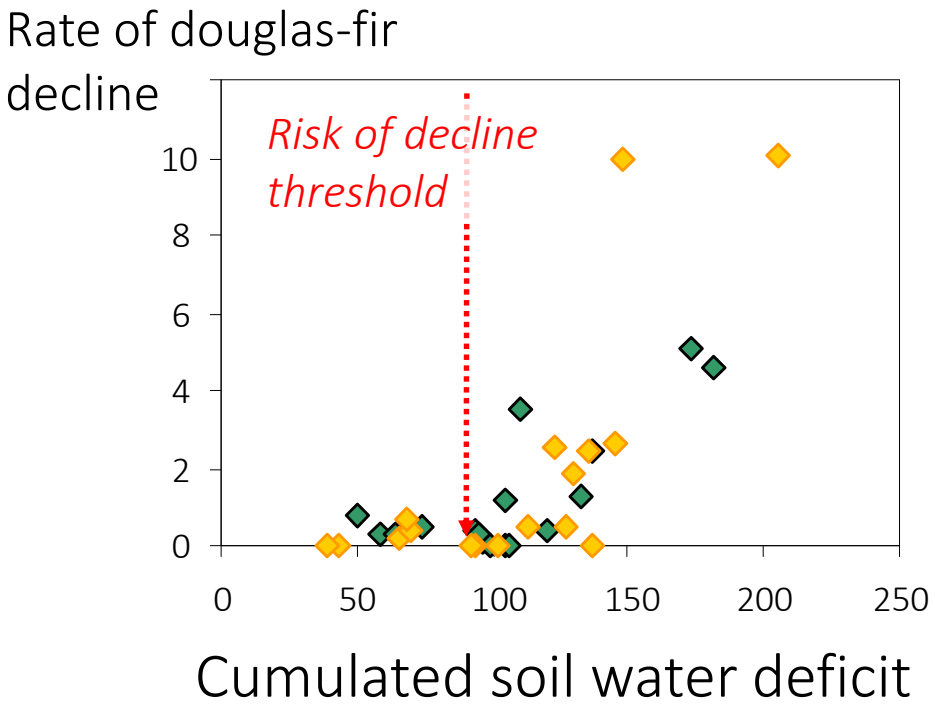

Drought events quantified by soil water balance calculation, Biljou©, INRAE, EEF Nancy

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- Common garden in France
- Variation between provenances for ring response to drought-years
- Large part of the natural area

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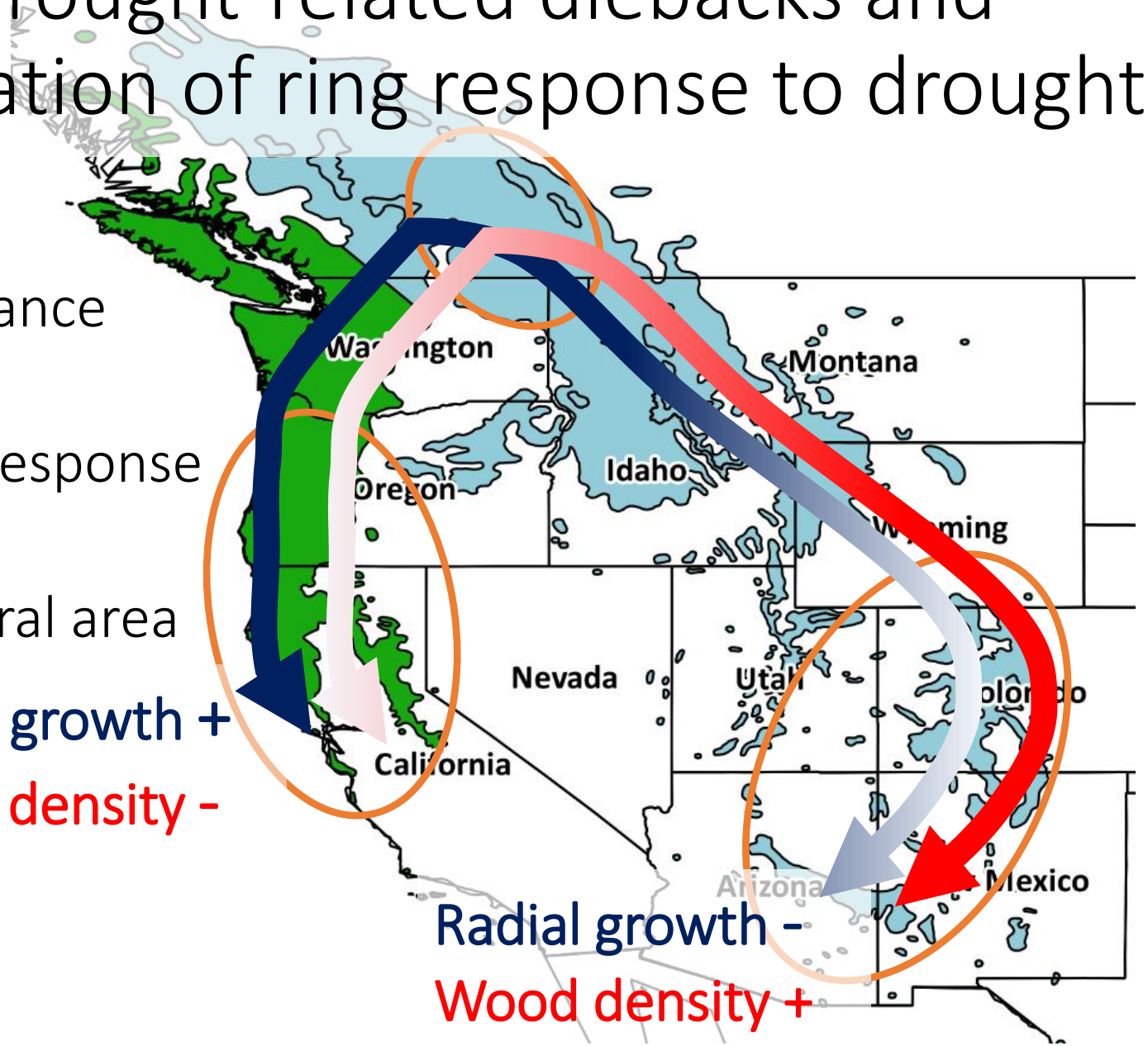

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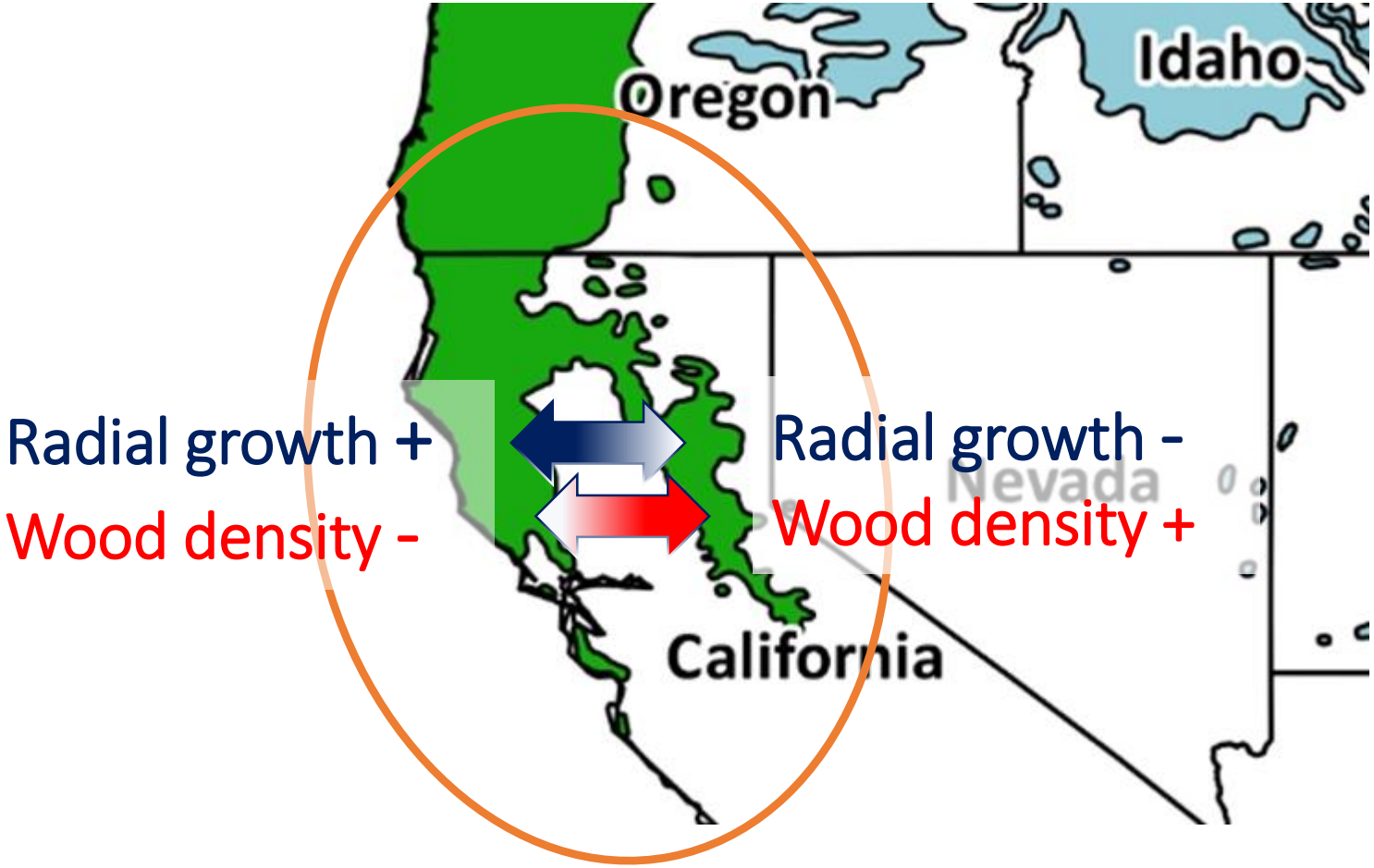
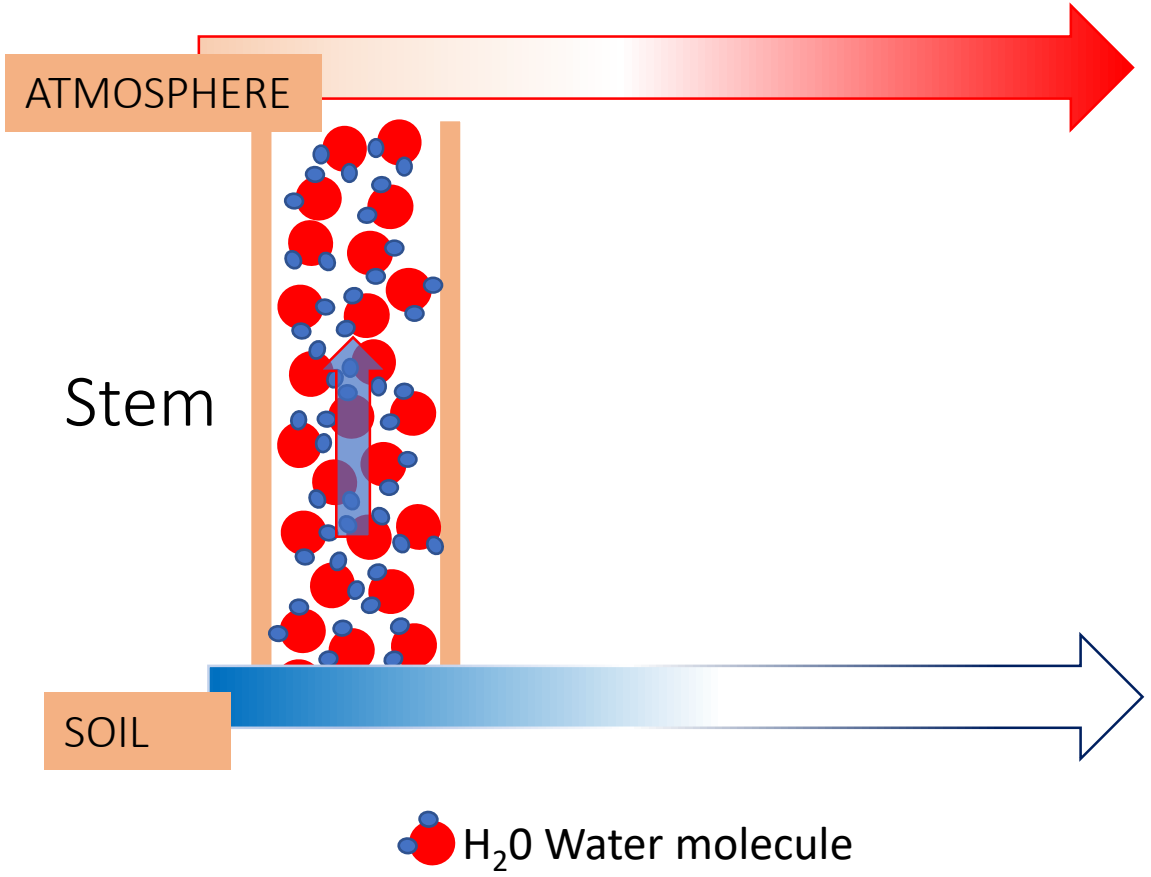


(4) 2010-2014: wood density, resistance to drought and the dynamics of cavitation

- Introduction of direct resistance-to-drought traits, linked with water conduction: *resistance to cavitation*



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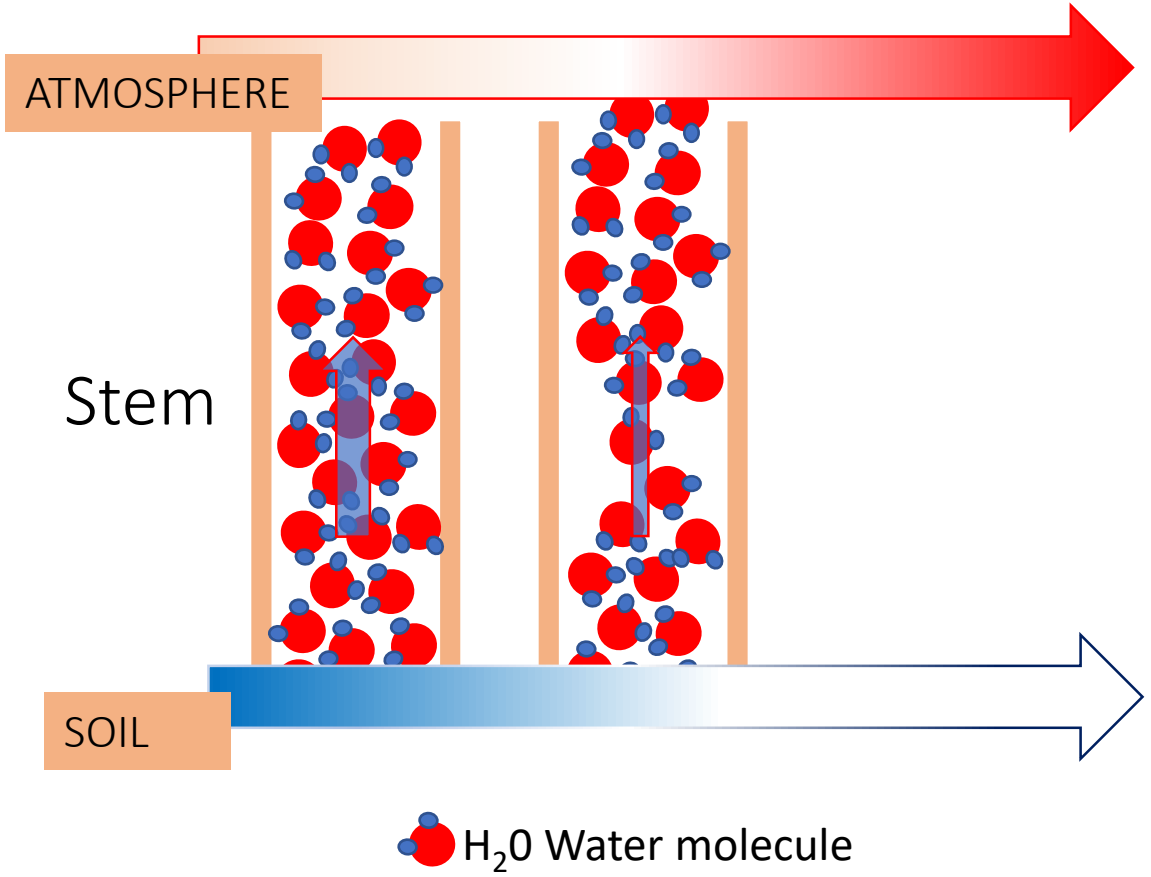

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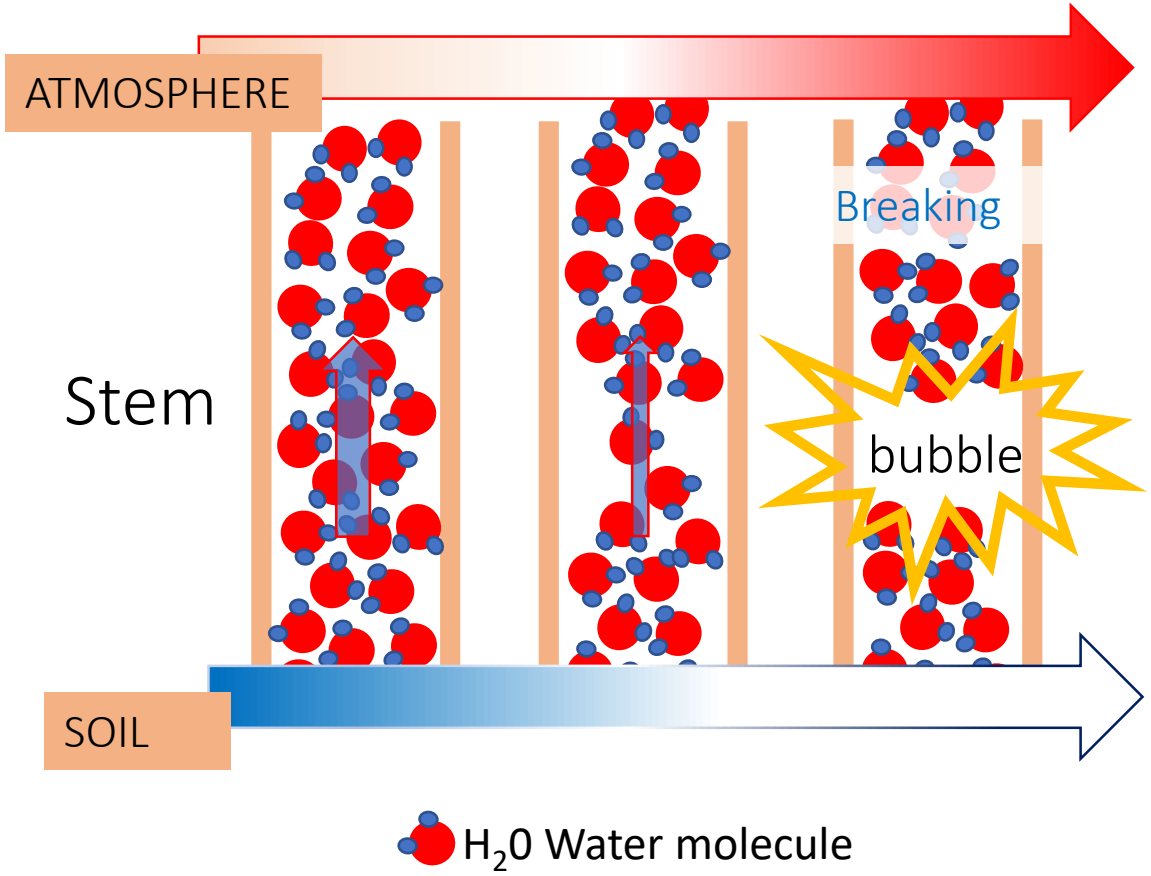
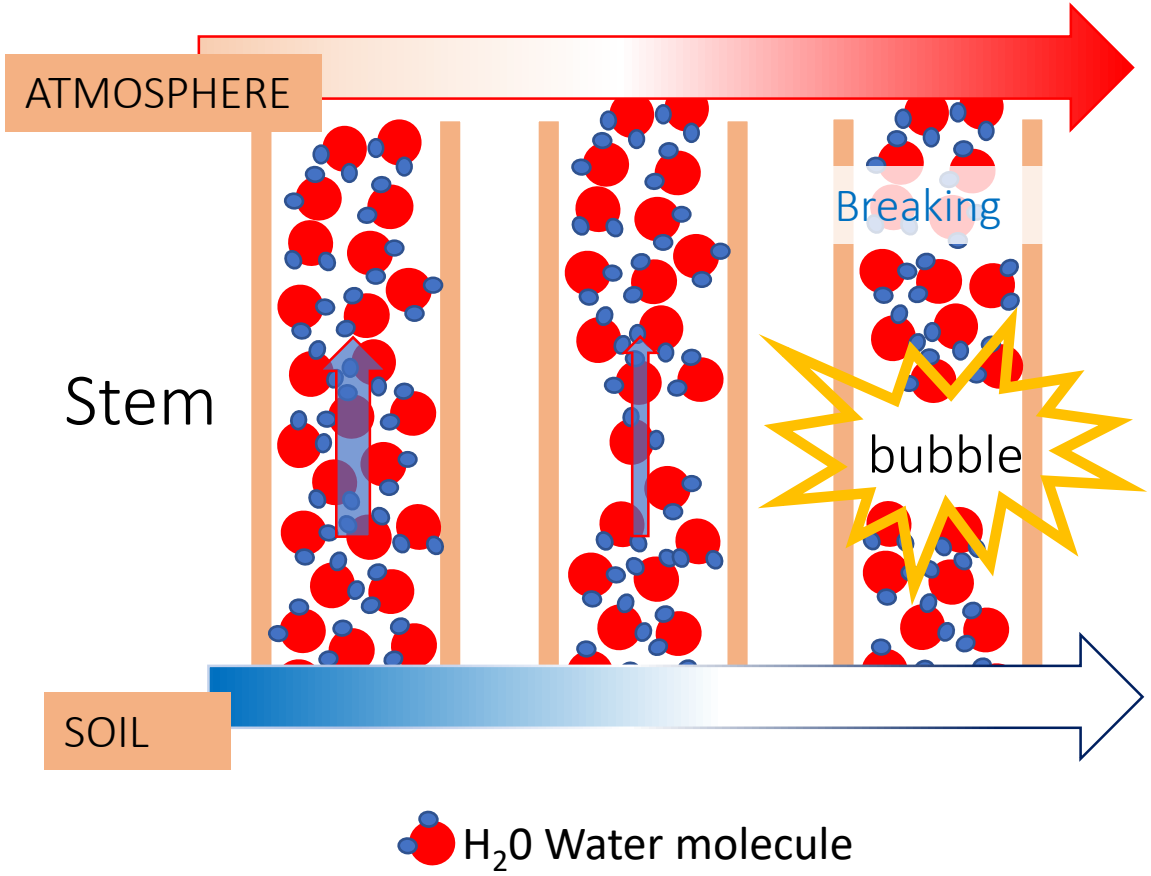


(4) 2010-2014: wood density, resistance to drought and the dynamics of cavitation

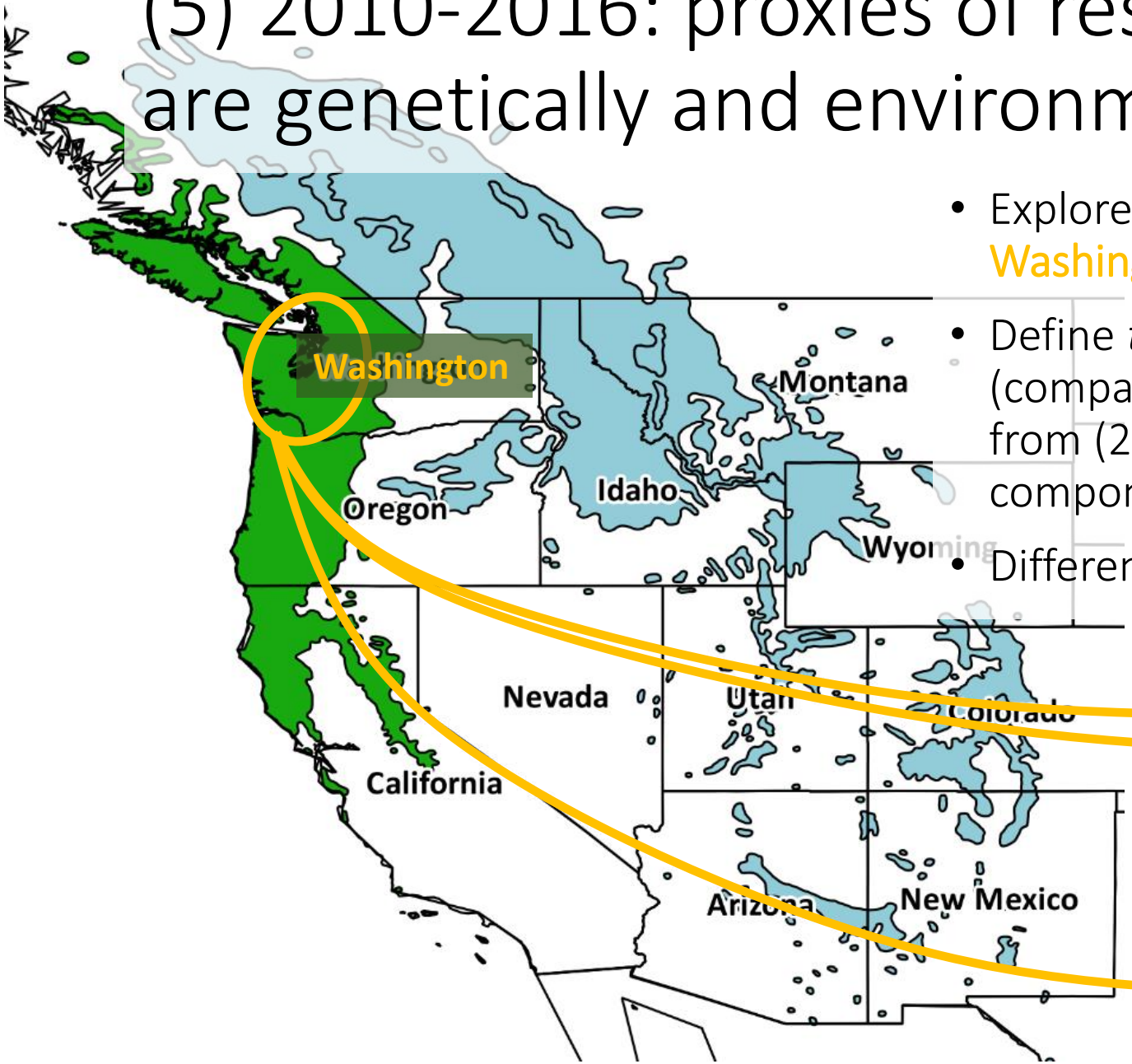
- Genetic variation
  - clones, families from coastal Washington-Oregon
- Relationships with ring density
  - Variables according to the part of the ring and the resistance to cavitation variable



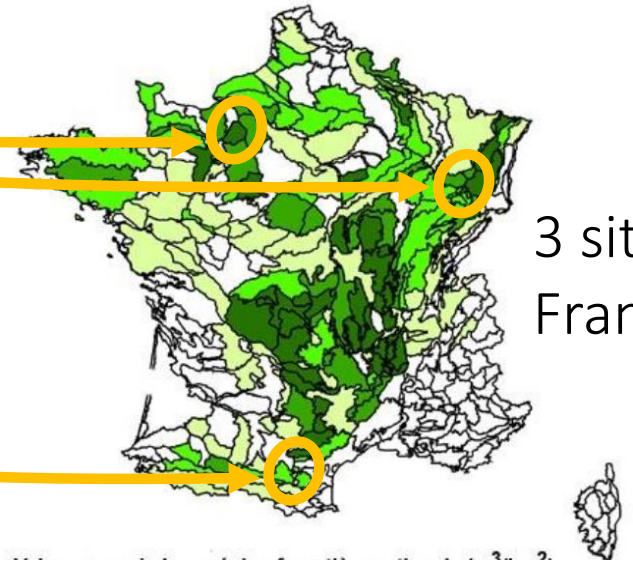
(4) 2010-2014: wood density, resistance to drought and the dynamics of cavitation

- Dynamics of within-ring cavitation propagation:
  cavitation starts in **latewood**, jumps to **earlywood** then ultimately affects the **transition** zone between early and latewood

(5) 2010-2016: proxies of resistance to drought are genetically and environmentally determined



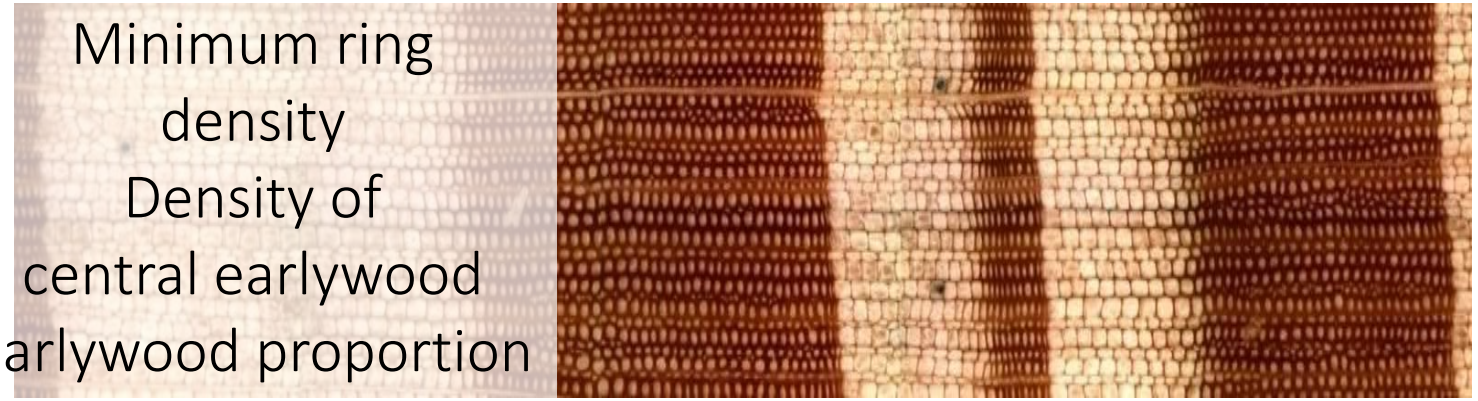
- Explores the potential of evolutionary adaptation of Washington state provenances
- Define *tree-ring proxies* of resistance to drought (comparison of dead and surviving trees, (2), with data from (2) and (3): relationship with the surviving component of fitness)
- Different proxies in different environmental conditions



3 sites in France

(5) 2010-2016: proxies of resistance to drought are genetically and environmentally determined

- *Genetic variation* and *heritability* (progeny tests)
- Define selection traits for improvement of resistance to drought
- Three **earlywood** ring variables have the highest potential of evolutionary adaptation



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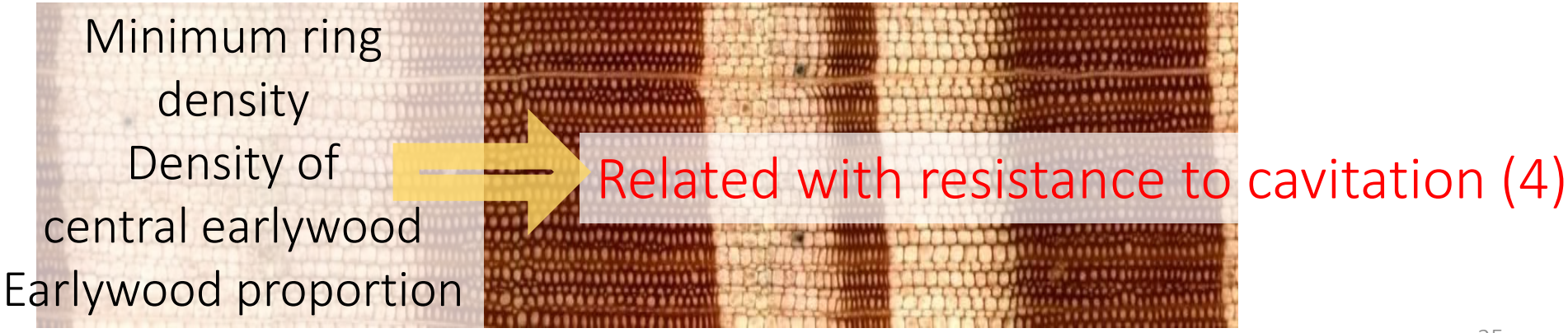


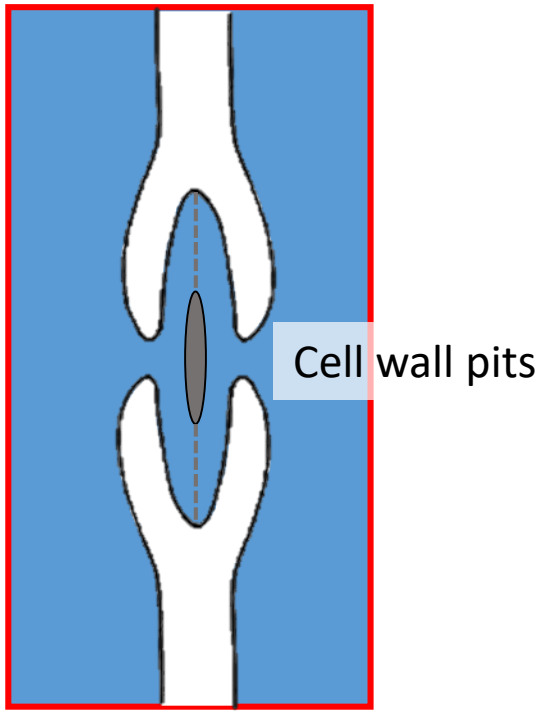
(6) 2016-2019: robustness and complexity of the evolutionary adaptation of resistance to drought

As usual: ring microdensity

Like (3): a larger part of the natural area

Like (4): **resistance to cavitation**, at a larger scale

For the first time: pits anatomy



Local adaptation for resistance to drought
in the Douglas-fir natural area

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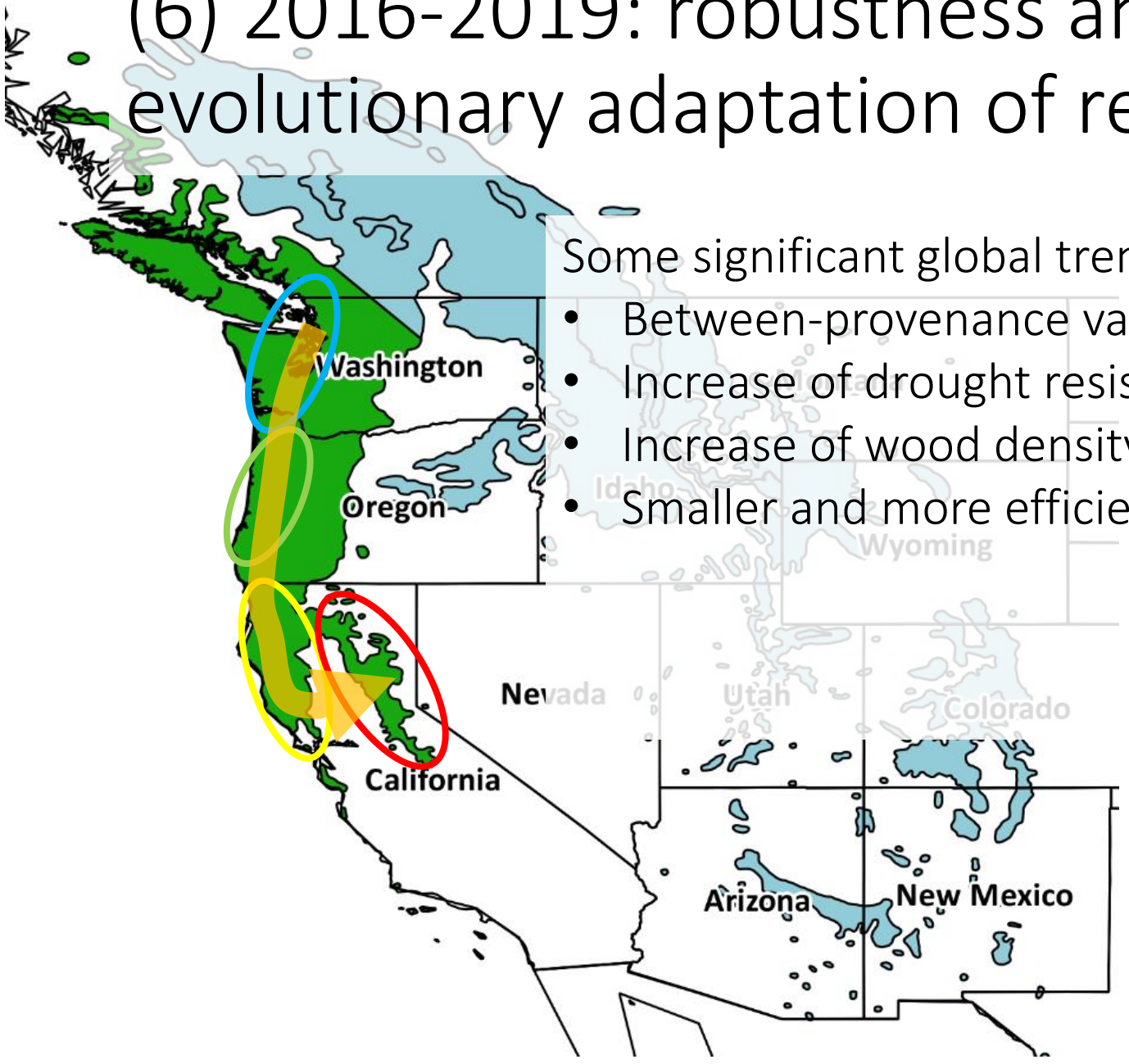

Some significant global trends. Climate variation (P, T) explains:

- Between-provenance variation
- Increase of drought resistance (resistance to cavitation)
- Increase of wood density
- Smaller and more efficient pits

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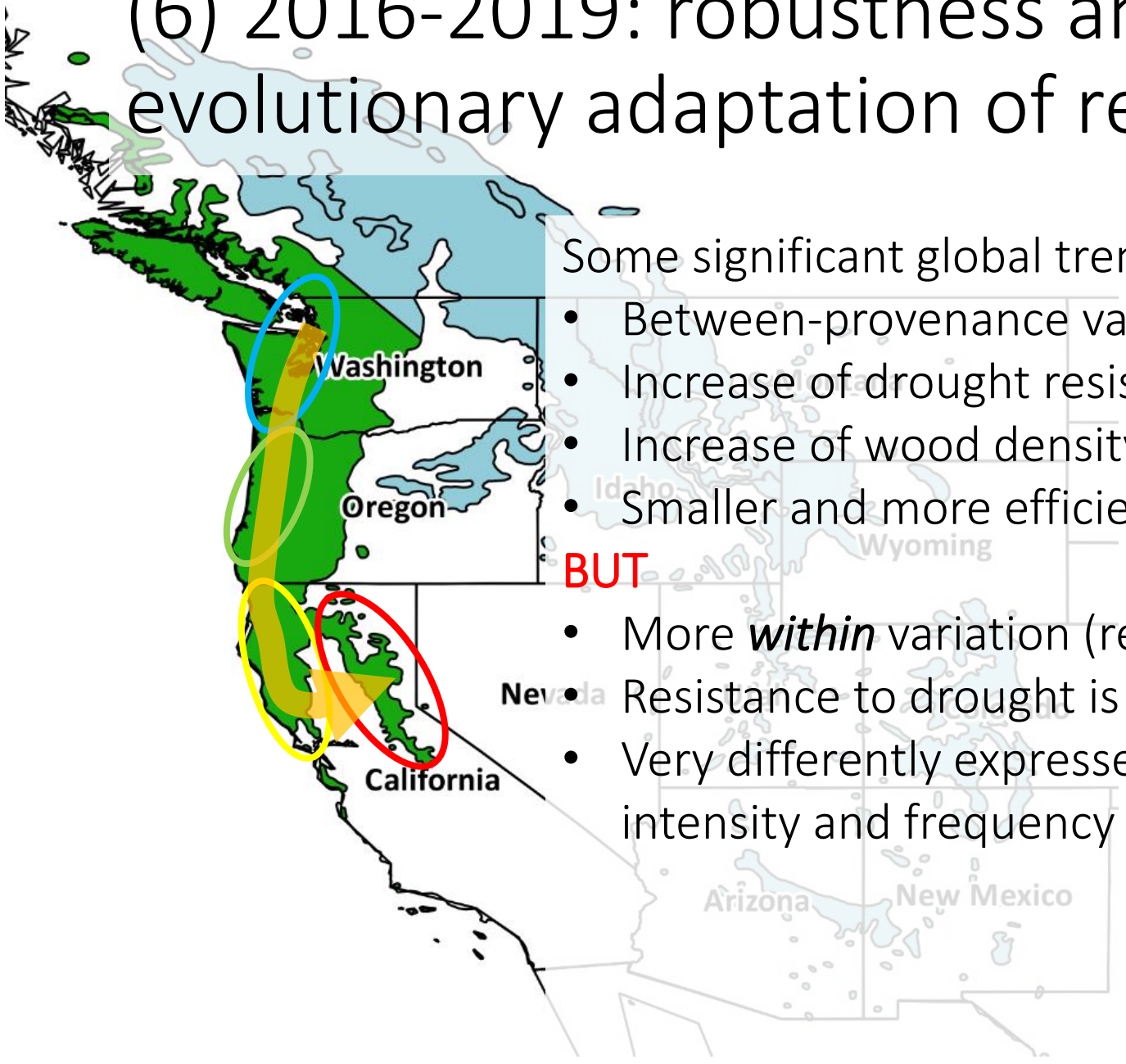

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BUT

- More ***within*** variation (region, provenance)
- Resistance to drought is a complex multifaceted trait,
- Very differently expressed according to (small) variation of the intensity and frequency of the drought stress

A “Douglas-fir resistance-to-drought” conclusion

- Structural traits linked to wood anatomy (ducts and pits) explain resistance to cavitation in branches and stems

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- Resistance to cavitation and resistance to drought are evolutionary traits shaped by climate variation in the natural range
- They are differently put in action according to the genetic origin and the local drought conditions
- The future of the Washington-Oregon origins in France is jeopardized by the global warming

References: list of related PhD thesis at INRAE

- (1) Philippe Rozenberg, 2001 « Contribution à l'étude de la variabilité génétique de propriétés du bois chez *Picea abies* et *Pseudotsuga menziesii* »
- (2) Alejandro Martinez Meier, 2009 « Réponse du douglas à des événements climatiques extrêmes : capacité d'adaptation au changement climatique »
- (3) Anne-Sophie Sergent, 2011 « Diversité de la réponse au déficit hydrique et vulnérabilité au dépérissement du douglas »
- (4) Guillermina Dalla-Salda, 2014 « Rôle fonctionnel et adaptatif du bois chez le douglas (*Pseudotsuga menziesii* (Mirb) Franco) : variabilité génétique des propriétés hydrauliques du xylème et relation avec la densité du bois »
- (5) Manuela Ruiz-Diaz, 2016 « Adaptation du douglas (*Pseudotsuga menziesii* (MIRB.) Franco) aux changements climatiques : étude rétrospective basée sur l'analyse de cernes »
- (6) Thibaud Chauvin, 2019 « Adaptation au changement climatique et potentiel évolutif du douglas (*Pseudotsuga menziesii* Franco.) : rôle des caractères hydrauliques, microdensitométriques et anatomiques du xylème »

- Thanks to Alejandro Martinez Meier, Anne-Sophie Sergent, Guillermina Dalla Salda, Manuela Ruiz Diaz Britez and Thibaud Chauvin
- And thank you for your attention