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

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

Tuesday 9th November 2021 – 16:00 CET / 07:00 PST

Philippe Rozenberg

INRAE Orleans, France

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



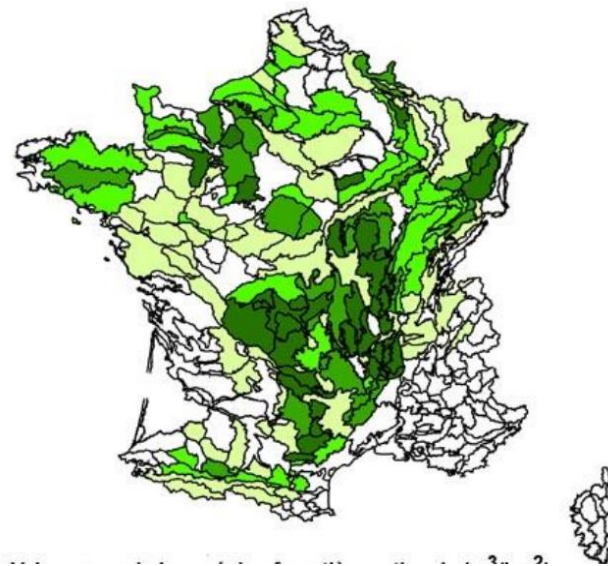
LE STUDIUM
Loire Valley
Institute for Advanced Studies



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



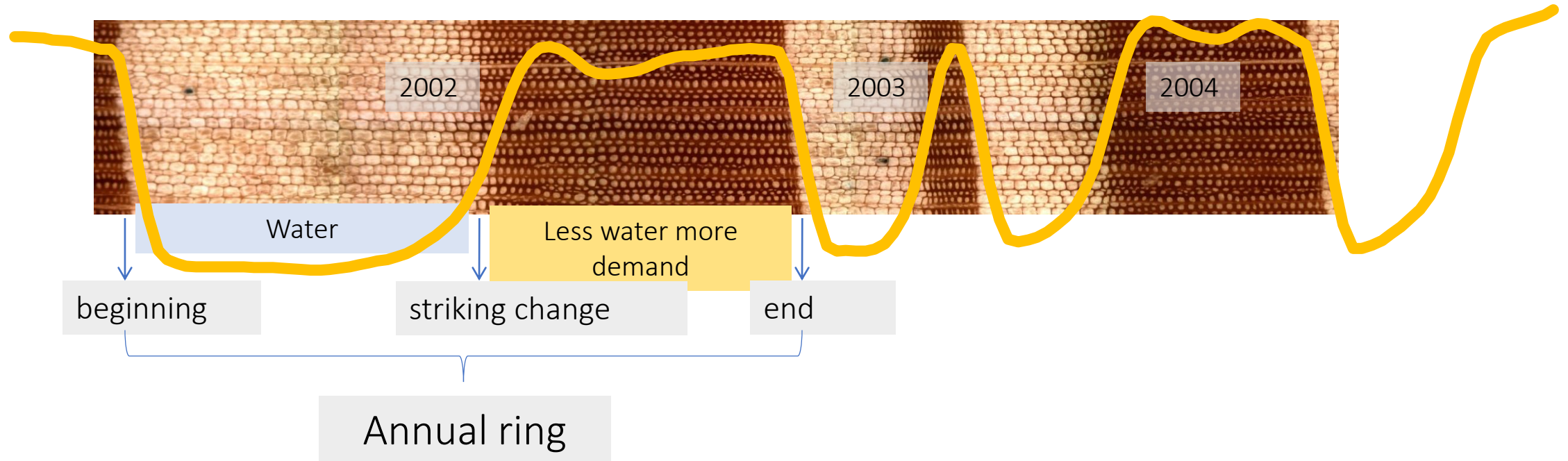
All based on wood, annual-ring features and sap conduction function

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

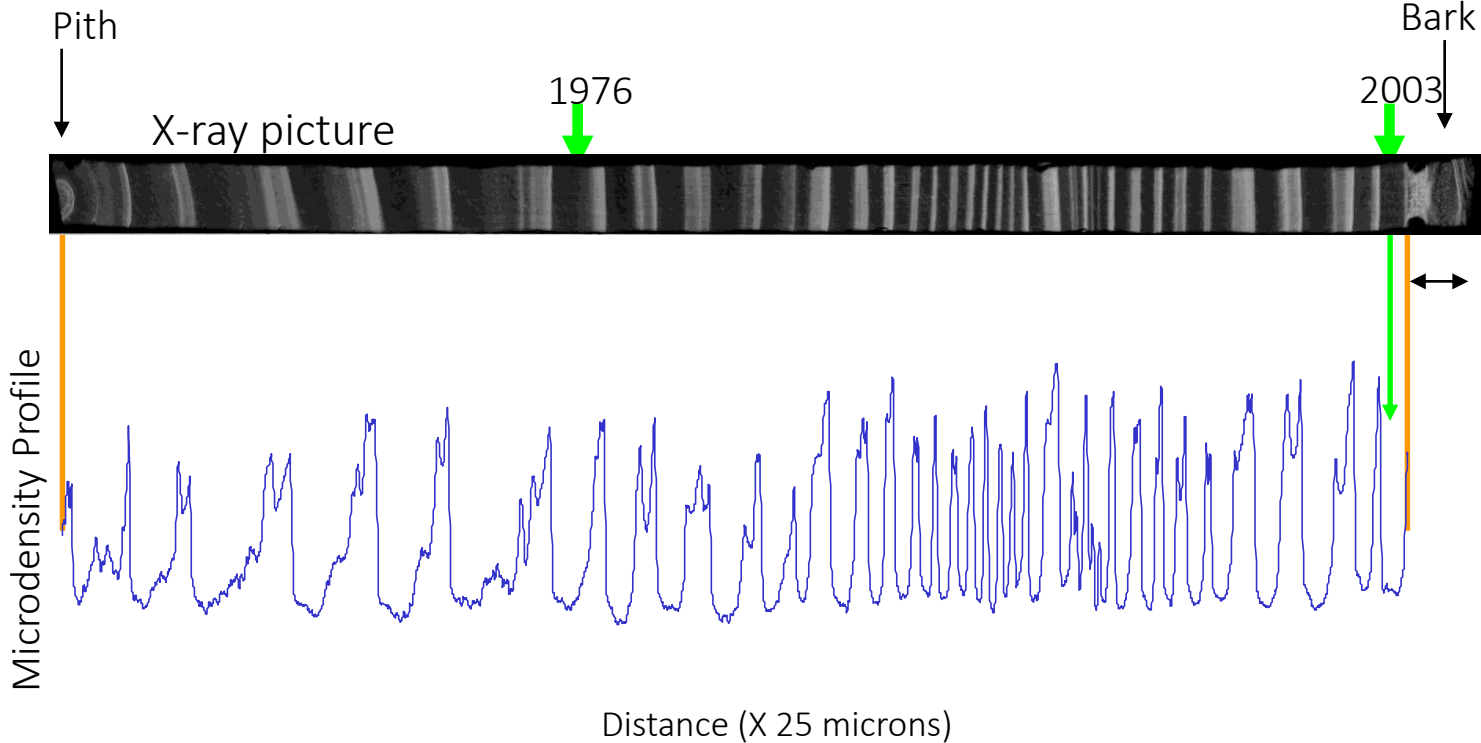


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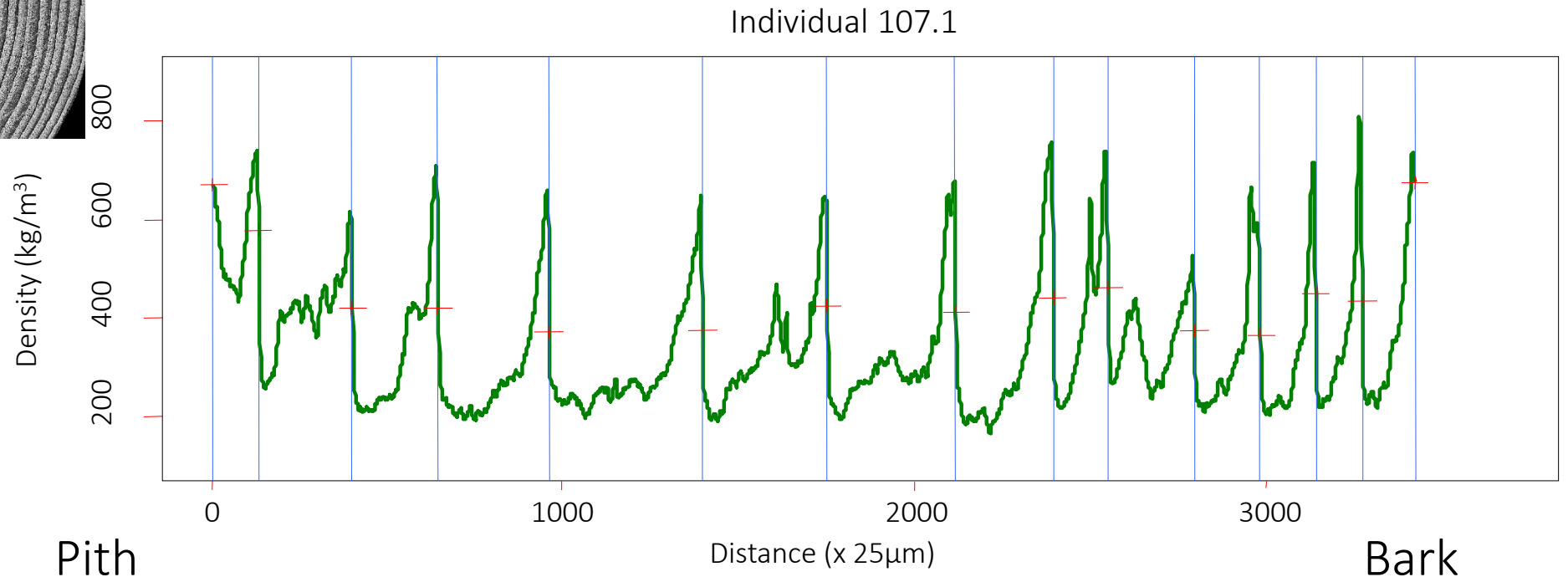
Microdensity profile



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



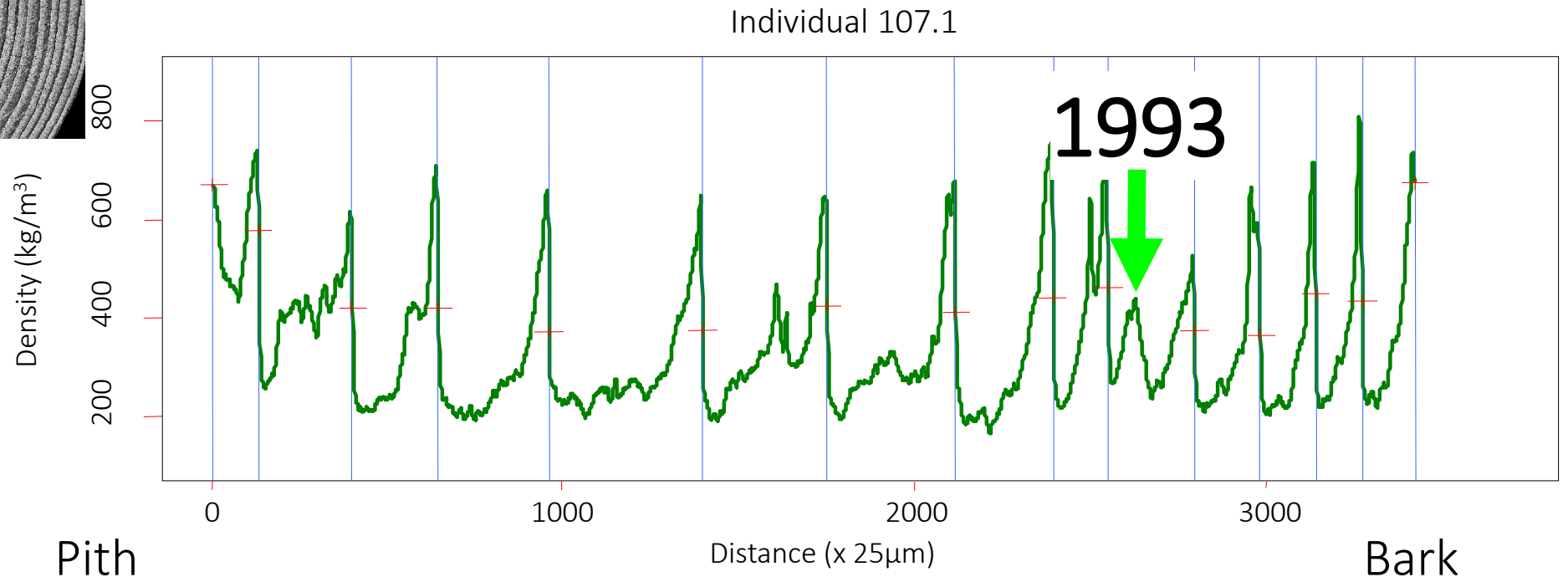
Annual-ring studies of the genetic and environmental determinism of tree response to biotic and abiotic stressors



(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



(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***

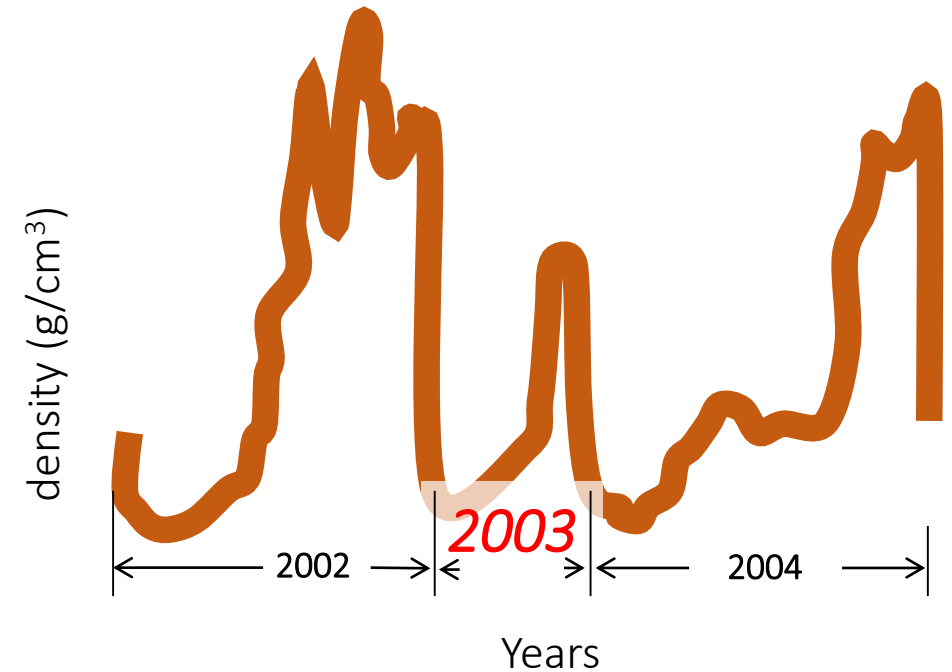
(2) 2005-2009: ring density records of adaptive response to drought



- Comparison of dead and surviving trees after a drought = relationship with the survival component of *fitness*
- **Density** (annual-ring microdensity) variables: (*proxies* of) ***adaptive*** traits for resistance to drought
- **Surviving** trees:
 - **Same** diameter
 - Significantly **denser**

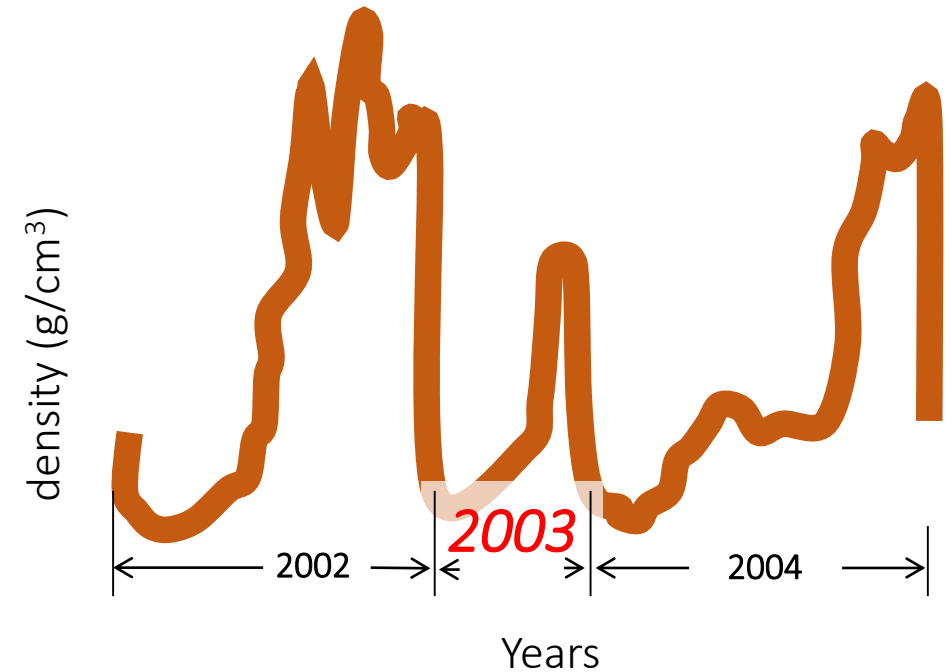
(2) 2005-2009: ring density records of adaptive response to drought

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



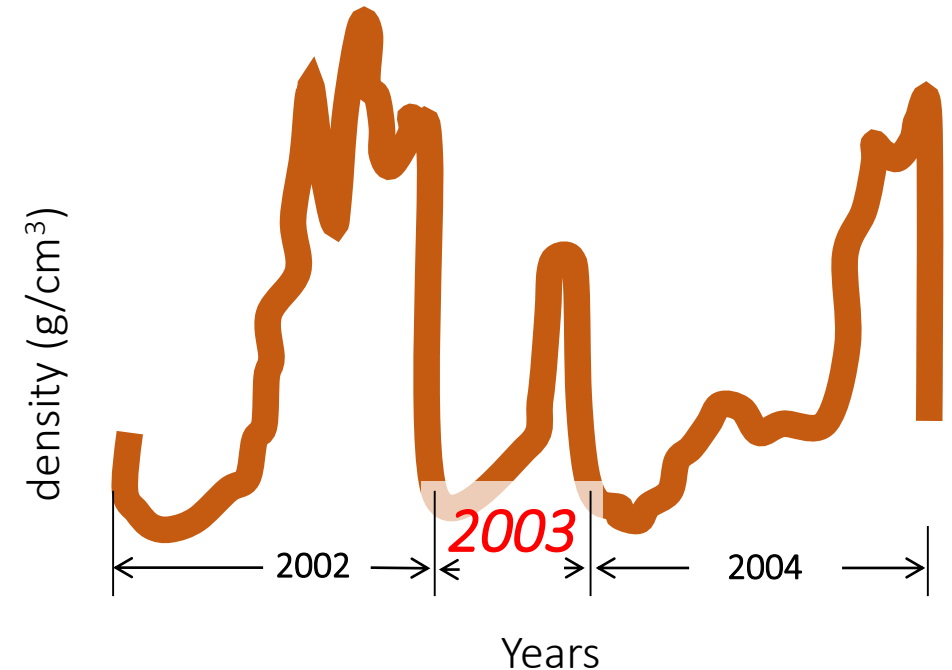
(2) 2005-2009: ring density records of adaptive response to drought

- **2003** ring significantly different from the previous and the next one
- 12 clones X 3 sites : the ring response to drought is **genetically determined**



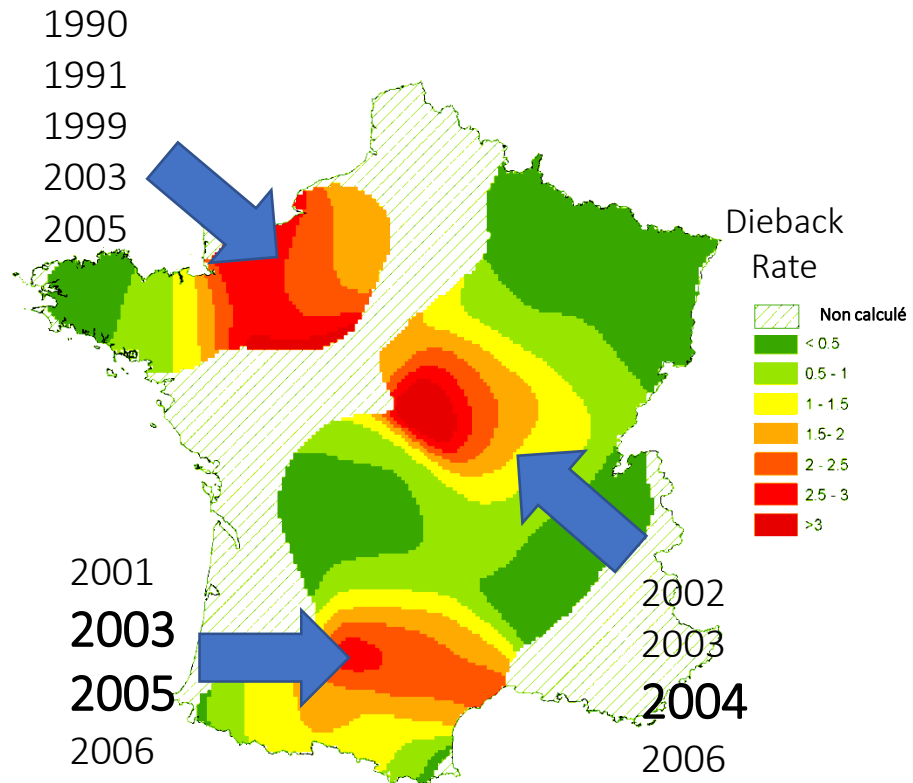
(2) 2005-2009: ring density records of adaptive response to drought

- **2003** ring significantly different from the previous and the next one
- 12 clones X 3 sites : the ring response to drought is genetically determined
- High potential of tree-rings to estimate *norms of reaction* and **phenotypic plasticity**



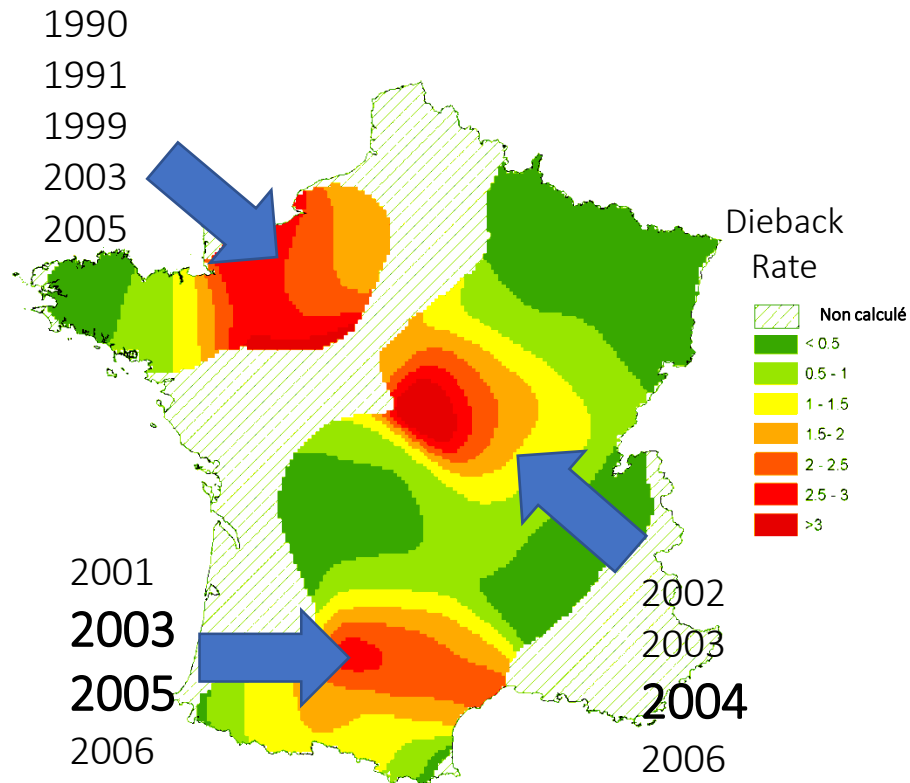
(3) 2007-2011: drought-related diebacks and provenance variation of ring response to drought

Douglas-fir forest plots with variable dieback rates

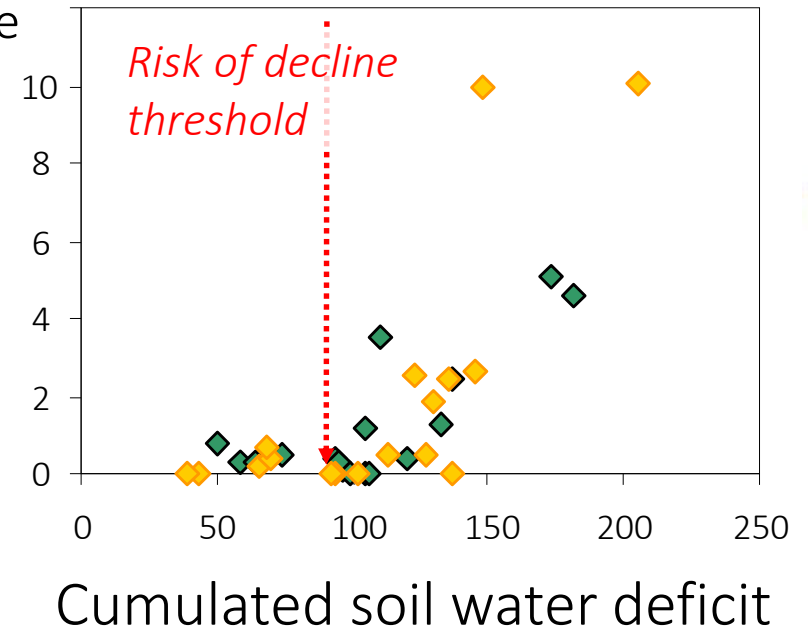


(3) 2007-2011: drought-related diebacks and provenance variation of ring response to drought

Douglas-fir forest plots with variable dieback rates



Rate of douglas-fir decline



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

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

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

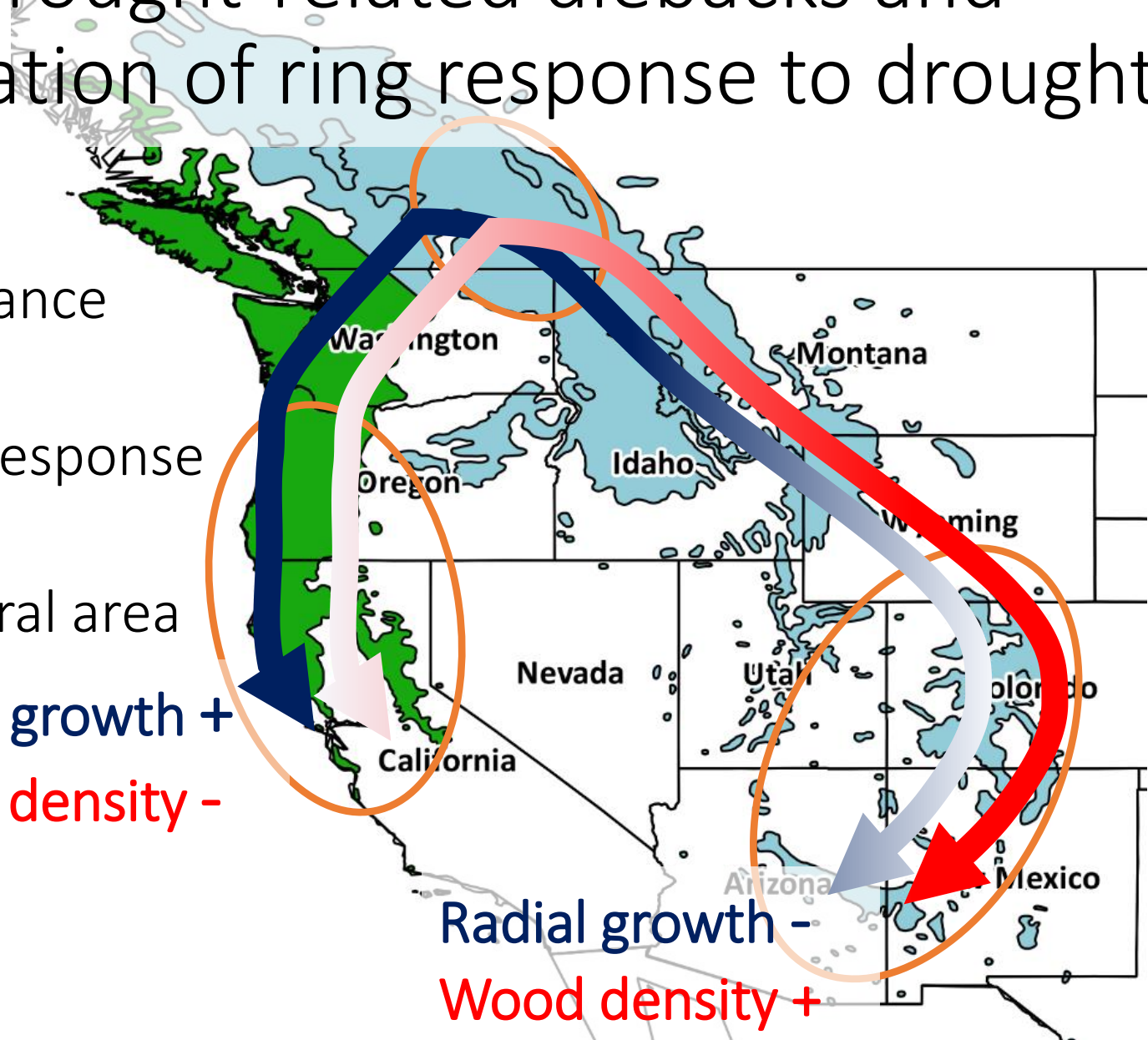


(3) 2007-2011: drought-related diebacks and provenance variation of ring response to drought

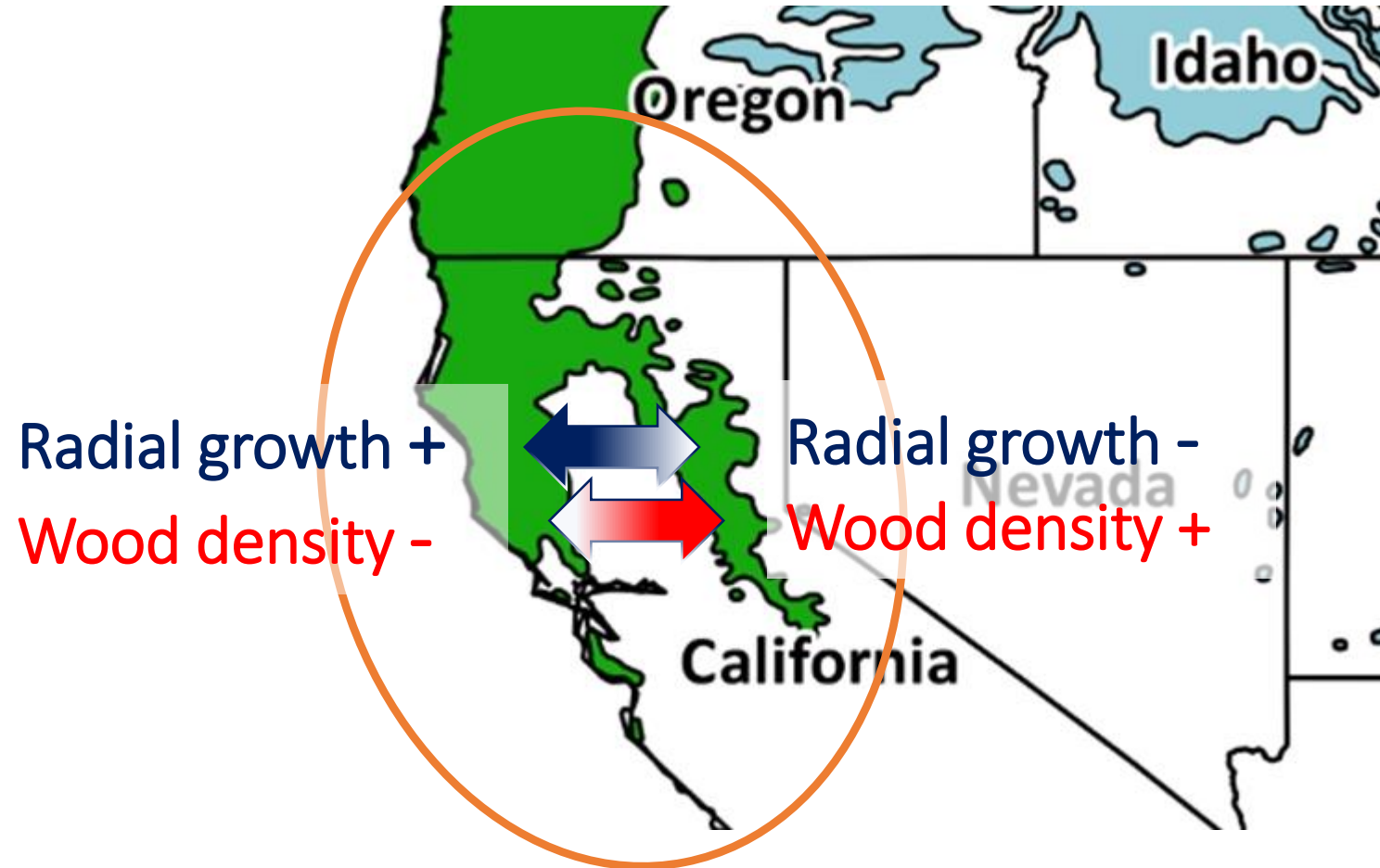
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Wood density -

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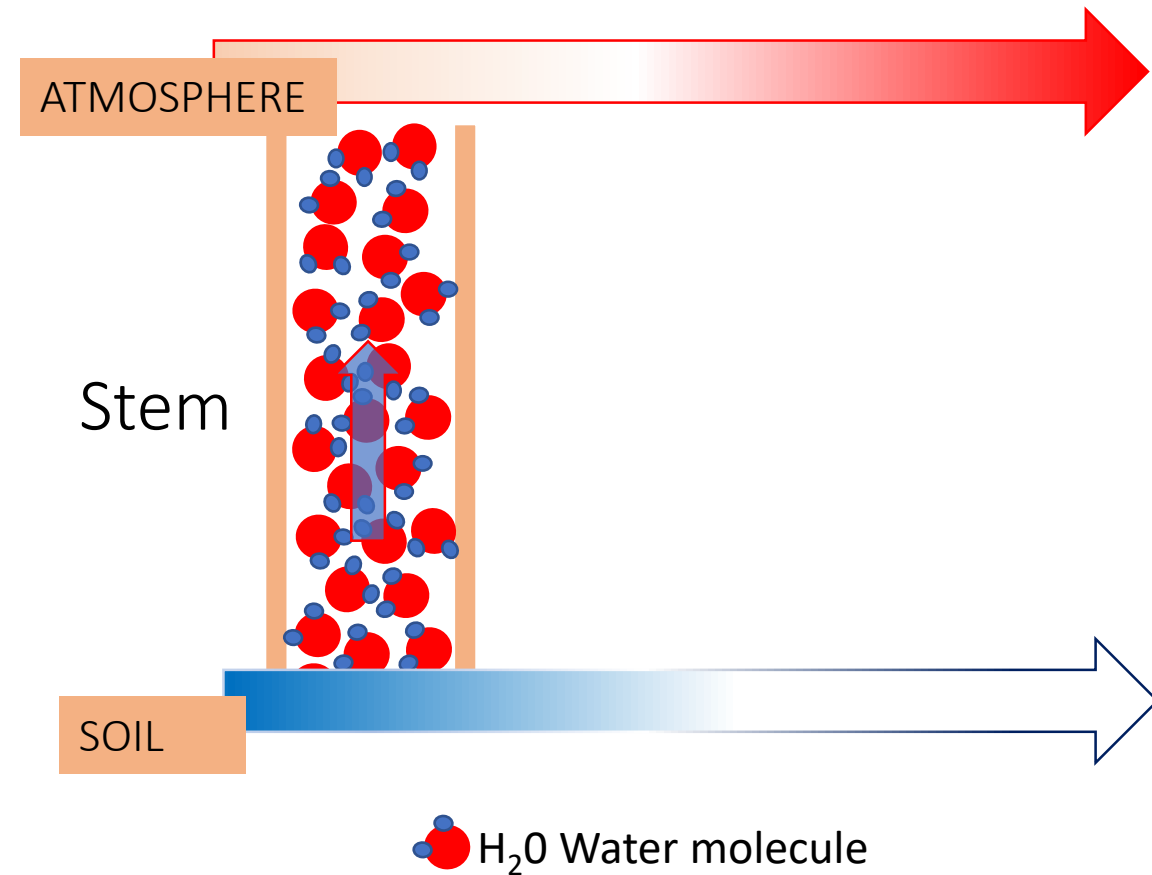


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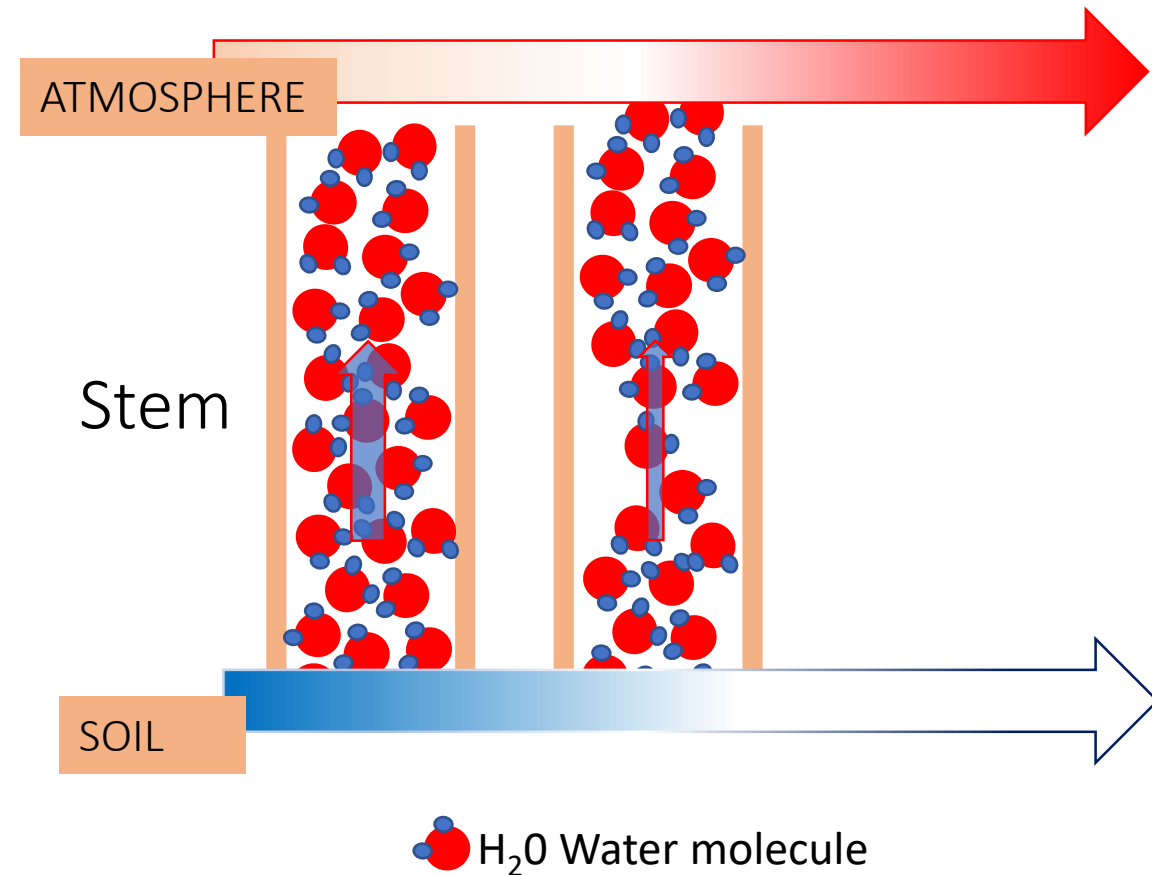
(4) 2010-2014: wood density, resistance to drought and the dynamics of cavitation

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



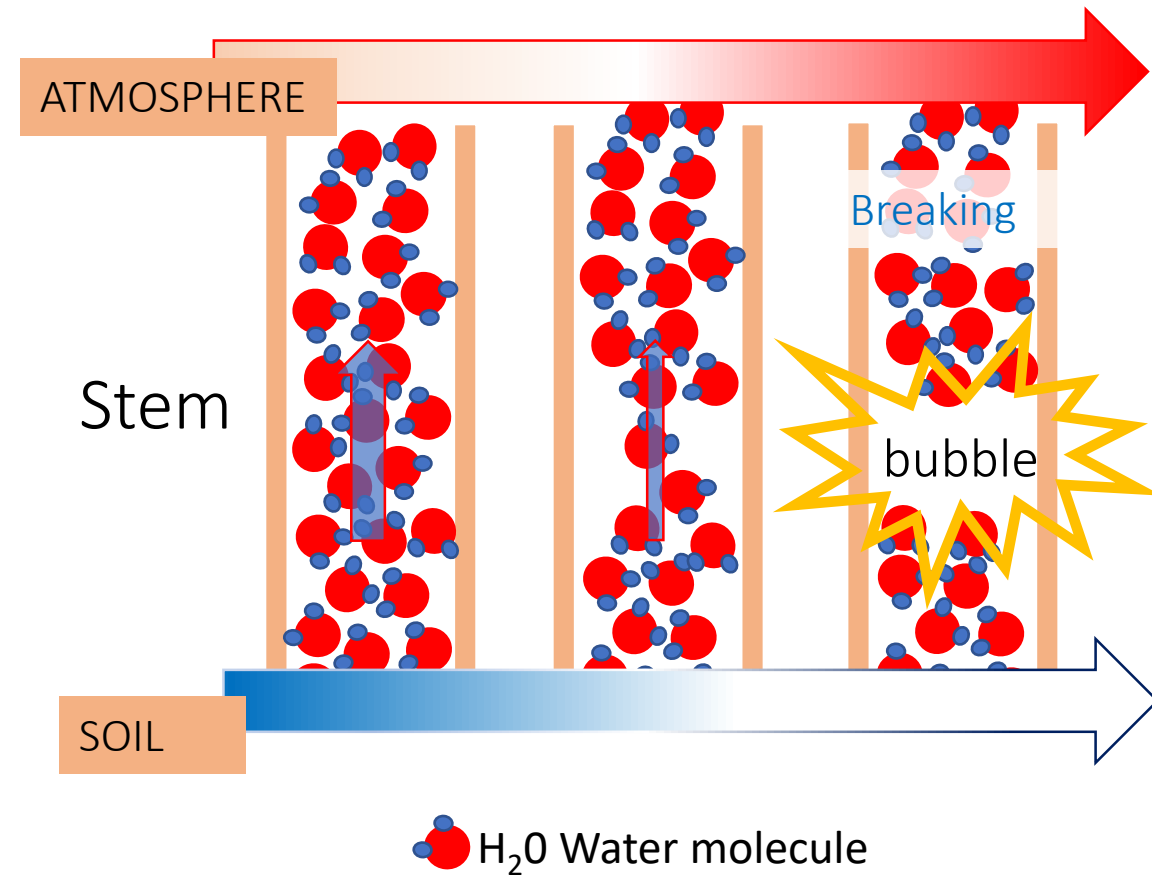
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- Resistance to cavitation



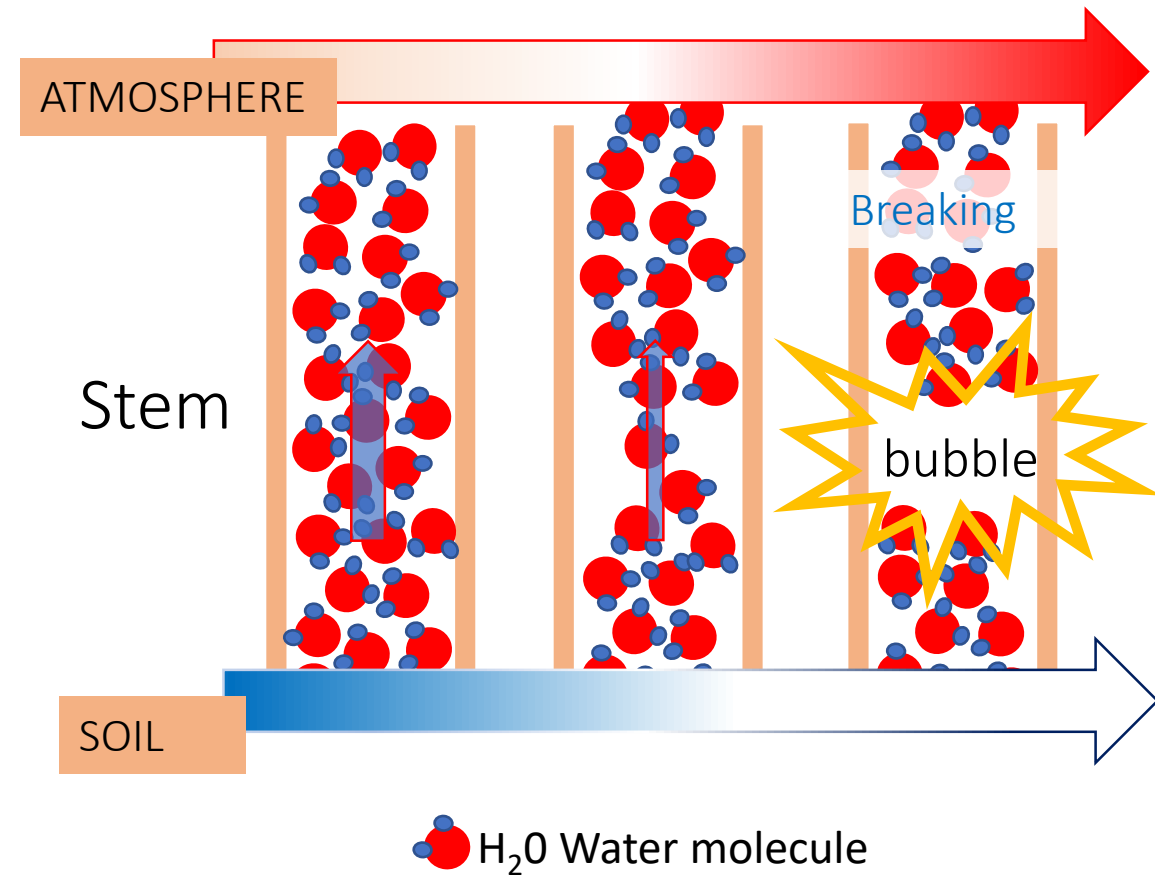
(4) 2010-2014: wood density, resistance to drought and the dynamics of cavitation

- Resistance to cavitation



(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



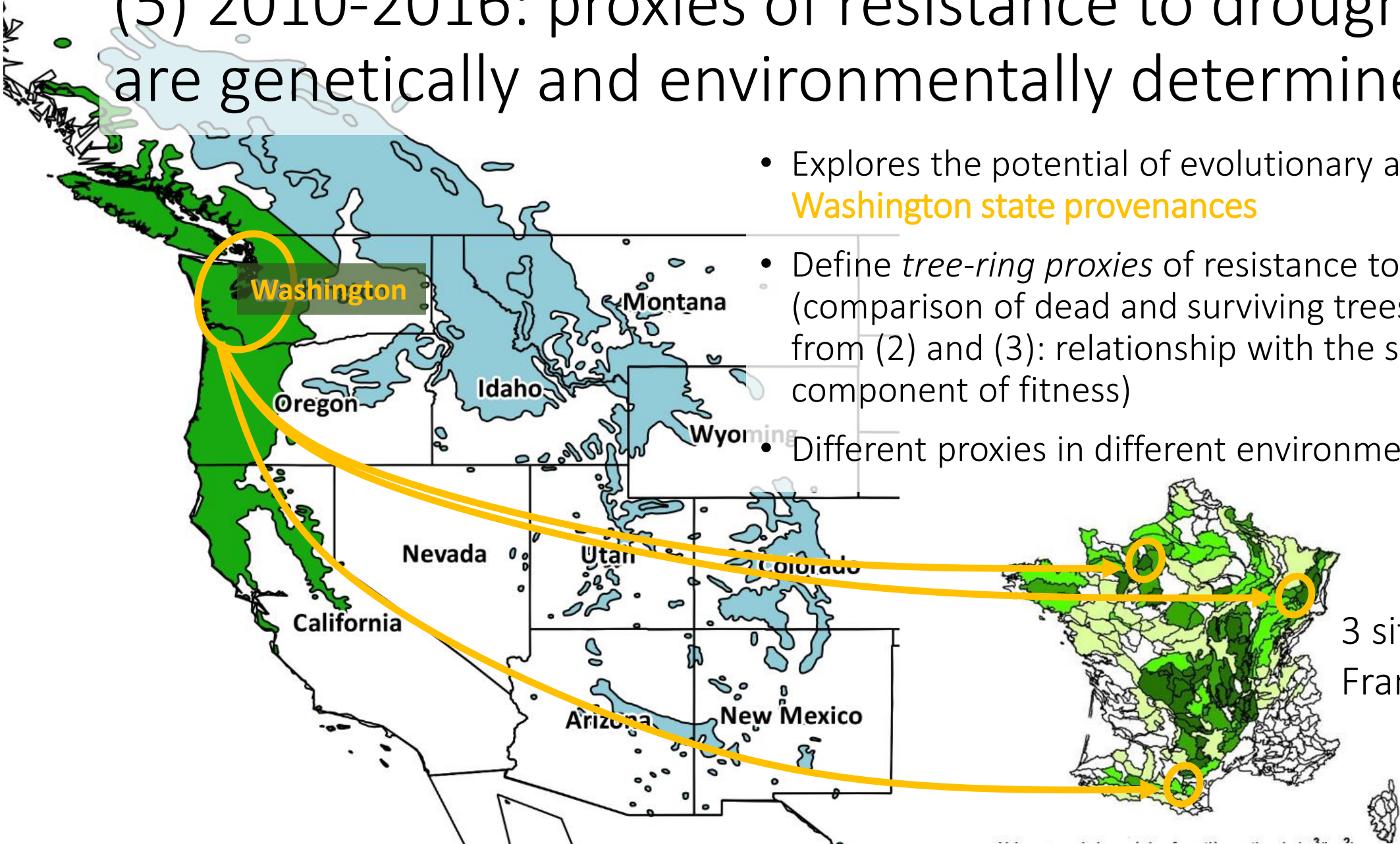
(4) 2010-2014: wood density, resistance to drought and the dynamics of cavitation

- 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

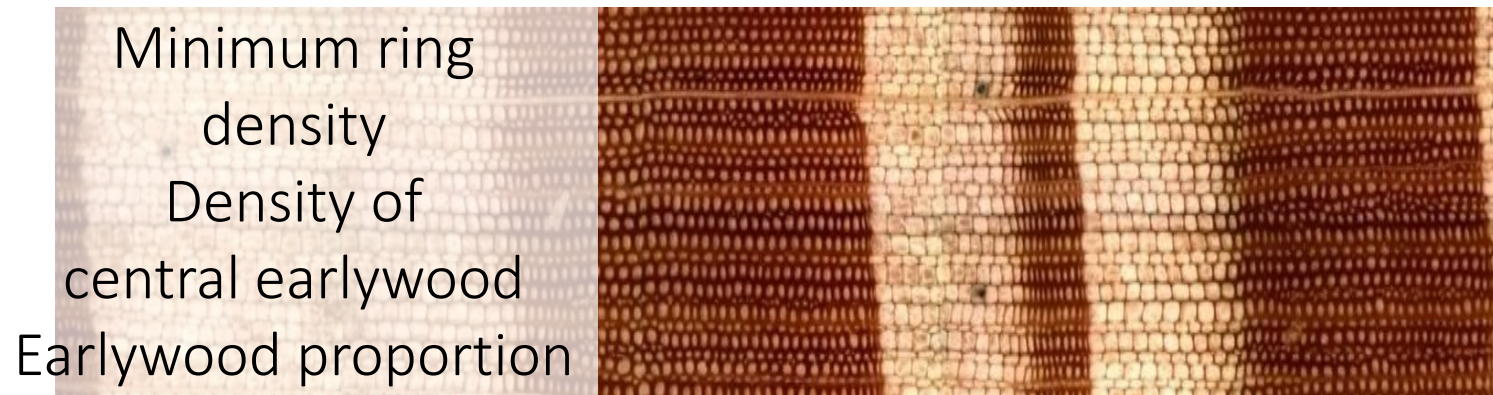
- Explores the potential of evolutionary adaptation of **Washington state provenances**
- Define *tree-ring proxies* of resistance to drought (comparison of dead and surviving trees, (2), with data from (2) and (3): relationship with the surviving component of fitness)
- Different proxies in different 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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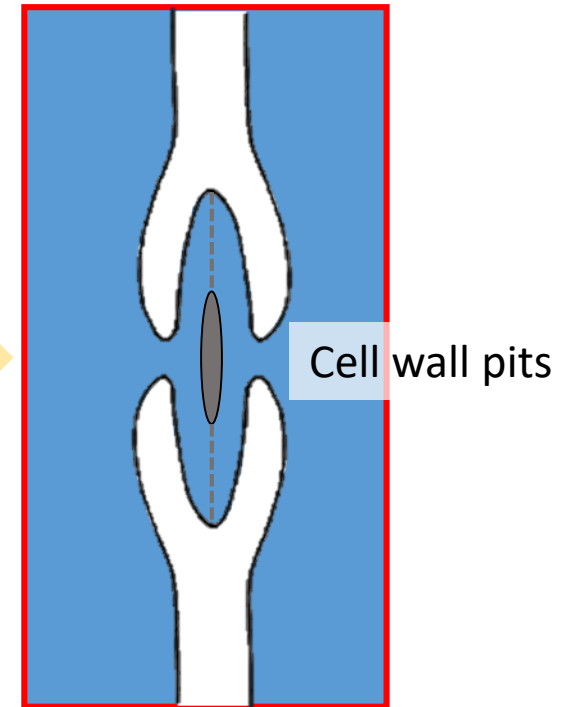
(6) 2016-2019: robustness and complexity of the evolutionary adaptation of resistance to drought

As usual: ring microdensity

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

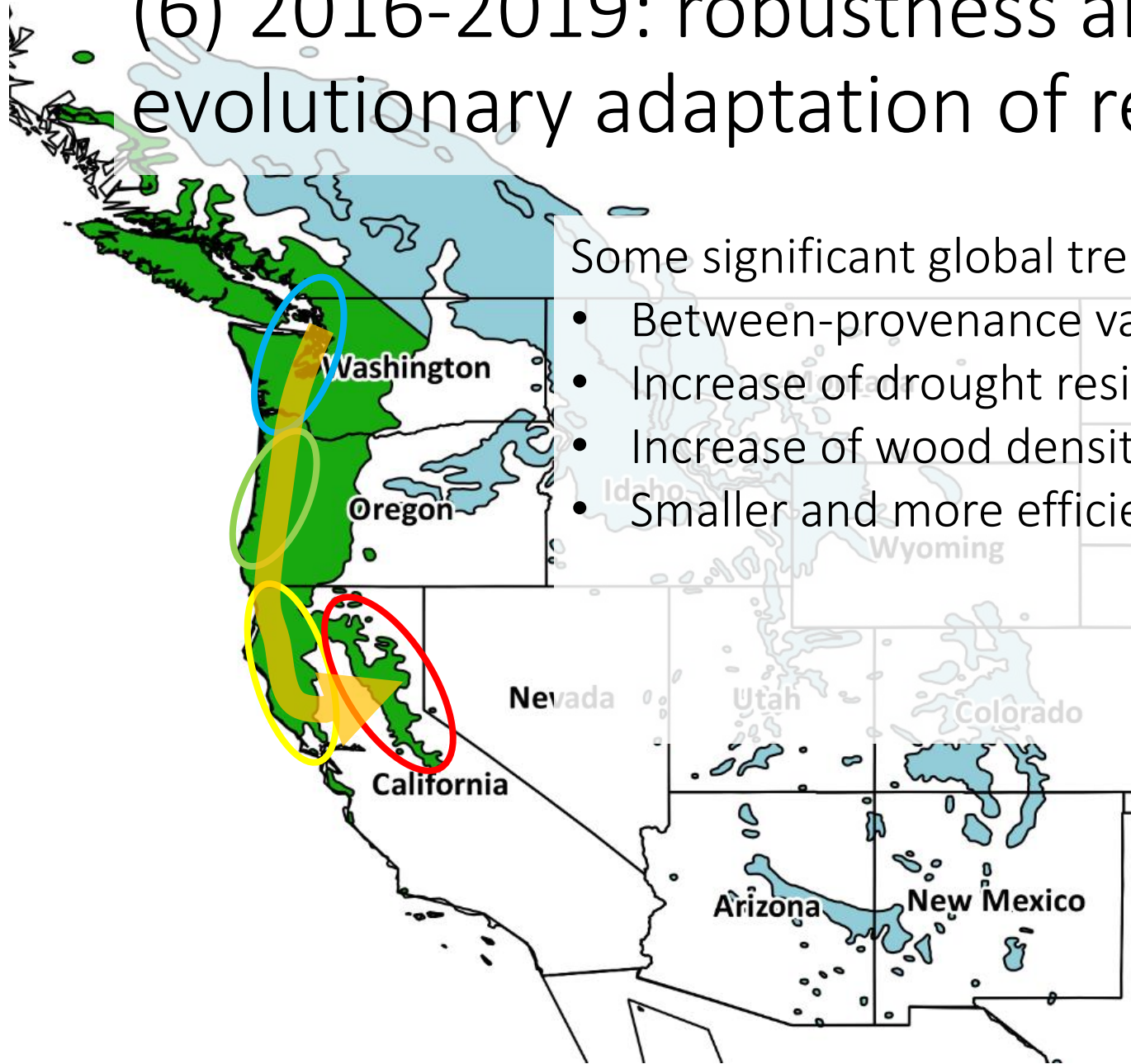
Like (4): **resistance to cavitation**, at a larger scale

For the first time: pits anatomy



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

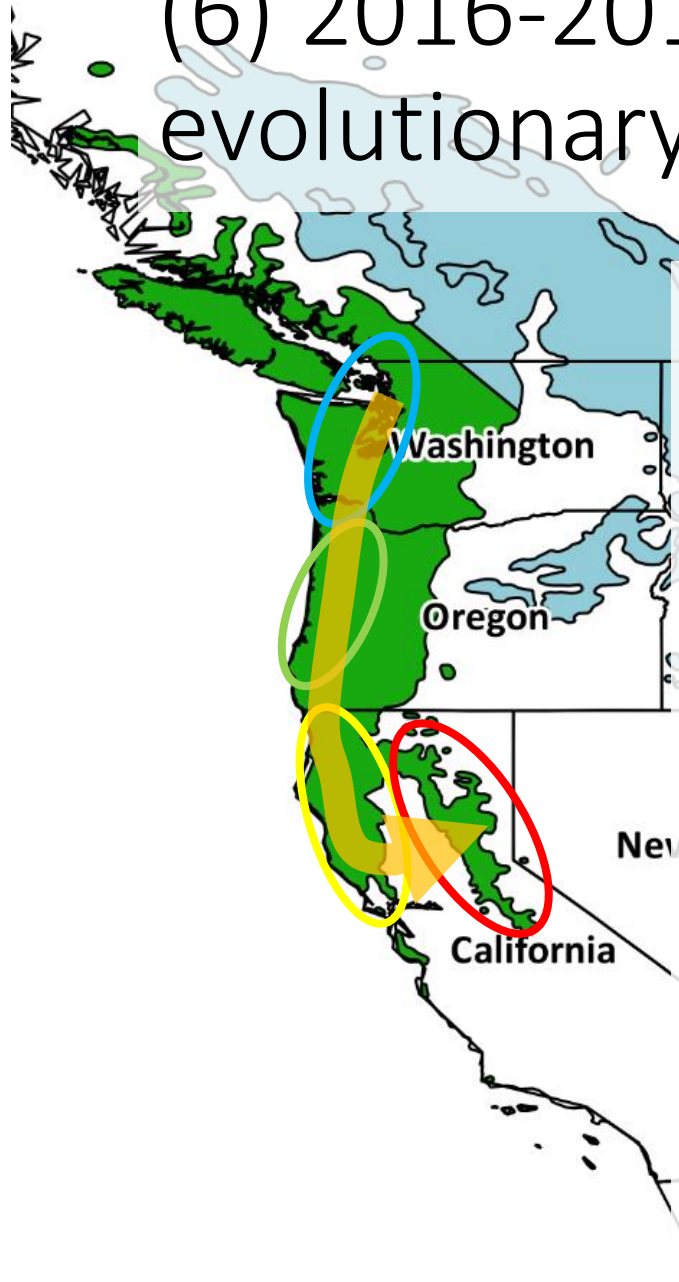
(6) 2016-2019: robustness and complexity of the evolutionary adaptation of resistance to drought



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

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



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

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

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

