

Introduction à la Dendrochronologie

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La dendrochronologie

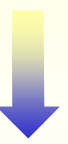
... c'est une discipline scientifique

qui utilise l'information contenue dans les cernes annuels de croissance des arbres pour une analyse spatiale et temporelle des processus physiques et biologiques



 **Dendron**
 =
 arbre

 **Chronos**
 =
 temps

 **Logos**
 =
 étude

} Analyse rétrospective
 de la croissance radiale
 des arbres



(Fritts, 1976, page 5)

Andrew E. Douglass... le père de la dendrochronologie

début de carrière en 1894 au
« Harvard College Observatory,
Arizona »

=> premier assistant du
Directeur de l'Observatoire
Astronomique

- Cernes fins / cernes larges
- Datation

mais les premiers étaient des français !
Duhamel et Buffon 1737 => froid/cerne fin

Andrew E. Douglass... le père de la dendrochronologie

A partir de la découverte de la relation entre cernes et dates, la dendrochronologie s'est développée comme science de la datation des séries chronologiques anciennes...

=> relier les « sunspots variations » aux variations des largeurs de cernes sur plusieurs siècles

=> « chronology building »

=> relations cernes fins et événements extérieurs

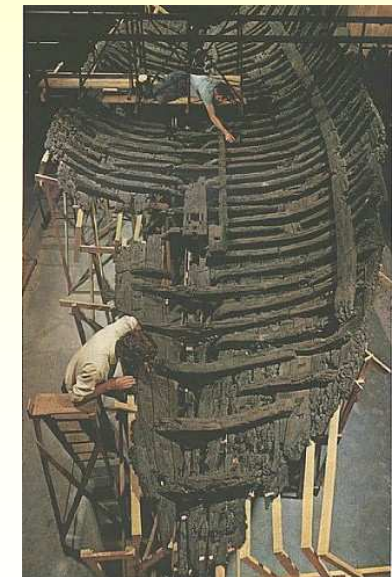
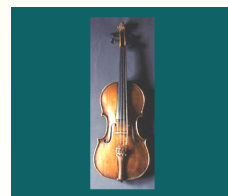
=> en 1914, première chronologie de 500 ans de *Pinus ponderosa*

=> utilisation de cette technique pour la datation de ruines Aztèque au Nouveau-Mexique....

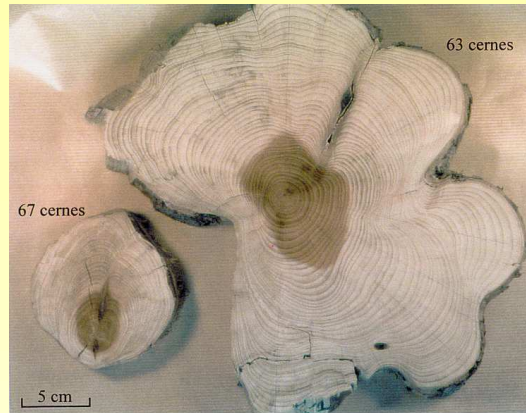


Les applications de la dendrochronologie

Domaine	Discipline	Applications
écologie	dendroécologie	Historique des feux (<i>dendropyrochronologie</i>) Dépérissement des forêts Croissance et dynamique des forêts
climatologie	dendroclimatologie	Périodes de froid, de sécheresse... Reconstruction du climat passé Analyse du climat présent
géologie	dendrogéomorphologie	Eruptions volcaniques..
anthropologie	dendroarchéologie dendroglaciologie (arbres morts)	Construction ancienne, habitation... Tourbières...



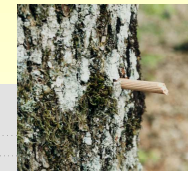
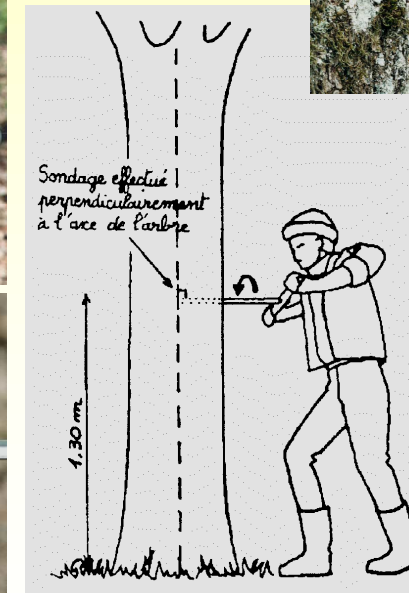
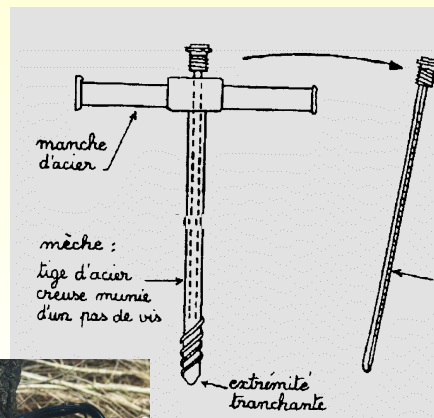
Les techniques de prélèvement



Analyse à partir de **rondelles**

- destructif
- bonne estimation de la variabilité intra-arbre

Analyse à partir de **carottes**
... tarière de Pressler



La préparation des échantillons...

Assurer une meilleure lisibilité des cernes

Planage, ponçage...

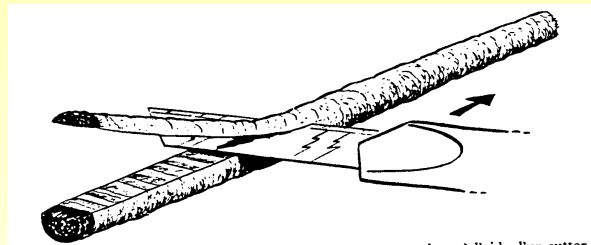
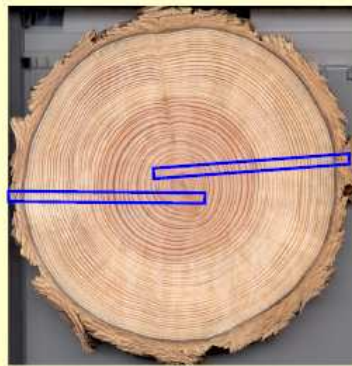
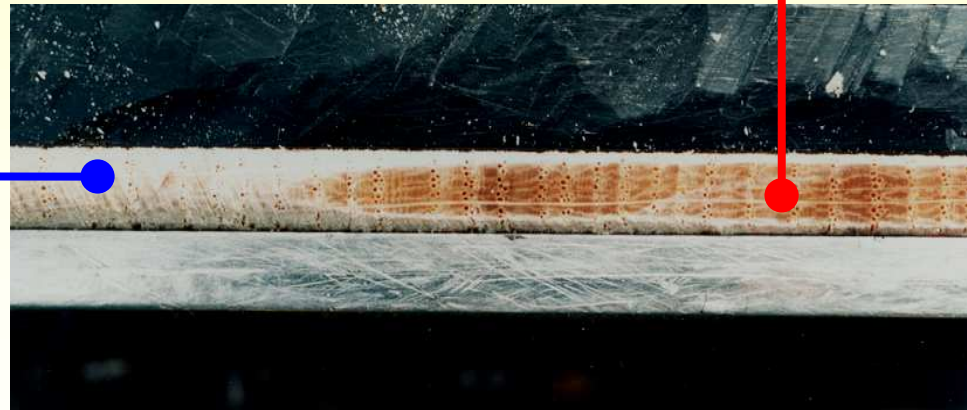


Fig. 53. Préparation du plan de mesure sur la carotte par tranchage à l'aide d'un cutter.

(Bert, 1992)

Zone non planée



Schematic of coring for typical tree

Zone planée

Le cerne de croissance... la base de la dendrochronologie

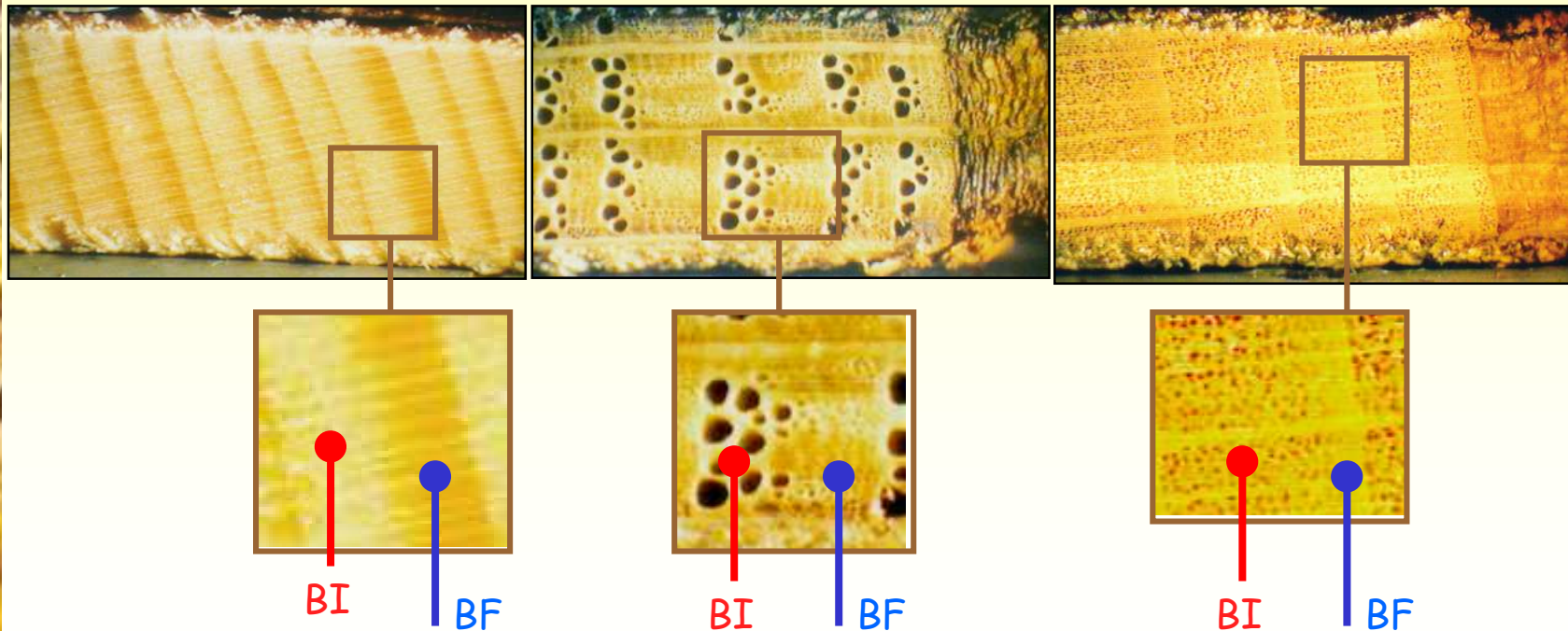
Anatomie des cernes annuels

➔ 1 Cerne = **bois initial** + **bois final**
... plus des paramètres de densité

Sapin

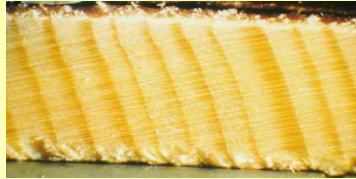
Chêne

Hêtre

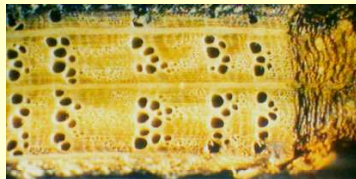


Le cerne de croissance... la base de la dendrochronologie

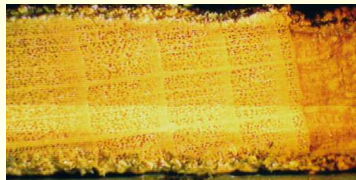
Sapin



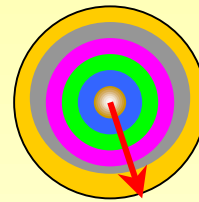
Chêne



Hêtre



Rythme annuel de croissance... le cerne



1995

1996

1997

1998

1999

2000

1

2

3

4

5

6

cœur = moelle

écorce

6 cernes de croissance



cerne le plus jeune : 1 an
date la plus ancienne : 1995

cerne le plus vieux : 6 ans
date la plus récente : 2000

Âge de l'arbre = âge du dernier cerne

Âge « cambial » ou « courant » = âge de l'arbre au moment de l'élaboration du cerne

Les principes de la dendrochronologie

1. Le principe d 'uniformité

Les processus physiques et biologiques qui gouvernent la croissance des arbres poussant actuellement sont les mêmes que ceux du passé et ont le même type d'action. La connaissance des conditions environnementales qui ont opéré dans le passé peut permettre de prédire ces conditions dans le futur

2. Le principe du facteur limitant

La croissance des arbres ne peut dépasser le niveau permis par le facteur le plus limitant

3. Le principe de l 'amplitude écologique

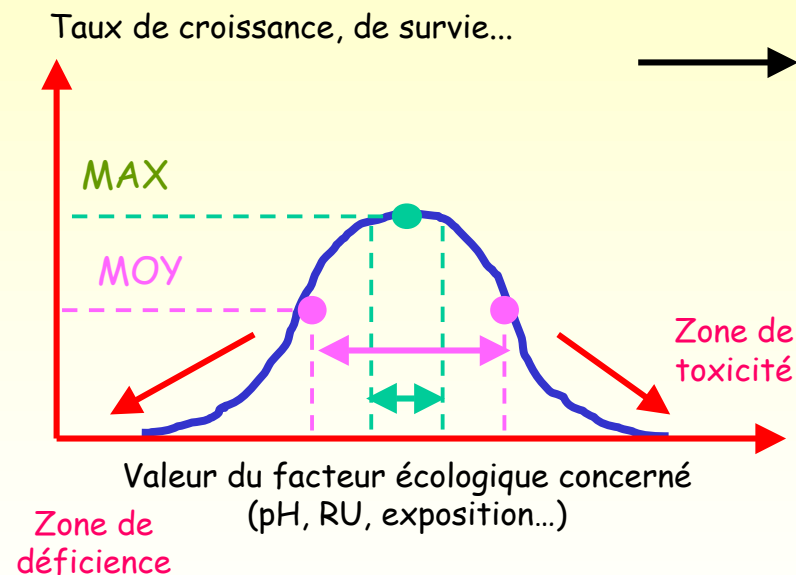
Une espèce peut pousser, se reproduire et se propager à travers une gamme d 'habitats importante ou restreinte. Elle sera plus sensible aux facteurs du milieu en limite de son aire



Les principes de la dendrochronologie

3. Le principe de l'amplitude écologique

Une espèce peut pousser, se reproduire et se propager à travers une gamme d'habitats importante ou restreinte. Elle sera plus sensible aux facteurs du milieu en limite de son aire



Ex. Dendroclimatologie

- altitude élevée (Tree line)
- situations sèches...

Les principes de la dendrochronologie

4. Le modèle linéaire de croissance (Cook, 1985)

Chaque cerne annuel (R_t) peut être décomposé en un ensemble de signaux selon un modèle additif ($t = \text{année}$)

$$R_t = A_t + C_t + \alpha D1_t + \alpha D2_t + E_t$$

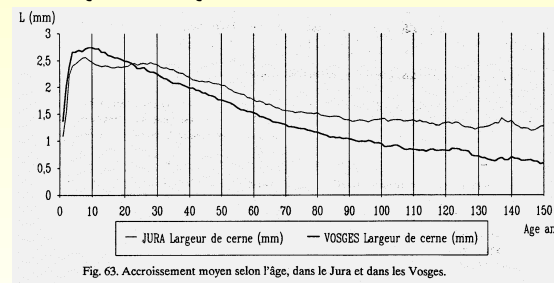
A_t = effet de l'âge biologique

C_t = effet du climat de l'année

$\alpha D1_t$ = effet de facteurs endogènes (fertilité, sylviculture, pathogènes, insectes...)

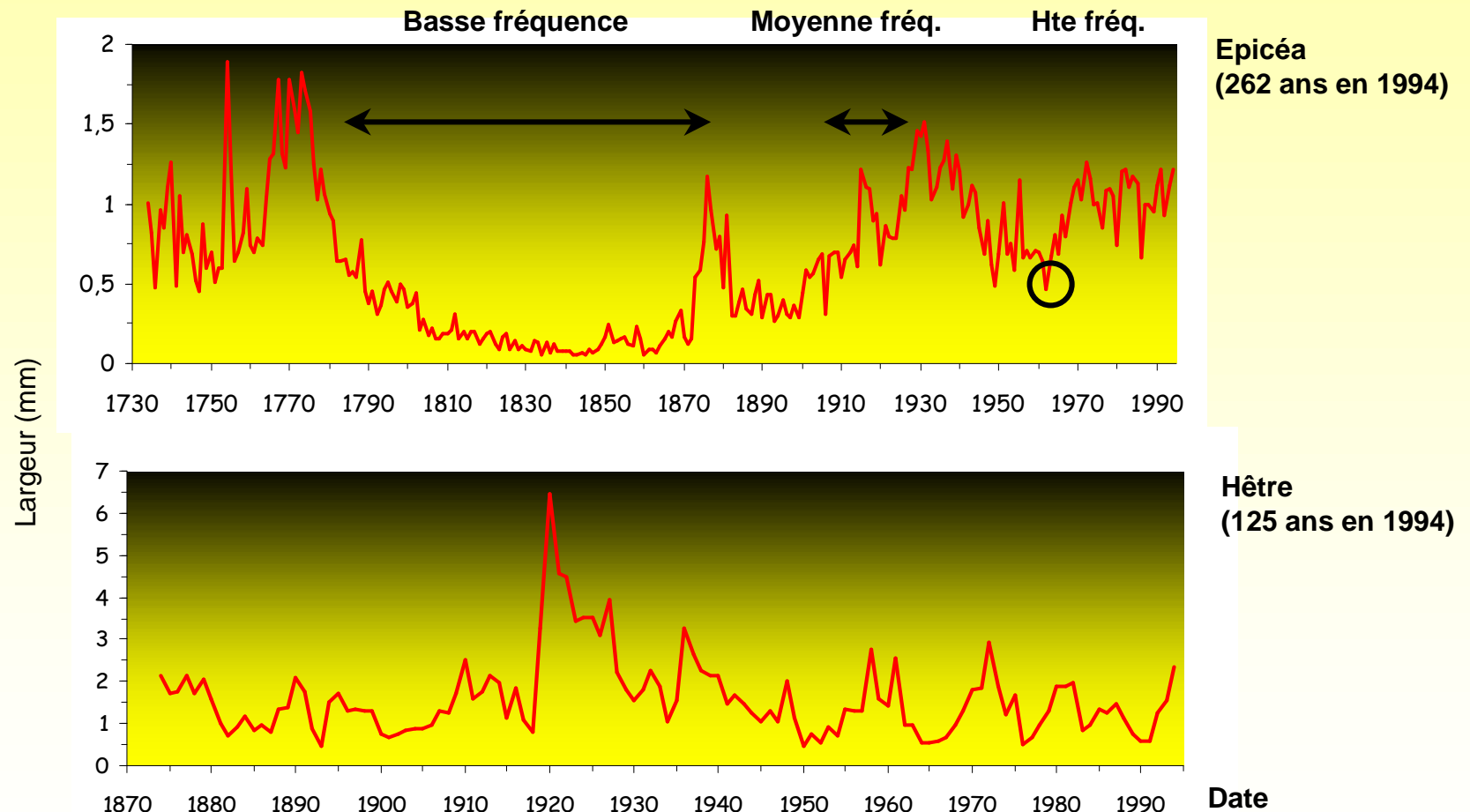
$\alpha D2_t$ = effet de facteurs exogènes (changement climatique, pollution, ozone, CO₂...) ($\alpha = 0$ ou 1)

E_t = effet aléatoire



Les principes de la dendrochronologie

4. Le modèle linéaire de croissance... I l'échelle temporelle



Les principes de la dendrochronologie

5. Le principe de réplication... la sélection des sites et des arbres

La sélection des sites doit maximiser le signal environnemental à étudier

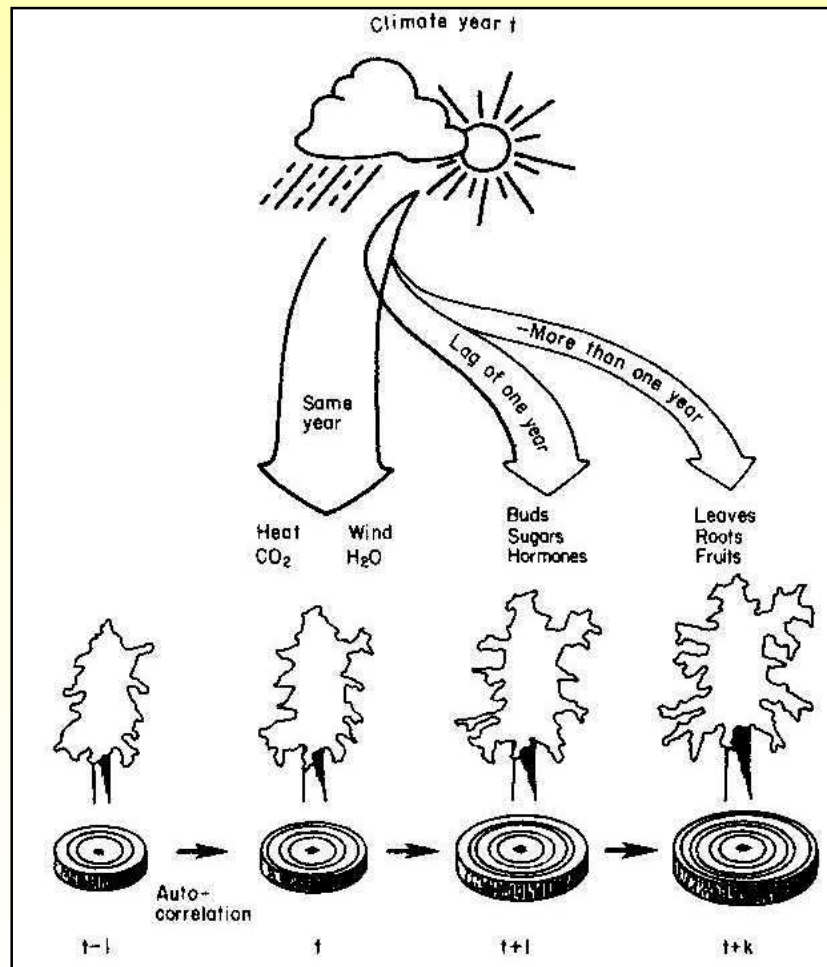
- signal climatique (Ct) : limite altitudinale de la forêt
- signal « écologique » (D1): gradient de milieux

Le signal étudié peut être amplifié et la somme des « bruits » minimisée en échantillonnant plus d'une carotte par arbre et plus d'un arbre par site => « **The site ring-width chronology** »

	arbre	peuplement	écosystèmes
échelle	Parcelle	Forêt	Massif-Région
Nb total d'arbres	+	++	+++
Nb carottes/arbre	+++	++	+
	Hêtre - Parcelle 50 Forêt de Haye	Hêtraie Forêt de Haye	Les hêtraies Plateau calcaire de Lorraine

Les principes de la dendrochronologie

Cerne annuel = ensemble de signaux complexes + arrière-effets (lag effects)



Exemple :

Principe général de l'effet du climat sur la mise en place du cerne...

(Fritts, 1976, page 26, Fig. 1.10)

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A close-up photograph of a textured surface, likely the cover or endpaper of an old book. The material is a light tan or yellowish-brown color with a mottled, aged appearance. Overlaid on this background is a repeating pattern of small, dark brown, circular or oval-shaped motifs. These motifs are arranged in vertical columns, with some appearing slightly larger or more prominent than others, creating a rhythmic, textured effect. The lighting is somewhat uneven, highlighting the texture of the material.

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A close-up photograph of a textured surface, likely the cover or endpaper of an old book. The material is a light tan or yellowish-brown color with a mottled, aged appearance. A prominent vertical crease or fold runs down the center of the image. On either side of this crease, there are numerous small, dark, circular holes or indentations, arranged in somewhat regular vertical columns. These features suggest a perforated or woven material, possibly a type of parchment or a specific bookbinding technique. The lighting is slightly uneven, with the center of the crease appearing brighter than the edges.

Les principes de la dendrochronologie

Faible précipitation et température élevée.... Cerne fin (généralement)

Un aperçu des mécanismes mis en œuvre pendant la saison de végétation précédente...

```
graph TD
    LP[LOW PRECIPITATION] --> LSC[Less cloud cover]
    LP --> LSM[Low soil moisture]
    LP --> LVP[Low vapor pressure]
    LSC --> MSR[More solar radiation]
    MSR --> HT[HIGH TEMPERATURE]
    HT --> IPT[Increased plant temperatures]
    IPT --> RE[Rapid evaporation]
    RE --> LVP
    RE --> DTM[Decreased transpiration during midday]
    DTM --> EEC[Less evaporative cooling]
    EEC --> IPT
    DTM --> SCD[stomatal closure during day]
    SCD --> INP[INCREASED WATER STRESS IN TREE]
    INP --> RNP[Reduced net photosynthesis]
    RNP --> LAF[Less assimilation of food]
    LAF --> LFT[Less food translocated and stored throughout the tree]
    LFT --> LPPC[LESS POTENTIAL FOR RAPID CAMBIAL GROWTH to A]
    LFT --> LCT[Less consumption of foods]
    LCT --> IR[Increased respiration]
    IR --> LFT
    IR --> LPPC
    IR --> LPPC
    LP --> DAM[Decreased activity in meristems during prior growing seasons]
    DAM --> FL[Fewer leaves]
    DAM --> SL[Smaller leaves]
    DAM --> FR[Fewer roots]
    FL --> LPA[Less photosynthetic area]
    LPA --> LPPC
    SL --> LMS[Less absorption of mineral salts]
    LMS --> LPPC
    FR --> DAW[Decreased absorption of water]
    DAW --> INP
    INP --> RNP
    INP --> LFT
    INP --> LPPC
```

The flowchart illustrates the mechanisms leading to fine growth rings (cernes fins) in trees due to low precipitation and high temperature. The process starts with LOW PRECIPITATION, which leads to Less cloud cover, More solar radiation, and HIGH TEMPERATURE. HIGH TEMPERATURE leads to Increased plant temperatures, which causes Rapid evaporation. Rapid evaporation leads to Low vapor pressure and Decreased transpiration during midday. Decreased transpiration during midday leads to Less evaporative cooling and stomatal closure during day. Stomatal closure during day leads to INCREASED WATER STRESS IN TREE. INCREASED WATER STRESS IN TREE leads to Reduced net photosynthesis, Less assimilation of food, and Less food translocated and stored throughout the tree. Less food translocated and stored throughout the tree leads to LESS POTENTIAL FOR RAPID CAMBIAL GROWTH (to A). Less assimilation of food also leads to Less consumption of foods, which increases respiration. Increased respiration leads to Less food translocated and stored throughout the tree and LESS POTENTIAL FOR RAPID CAMBIAL GROWTH (to A). Low precipitation also leads to Low soil moisture and Low vapor pressure. Low soil moisture leads to Decreased activity in meristems during prior growing seasons, which results in Fewer leaves, Smaller leaves, and Fewer roots. Fewer leaves leads to Less photosynthetic area, which leads to LESS POTENTIAL FOR RAPID CAMBIAL GROWTH (to A). Smaller leaves lead to Less absorption of mineral salts, which leads to LESS POTENTIAL FOR RAPID CAMBIAL GROWTH (to A). Fewer roots lead to Decreased absorption of water, which leads to INCREASED WATER STRESS IN TREE. INCREASED WATER STRESS IN TREE also leads to Reduced net photosynthesis, Less assimilation of food, and Less food translocated and stored throughout the tree, all of which lead to LESS POTENTIAL FOR RAPID CAMBIAL GROWTH (to A).

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Les principes de la dendrochronologie

Faible précipitation et température élevée.... Cerne fin (généralement)

Un aperçu des mécanismes mis en œuvre pendant la saison de végétation précédente...

```
graph TD
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    MSR --> HT[HIGH TEMPERATURE]
    LVP --> RE[Rapid evaporation]
    RE --> HT
    HT --> IPT[Increased plant temperatures]
    IPT --> LEC[Less evaporative cooling]
    LEC --> HT
    LSM --> DAM[Decreased activity in meristems during prior growing seasons]
    DAM --> FL[Fewer leaves]
    DAM --> SL[Smaller leaves]
    LSM --> FR[Fewer roots]
    FR --> DAW[Decreased absorption of water]
    DAW --> IWT[INCREASED WATER STRESS IN TREE]
    LVP --> IWT
    IWT --> RNP[Reduced net photosynthesis]
    IWT --> SCD[stomatal closure during day]
    RNP --> LA[Less assimilation of food]
    SCD --> IR[Increased respiration]
    IPT --> IR
    IR --> IC[Increased consumption of foods]
    LA --> LFT[Less food translocated and stored throughout the tree]
    IC --> LFT
    LFT --> LPP[Less production of cell parts and substances]
    LFT --> LRCG[LESS POTENTIAL FOR RAPID CAMBIAL GROWTH to A]
    LPP --> PCGR[Possible changes in production of growth regulators]
    PCGR --> LRCG
    FL --> LPA[Less photosynthetic area]
    LPA --> LPP
```

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Les principes de la dendrochronologie

Faible précipitation et température élevée.... Cerne fin (généralement)

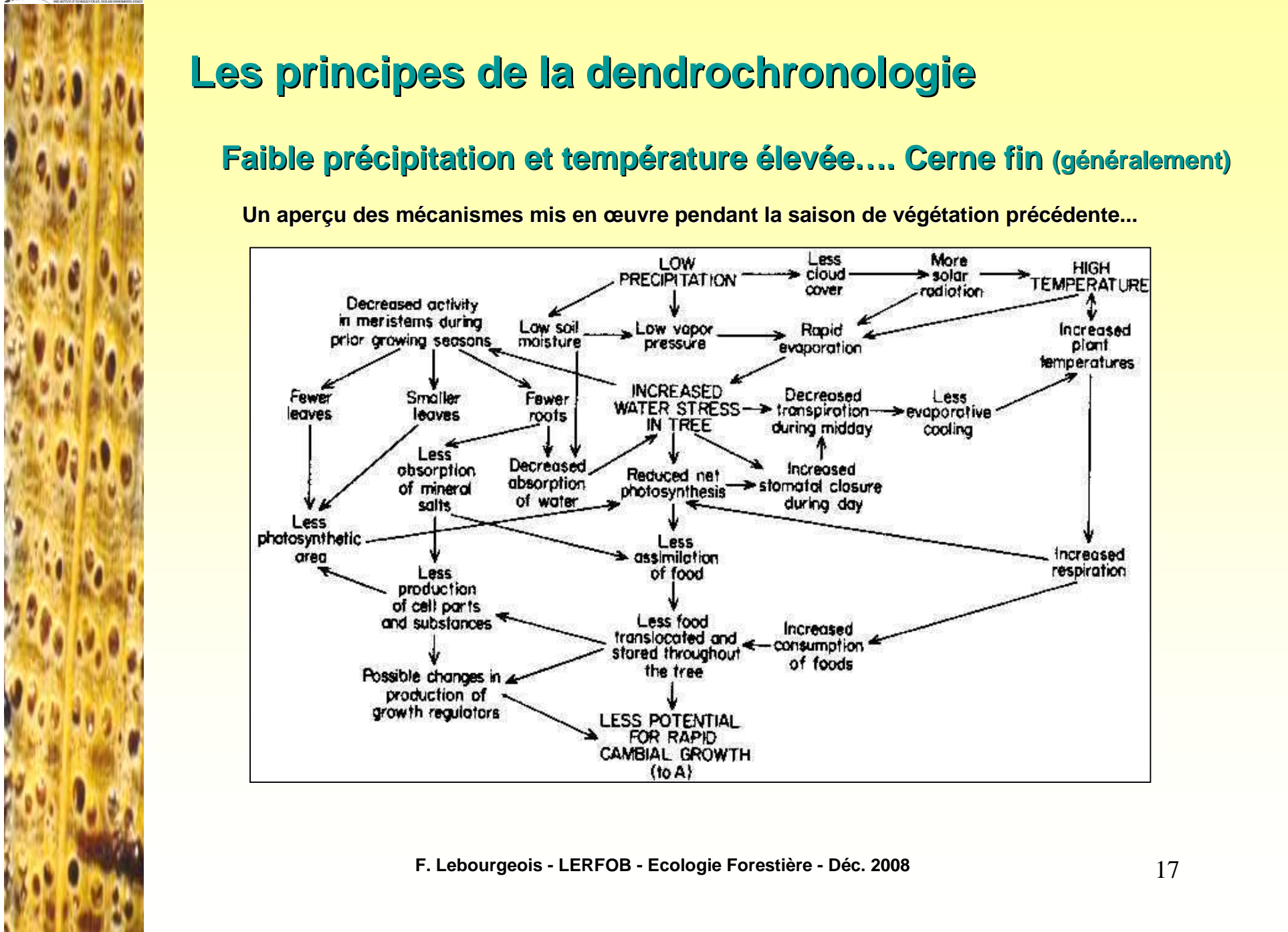
Un aperçu des mécanismes mis en œuvre pendant la saison de végétation précédente...

```
graph TD; LP[LOW PRECIPITATION] --> LSC[Less cloud cover]; LP --> LSM[Low soil moisture]; LP --> LVP[Low vapor pressure]; LSC --> MSR[More solar radiation]; MSR --> HT[HIGH TEMPERATURE]; HT --> IPT[Increased plant temperatures]; IPT --> RE[Rapid evaporation]; RE --> DTM[Decreased transpiration during midday]; DTM --> ELC[evaporative cooling]; ELC --> IPT; IPT --> IR[increased respiration]; IR --> ICF[Increased consumption of foods]; ICF --> LFST[Less food translocated and stored throughout the tree]; LFST --> LPGA[LESS POTENTIAL FOR RAPID CAMBIAL GROWTH to A); LFST --> PCG[Possible changes in production of growth regulators]; PCG --> LPGA; LFST --> LPP[Less production of cell parts and substances]; LPP --> LPGA; LPGA --> LPGA; LPGA --> LPGA;
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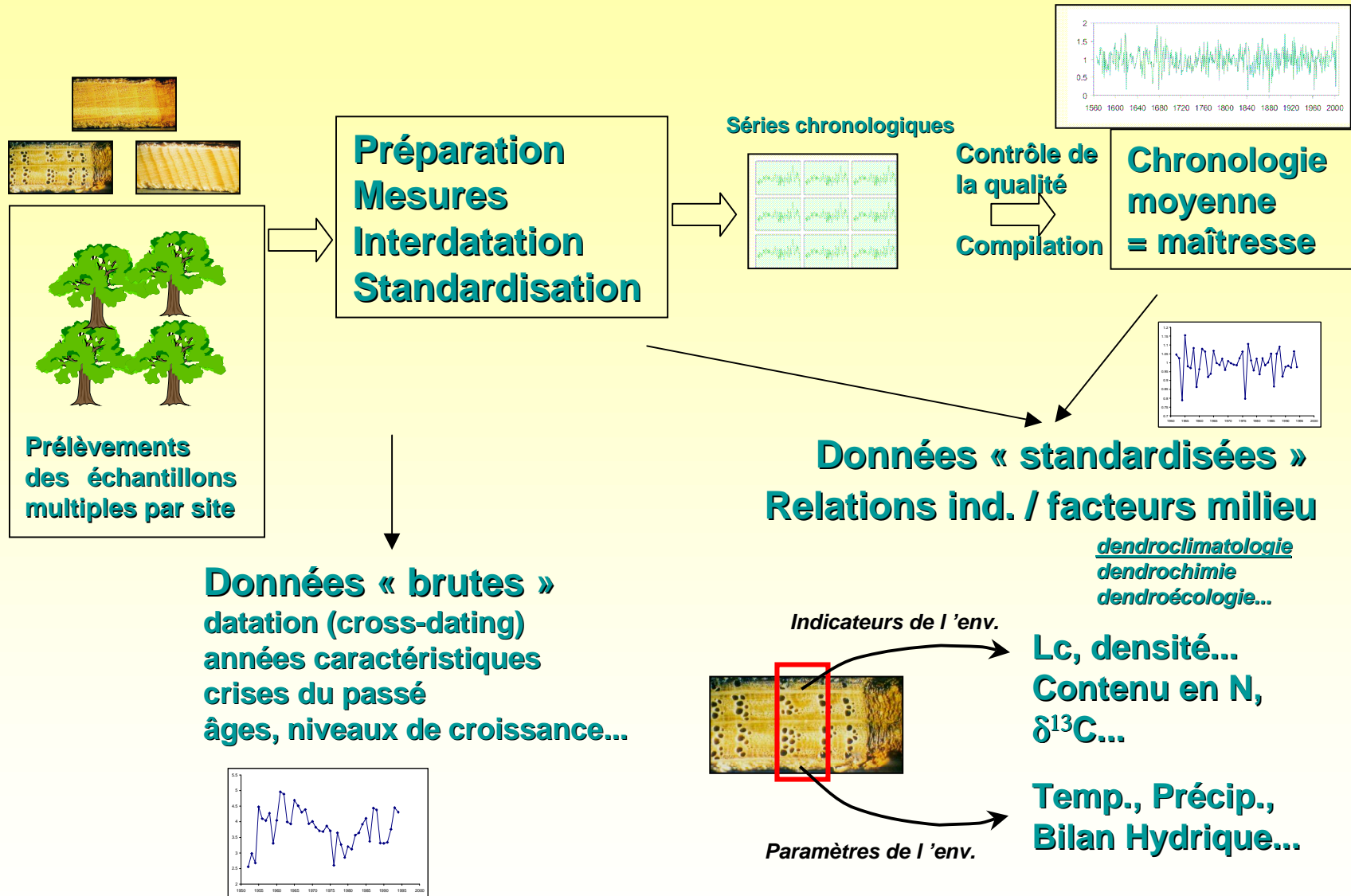
The flowchart illustrates the complex physiological responses of a tree to environmental stressors like low precipitation and high temperature. It shows how these conditions lead to water stress, reduced photosynthesis, increased respiration, and ultimately result in less food being available for cambial growth, leading to finer growth rings.

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Les étapes pour construire les chronologies



Quelques applications de la dendrochronologie

Volet 1

Datation et analyses des événements du passé



Quelques applications de la dendrochronologie

Connaissance de l'âge des très vieux arbres...

Rocky Mountain Tree-Ring Research

Home | Projects & Data | Tree-Ring Basics | Photo Gallery | OLDLIST | Some Links

OLDLIST is a database of ancient trees. Its purpose is to identify maximum ages that different species can attain such that exceptionally old age individuals may be recognized. In addition to the original OLDLIST, Neil Pederson at Eastern Kentucky University has started the **Eastern OLDLIST** focused on old trees in the eastern US.

- Text of a paper about OLDLIST
- Submit a Tree for Inclusion on the OLDLIST
- References for OLDLIST trees

Five types of ages are recognized in the database:

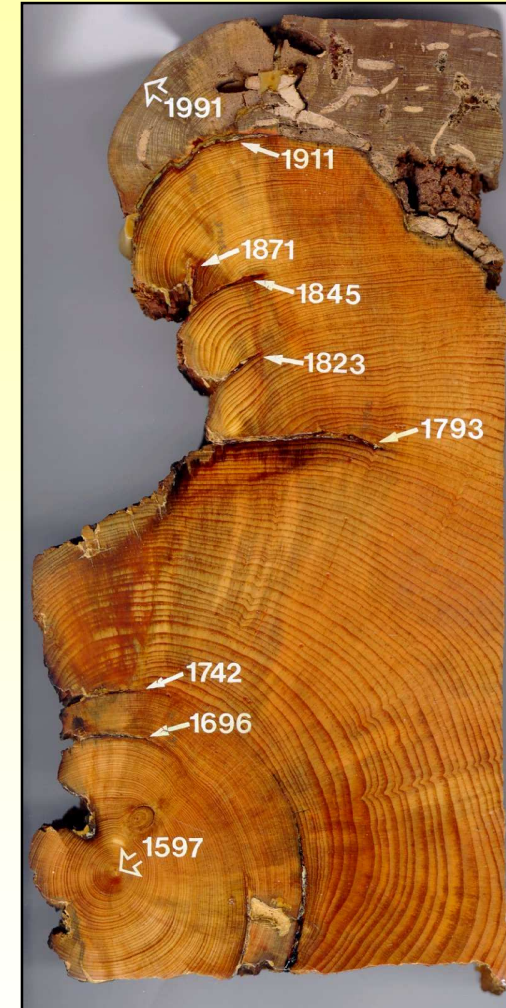
- XD: crossdated
- RC: ring counted
- EX: extrapolations (usually based on ring measurements)
- HI: historic record
- C14: radiocarbon dated wood samples from a tree (added 2007)

Crossdated ages are derived through recognized dendrochronological procedures (e.g., Stokes and Smiley 1968; Swetnam, Thompson, and Sutherland 1985; Schweingruber 1987). For a crossdated age, there should be no question of the age of the portion of the tree sampled, except in any portion of the ring series not confidently crossdated with either other trees at the same site or other sites in the area. Ring-counted ages are derived by simple ring counts and may contain errors in age due to missing or false rings, suppressed areas, or other tree-ring anomalies. "Age" in these first two types will invariably be a minimum age rather than true chronological age owing to the difficulty of sampling a tree exactly at the point of germination. Extrapolations are ages derived by regression from age/size relationships (e.g., Stephenson and Demetry 1995) or other mathematical or graphical methods. Ranges of ages derived by extrapolations are welcome and can be accommodated in the database. Historical ages are based upon historical reference to the tree. At present, OLDLIST contains only one historical age, that for *Ficus religiosa* at a Buddhist Temple in Anuradhapura, Sri Lanka. A continuous historical account of four trees planted there in the 3rd century B.C. has been kept (letter to R.J. Hartesveldt from Ambassador of Sri Lanka in the USA, December 15, 1972). An individual tree may have up to two entries in the database. For example, a tree may have one entry for the age of a crossdated radial increment core and a second for an extrapolation age to a possible pith or germination date.

Note: Patrut et al. (2007) used radiocarbon dating on pieces of what may be the largest known baobab tree (*Adansonia digitata*) to determine that the tree was at least 1250 ± 50 years old when it recently died. This is now the oldest known angiosperm tree, at least twice as old as the second oldest confirmed age for an angiosperm species (although note also the addition of two oaks reported in Jon 1959 that are 866 and 930 years, sent to me by Alexei Rivera; however, we cannot find the original references and these ages cannot be confirmed).

Species	Age	Type	ID	Location	Collector(s), Dater(s)
---------	-----	------	----	----------	------------------------

<http://www.rmtrr.org/oldlist.htm>



copyright Peter M. Brown.

OLDLIST: A Database of Maximum Tree Ages; Peter M. Brown
Text of a paper published in: J.S. Dean, D.M. Meko, and T.W. Swetnam (eds) 1996. Proceedings of the International Conference on Tree Rings, Environment, and Humanity: Relationships and Processes, 17-21 May, 1994, Tucson, Arizona. Radiocarbon 1996:727-731.

Les plus vieux arbre vivant connu...

Pinus longaeva, the bristlecone pine...

environ 4800 ans

White Mountains of Eastern California



Quelques applications de la dendrochronologie

Connaissance de l'âge des très vieux arbres...

Bristlecone pine tree rings and volcanic eruptions over the last 5000 yr

Quaternary Research 67 (2007) 57–68

Matthew W. Salzer *, Malcolm K. Hughes

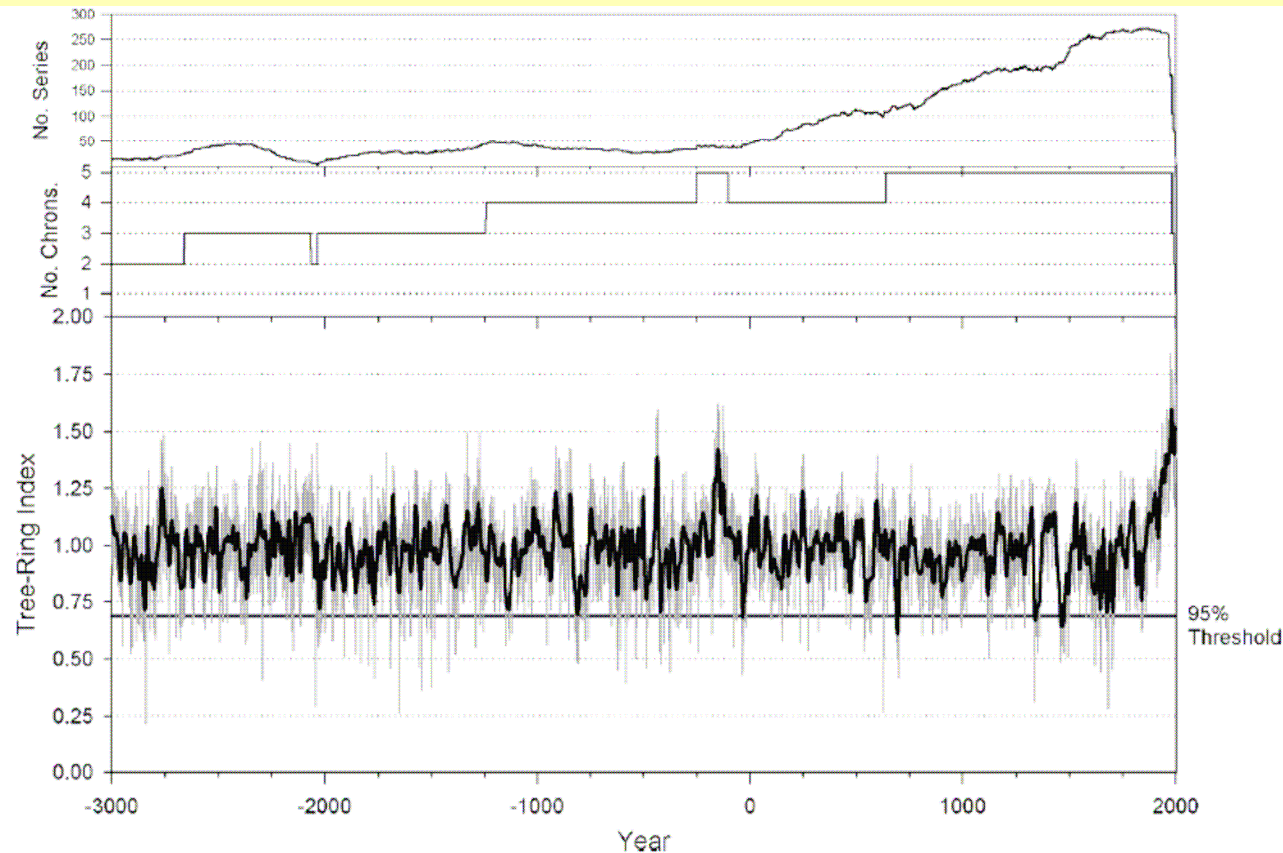


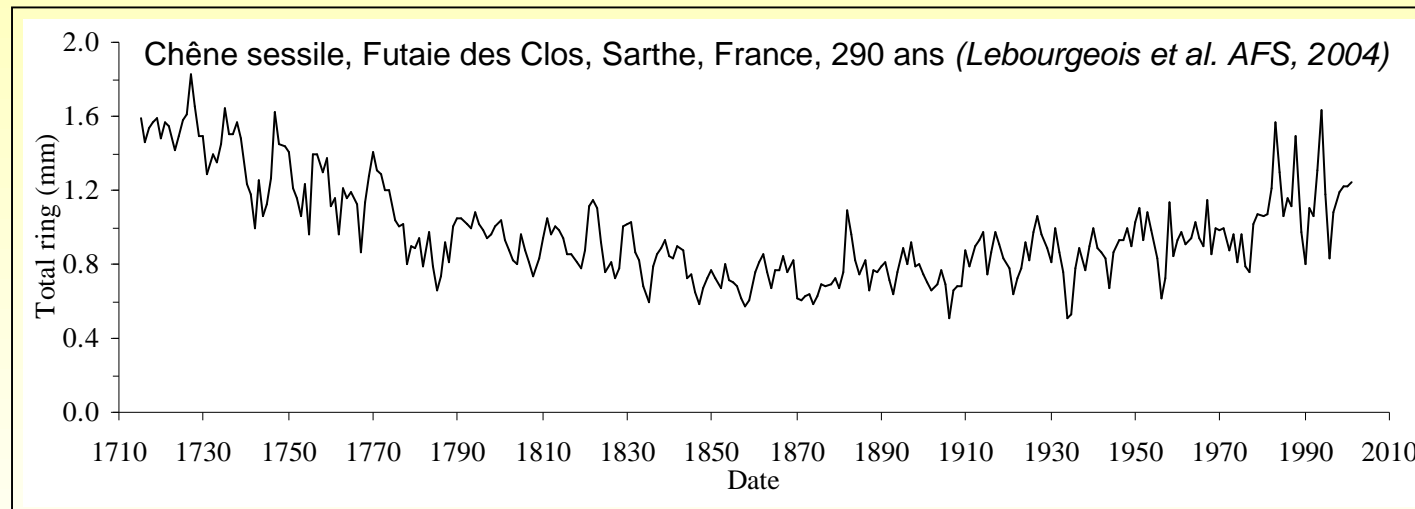
Figure 2. Time-series plot of regional high elevation tree-ring index from 3000 BC to AD 2002 (HI5 chronology-variance-adjusted normalized mean of five subalpine bristlecone pine chronologies). Dark thicker line smoothed with a 20-yr spline. Upper panel is total number of series in the chronology; middle panel is total number of chronologies through time.

Quelques applications de la dendrochronologie

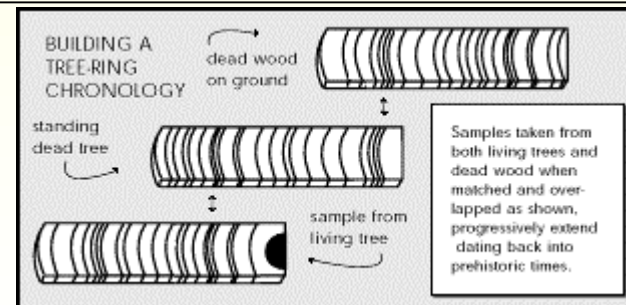
Construction des chronologies anciennes...

utilisation des années caractéristiques... la datation

Utilisation de longues chronologies d'arbres vivants pour reconstruire des chronologies anciennes... chênes, mélèze, pin sylvestre



Recherches de séquences caractéristiques communes...

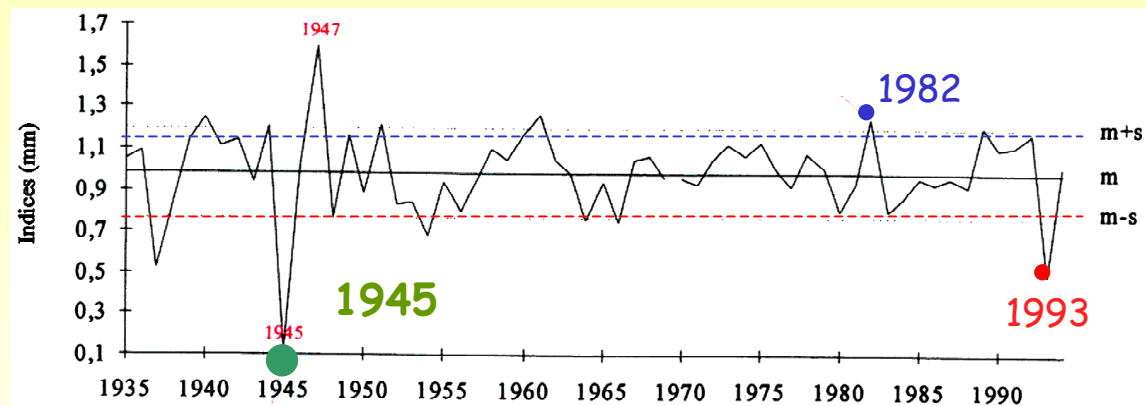


Quelques applications de la dendrochronologie

Construction des chronologies anciennes...

utilisation des années caractéristiques... la datation

Années présentant des variations de croissance communes à la majorité des arbres du peuplement (Pointer years)



(Bertaudière, 1999)

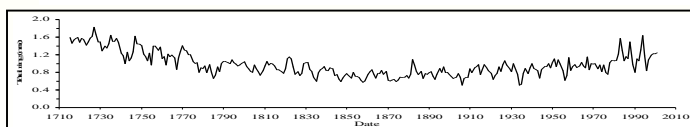
Quelques applications de la dendrochronologie

Chêne sessile, Futaie des Clos, Sarthe, France, 290 ans (*Lebourgeois et al. AFS, 2004*)

Table IV. Calendar years characterized by a strong relative decrease (negative pointer years) or increase (positive pointer years) in radial growth for each ring component. TR = total ring; EW = Earlywood; LW = Latewood. The years refer to a strong relative increase or decrease (> 10%) found in at least 75% of the 18 crossdated trees (period 1715–2001).

Negative pointer years (Relative decrease in %)							
Year	TR	EW	LW	Year	TR	EW	LW
1996	-27	-18	-33	1915	-22		-31
1995	-22		-29	1906	-26	-23	-26
1989	-30		-41	1892			-18
1985			-22	1887			-26
1984			-11	1883			-22
1976			-31	1870	-23		
1968	-26		-31	1824			-25
1959	-23		-34	1784			-32
1956	-25		-28	1778	-16		
1952		-16		1755	-20		-20
1944	-17		-23	1722		-16	
1934	-29		-40				
1921			-22				
Total:				13	4	20	

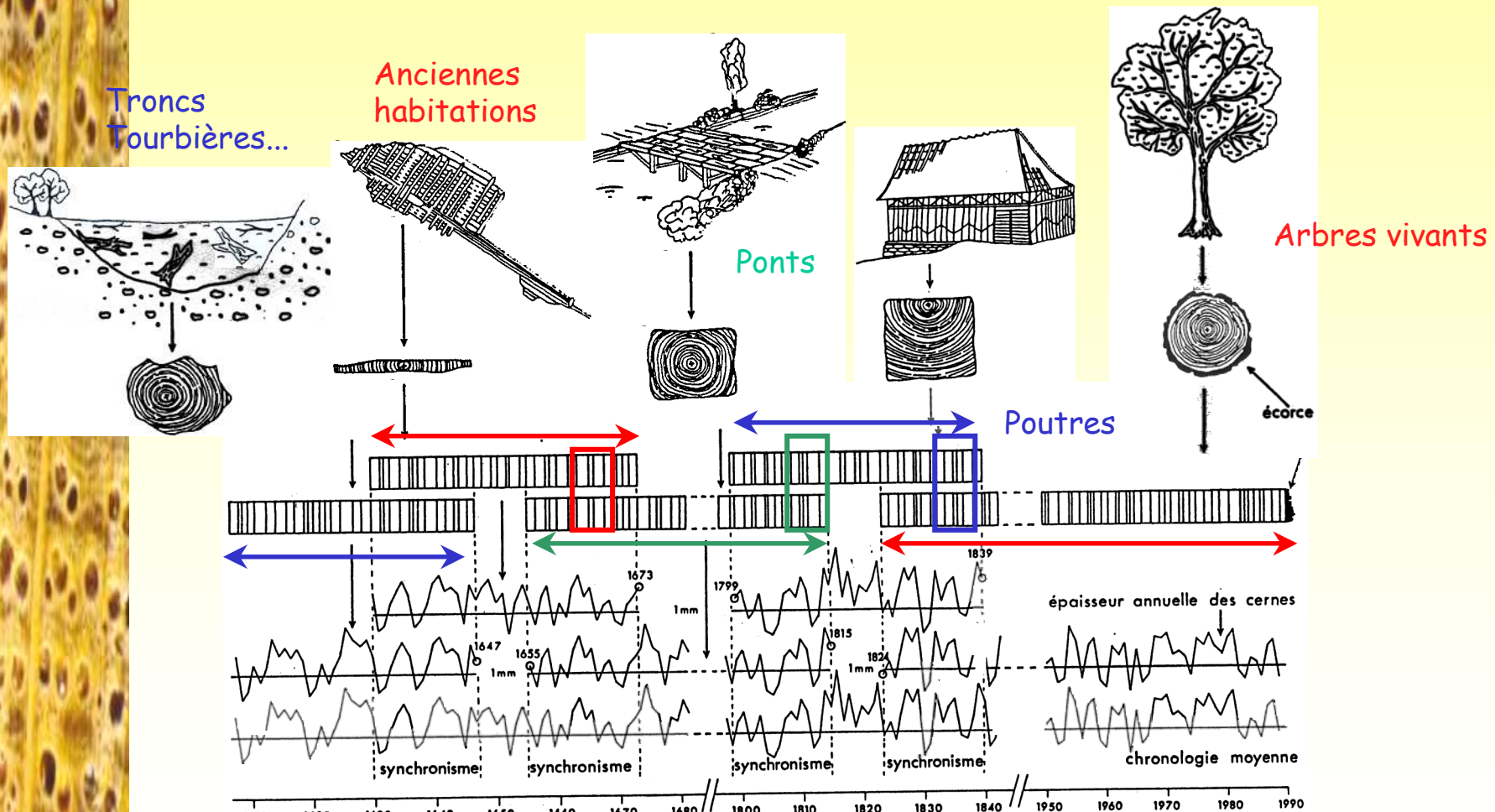
Positive pointer years (Relative increase in %)							
Year	TR	EW	LW	Year	TR	EW	LW
1998		30		1897			31
1997	32		73	1894	20		41
1994	28		41	1882			109
1993	26		59	1881		32	
1991		45		1865		25	
1988	37		68	1848			44
1983	32	35	34	1829	30		41
1978	40		91	1821	28		39
1973			41	1789	27		46
1967	28	22	46	1787	23		40
1958	52		104	1786			39
1937		32		1783			59
1936	47		169	1769		26	
1931		25		1768	36		63
1924		18		1763	26		
1916			47	1756	56		94
1917		34		1747	28		38
1907	38		58	1743	32	25	49
Total:				20	12	26	



Quelques applications de la dendrochronologie

Construction des chronologies anciennes...

utilisation des années caractéristiques... la datation

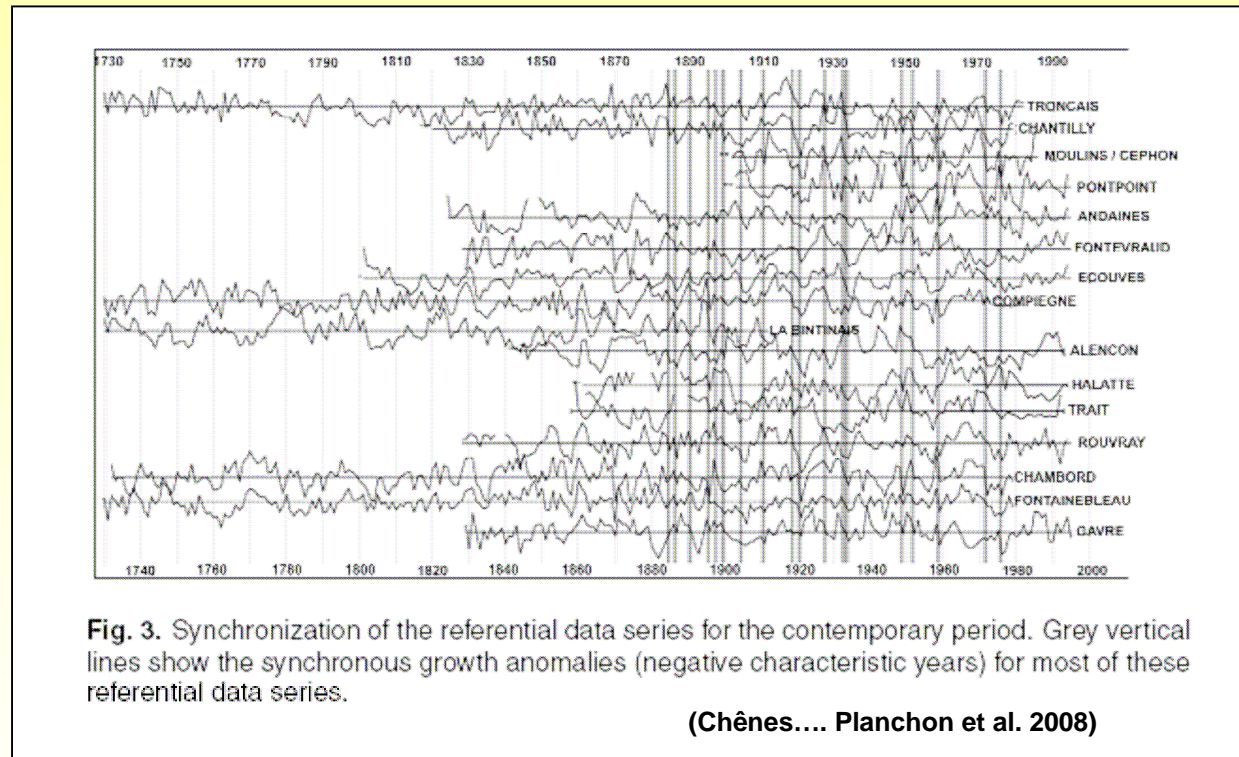


(Lambert et al. 1992)

Quelques applications de la dendrochronologie

Construction des chronologies anciennes...

utilisation des années caractéristiques... la datation



(Voir aussi Pilcher, AFS, 1996, 53, 663-670)

Quelques applications de la dendrochronologie

Construction des chronologies anciennes... utilisation des années caractéristiques... la datation

Construction des chronologies anciennes... de 500 à plus de 7000 ans !

=> A 7100-year tree-ring chronology aids scientists; old trees draw visitors to California mountains
C. W. Ferguson, Science 23 February 1968, Vol. 159. no. 3817, pp. 839 - 846

=> A 7272-year tree-ring chronology for western Europe
J. R. Pilcher, M. G. L. Baillie*, B. Schmidt† & B. Becker‡ (Nature, 312, 1984)*
Pinus aristata and Pinus longaeva growing in the White Mountains of California

=> A 7500-YEAR UNBROKEN SCOTS PINE TREE-RING CHRONOLOGY FOR FINNISH LAPLAND
ERONEN, Matti, HELAMA, Samuli, LINDHOLM, Markus, and TIMONEN, Mauri, XVI INQUA Congress Paper No. 5-37, 2003

=> Construction and dating of a 5000 year english bog Oak tree ring chronology.
Brown and Baillie, 1992, International Dendrochronological Symposium Tree rings and Environnement Lund University Department of Quaternary Geology, 72-75

=> A millennium-long tree-ring chronology of *Sabina przewalskii* on northeastern Qinghai-Tibetan Plateau
Qi-Bin Zhang, a, and Hongyan Qiua, Dendrochronologia, 24, 2-3, 2007, 91-95

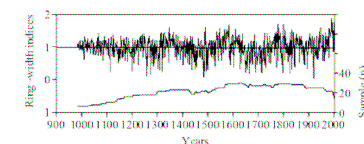
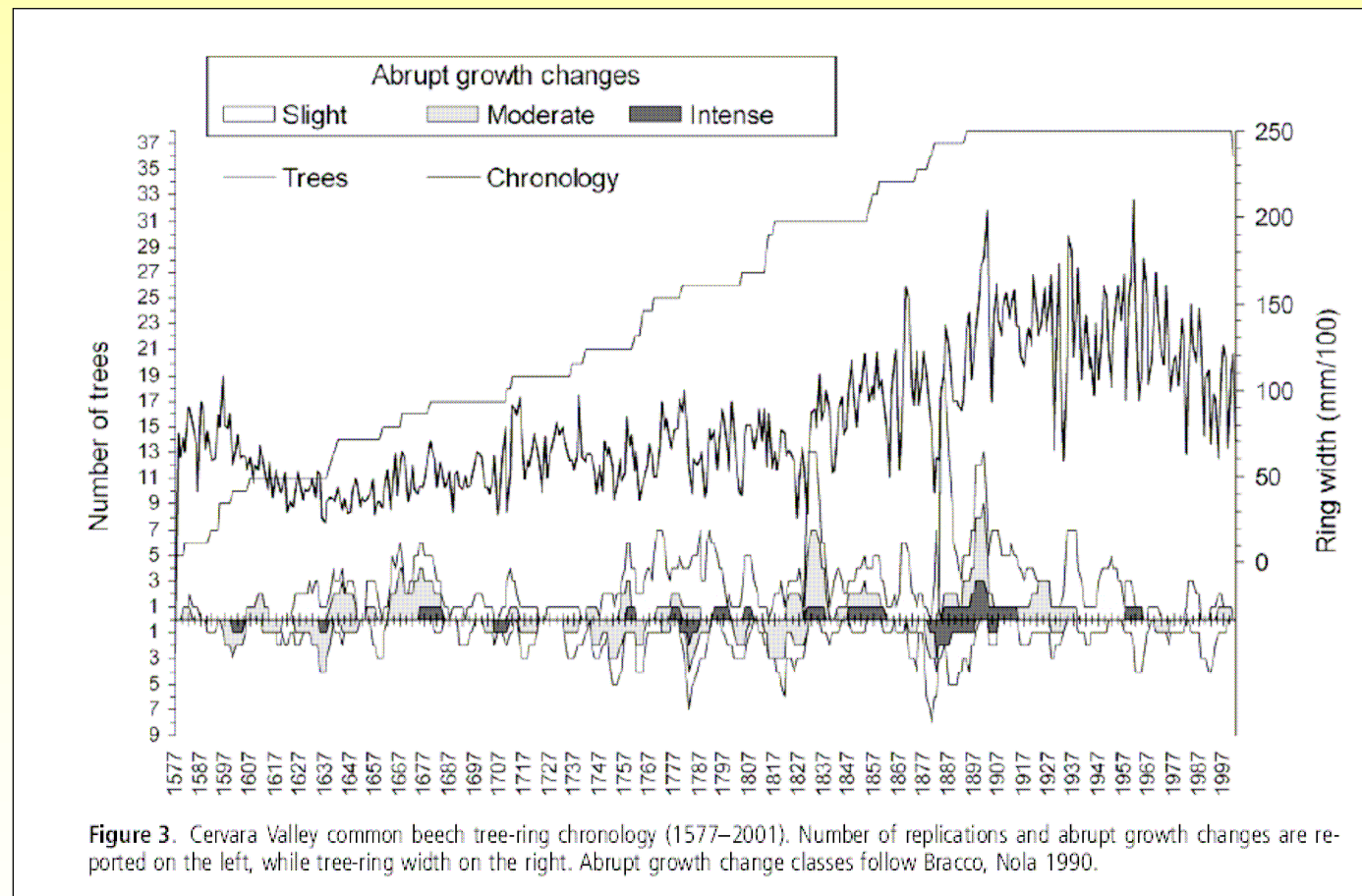


Fig. 3. The 1017-year ring-width chronology of *Sabina przewalskii* Kom. and the number of samples for each year in Delingha area of northeastern Qinghai-Tibetan Plateau.

Quelques applications de la dendrochronologie

Construction des chronologies anciennes...

utilisation des années caractéristiques... la datation



A long-term tree ring beech chronology from a high-elevation old-growth forest of Central Italy

Piovesan et al. 2003, dendrochronologia, 21/1, 13-22
longueur 1577 à 2001

Quelques applications de la dendrochronologie

Datation d'habitations anciennes

<http://www.dendrolab.ca/realisations/mlamontagne/mlamontagne.htm>

<http://www2.ulg.ac.be/dendro/>

Datation de la Maison Lamontagne, monument historique classé



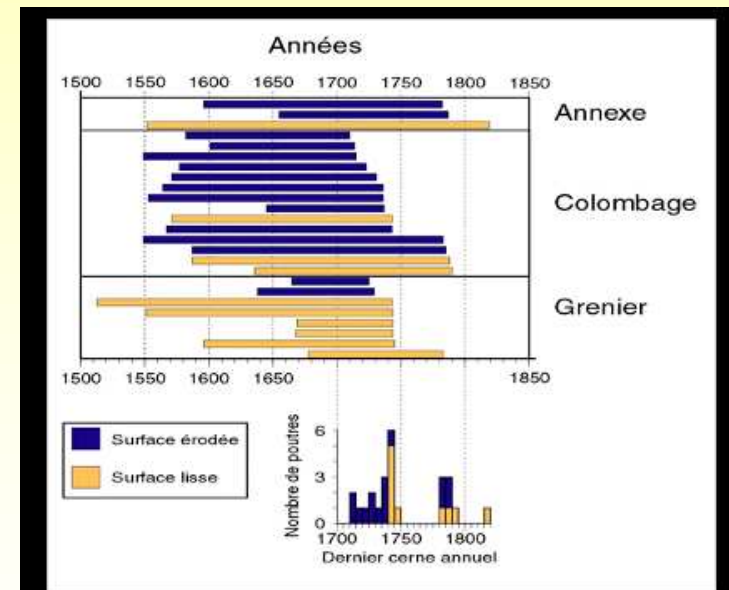
La Maison Lamontagne, classée monument historique par le Ministère des Affaires Culturelles en 1974

**Grenier et colombage = 1743-1745
et rénovations / extensions par la suite**



témoignage architectural du régime français dans la région du Bas-St-Laurent

La période se situant entre 1744 et 1791 fut avancée comme étant celle où se déroula fort probablement cette construction. Ces assomptions se basent sur la date de mariage de Basile Côté et Marie Agnès Lepage (1744), petite-fille du premier seigneur de Rimouski, à qui la terre où est aujourd'hui érigée la Maison Lamontagne fut liguée.



Période de vie mesurée pour chacun des échantillons datés provenant de la maison Lamontagne. Qui plus est, le nombre d'échantillons présentant le dernier cerne de croissance en fonction du temps est présenté en bas de la figure.

Quelques applications de la dendrochronologie

Reconstruction du climat passé...

Indicateurs de l'env. = f (Paramètres de l'env.) \rightarrow $P = f(I)$

Lc, densité...
Contenu en N,
 $\delta^{13}C$, $\delta^{18}O$...

Temp., Précip., Bilan
Hydrique...

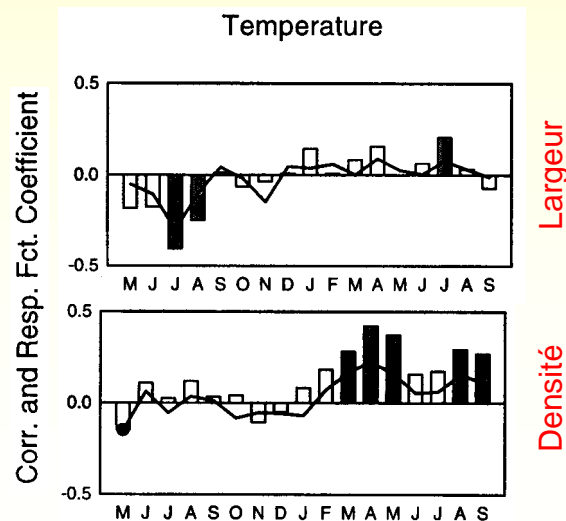
\rightarrow Reconstruction des variations de température dans le passé

Abies amabilis - Colombie Britannique (Vancouver) (Bobry et Klinka 1998)

Longueur de la chronologie: 1770-1990

Largeur
Densité

coeur  écorce



1892

1990

Données Météo - T °C et P (mm) mensuelles

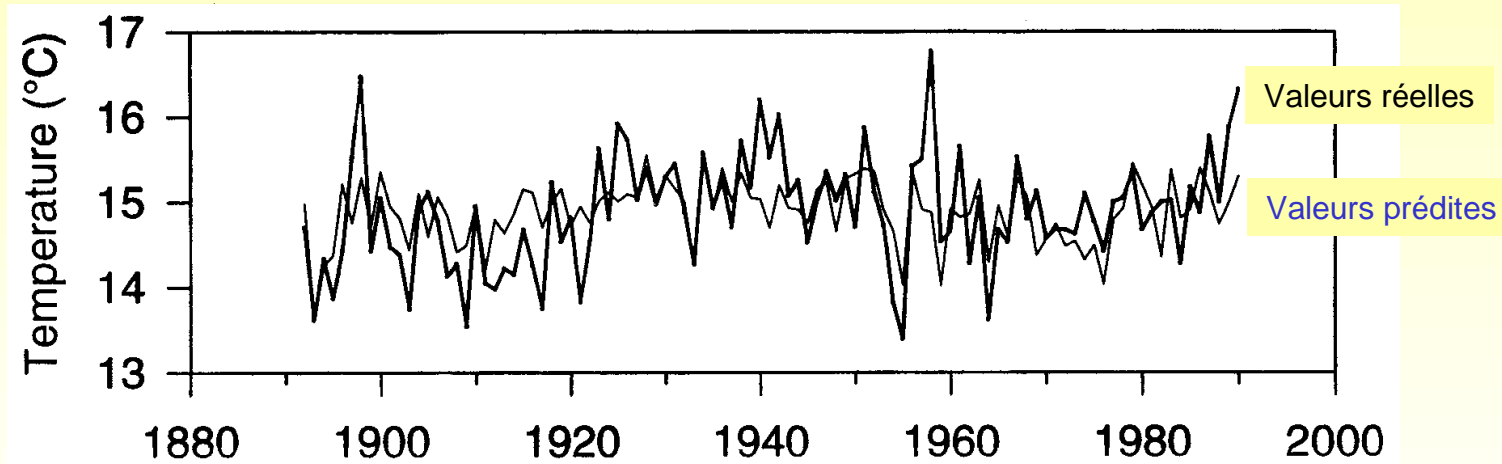
Etape 1 : analyse des corrélations

Quelques applications de la dendrochronologie

Reconstruction du climat passé...

Etape 2 : élaboration du modèle prédictif des températures

$$T \text{ (avril à septembre)}_{t-1} = 9.697 + 5.922 \text{ (densité)}_{t-1} - 0.742 \text{ (largeur)}_t$$

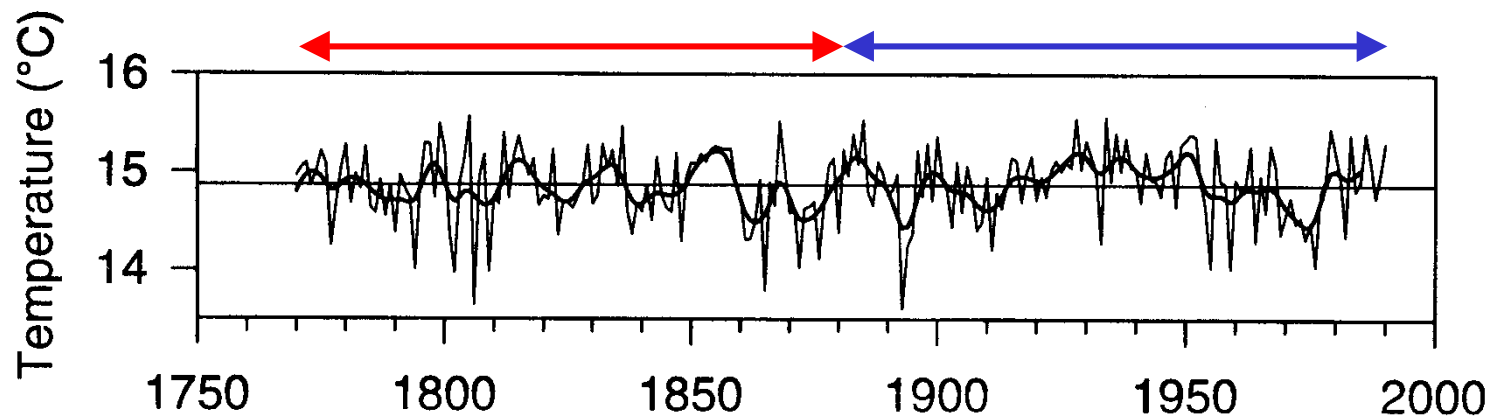
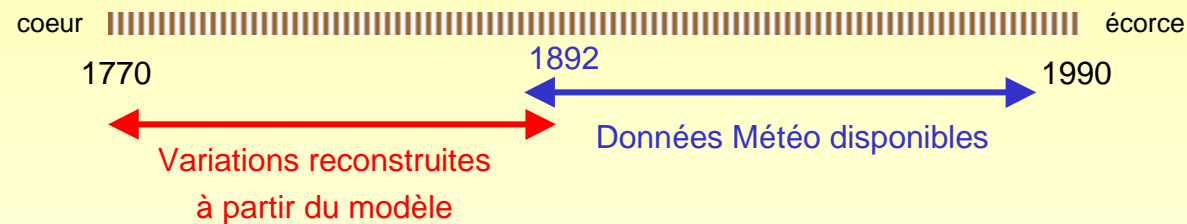


Quelques applications de la dendrochronologie

Reconstruction du climat passé...

Etape 3 : reconstruction des températures dans le passé (1770-1892)

Longueur de la chronologie: 1770-1990



Quelques applications de la dendrochronologie

Reconstruction du climat passé...

Maximum growing season temperature in Western Europe: multi proxy reconstructions in Fontainebleau from 1596 to 2000

N. Etien¹, V. Daux¹, V. Masson-Delmotte¹, M. Stievenard¹, V. Bernard², S. Durost³, M. T. Guillemin¹, O. Mestre⁴, and M. Pierre¹

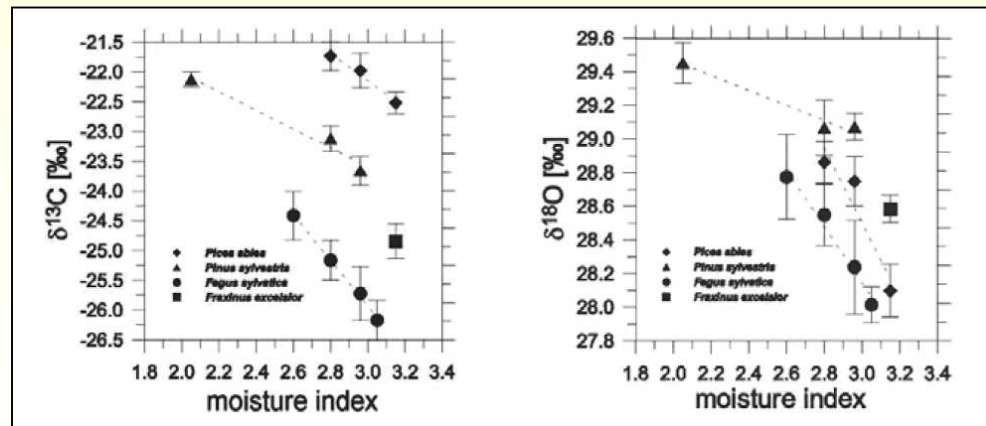
Clim. Past Discuss., 3, 1063–1117, 2007
www.clim-past-discuss.net/3/1063/2007/
© Author(s) 2007. This work is licensed under a Creative Commons License.

The oxygen and carbon isotopic ratios in tree cellulose are sensitive bio-indicators, and offer the possibility to study integrated information on the variability of the climate and water cycle even in temperate areas where classical dendroclimatology does not apply (McCarroll and Loader, 2004).

$\delta^{13}\text{C}$ cellulose = f(temp, humidité relative et bilan hydrique)

$\delta^{18}\text{O}$ cellulose = f($\delta^{18}\text{O}$ précipitation, etc)

Mesure sur arbres vivants / morts => corrélation avec climat
=> reconstruction climat passé...

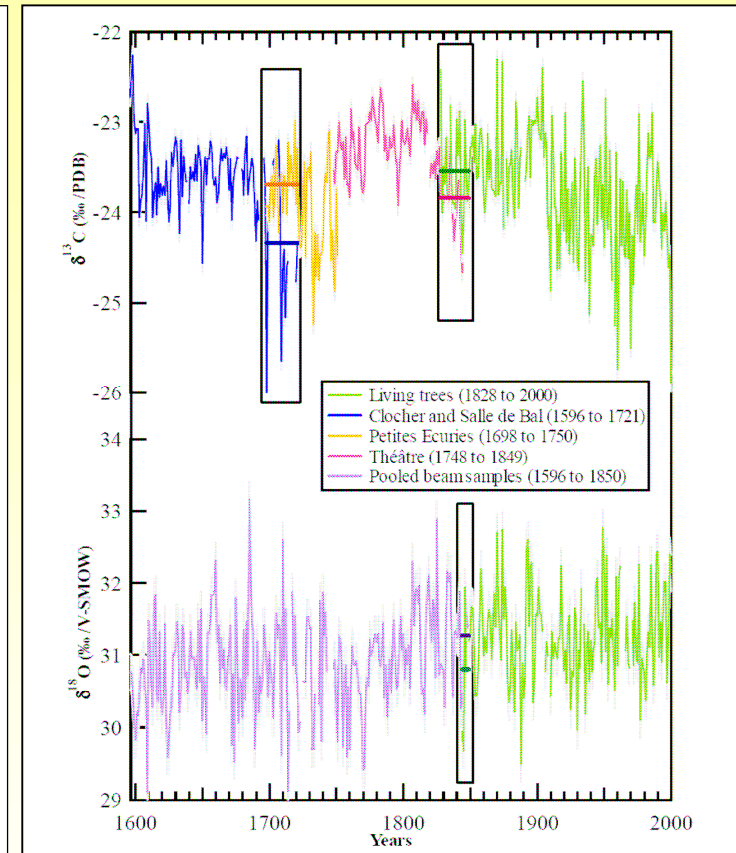
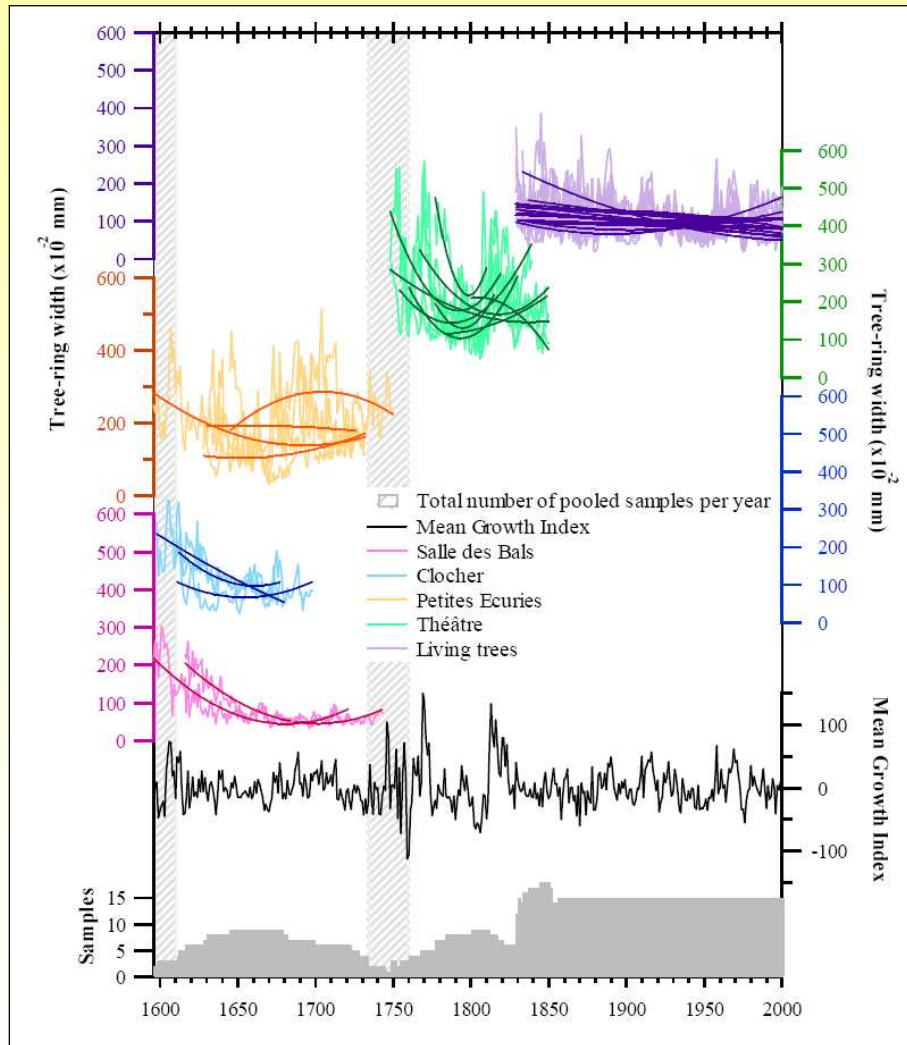


Site sec => enrichissement
=> fermeture des stomates

(Saurer et al. 2000)

Quelques applications de la dendrochronologie

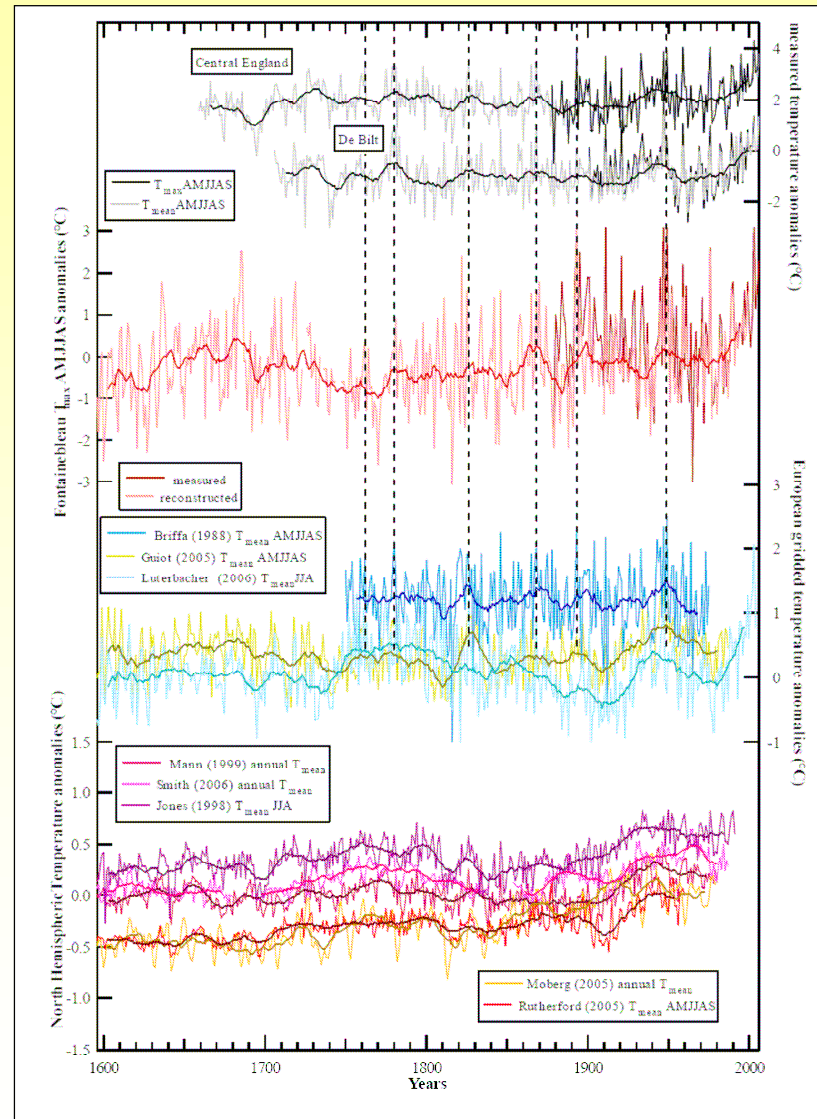
Reconstruction du climat passé...



T max (SV) = f ($\delta^{18}\text{O}$)
1879-2000

Quelques applications de la dendrochronologie

Reconstruction du climat passé...



Quelques applications de la dendrochronologie

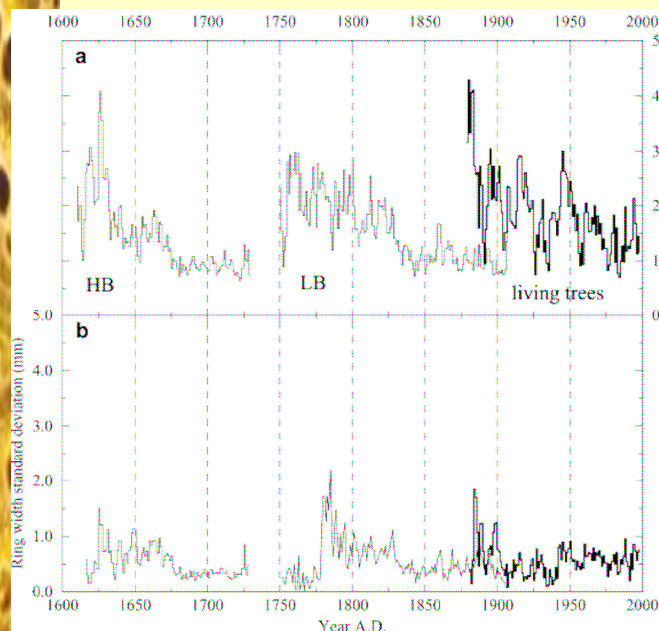
Modifications du fonctionnement physiologique des arbres

V. Masson-Delmotte · G. Raffalli-Delercq · P. A. Danis
P. Yiu · M. Stievenard · F. Guibal · O. Mestre
V. Bernard · H. Goosse · G. Hoffmann · J. Jouzel

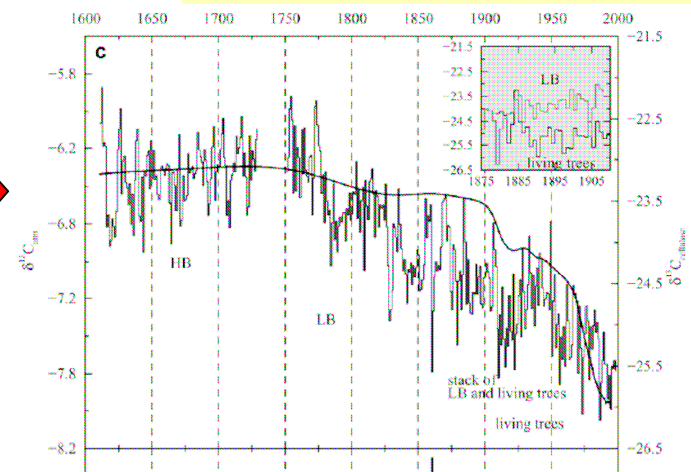
Changes in European precipitation seasonality and in drought frequencies revealed by a four-century-long tree-ring isotopic record from Brittany, western France

Climate Dynamics (2005) 24: 57–69
DOI 10.1007/s00382-004-0458-1

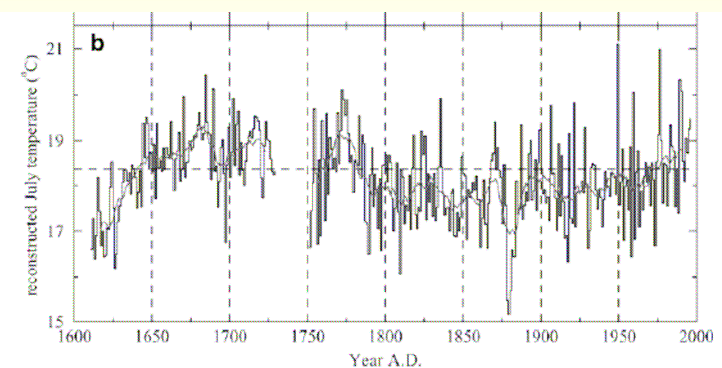
1. Data de cernes



2. Discrimination isotopique

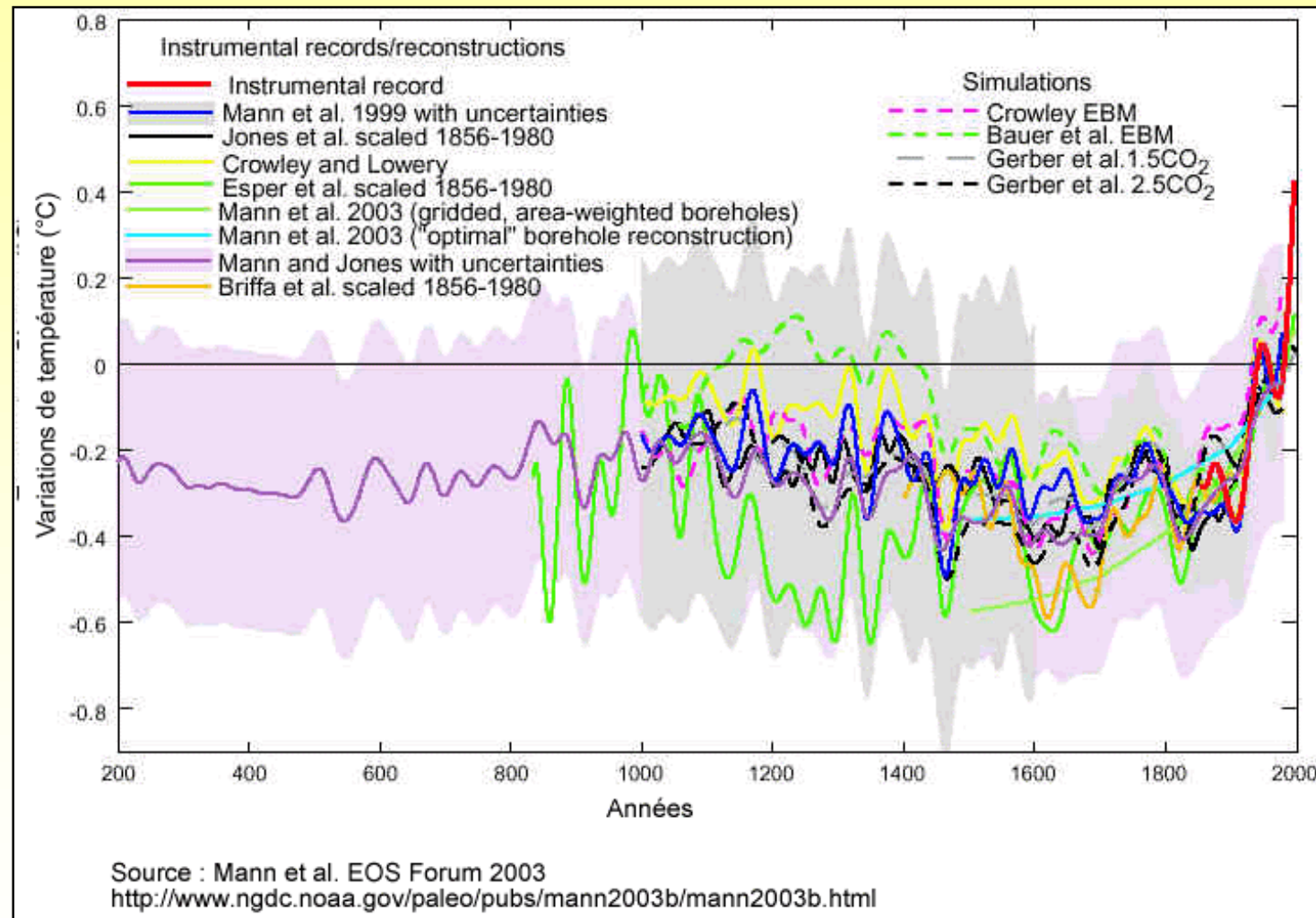


3. Relation climat / Isotope ici avec T juillet... et reconstruction



Quelques applications de la dendrochronologie

Reconstruction du climat passé...



Quelques applications de la dendrochronologie

Datation des éruptions volcaniques

Global Change Biology (2007) 13, 1–16, doi: 10.1111/j.1365-2486.2007.01350.x

RESEARCH PAPER

Volcanic explosive eruptions of the Vesuvio decrease tree-ring growth but not photosynthetic rates in the surrounding forests

GIOVANNA BATTIPAGLIA*, PAOLO CHERUBINI†, MATTHIAS SAURER‡, ROLF T. W. SIEGWOLF§, SANDRO STRUMIA* and M. FRANCESCA COTRUFO*

*Department of Environmental Sciences, Second University of Naples, Via Vicini 43, I-81100 Caserta, Italy; †WSL Swiss Federal Institute for Forest, Snow and Landscape Research, CH-8903 Birmensdorf, Switzerland; ‡PSI Paul Scherrer Institute, CH-5232 Villigen, Switzerland

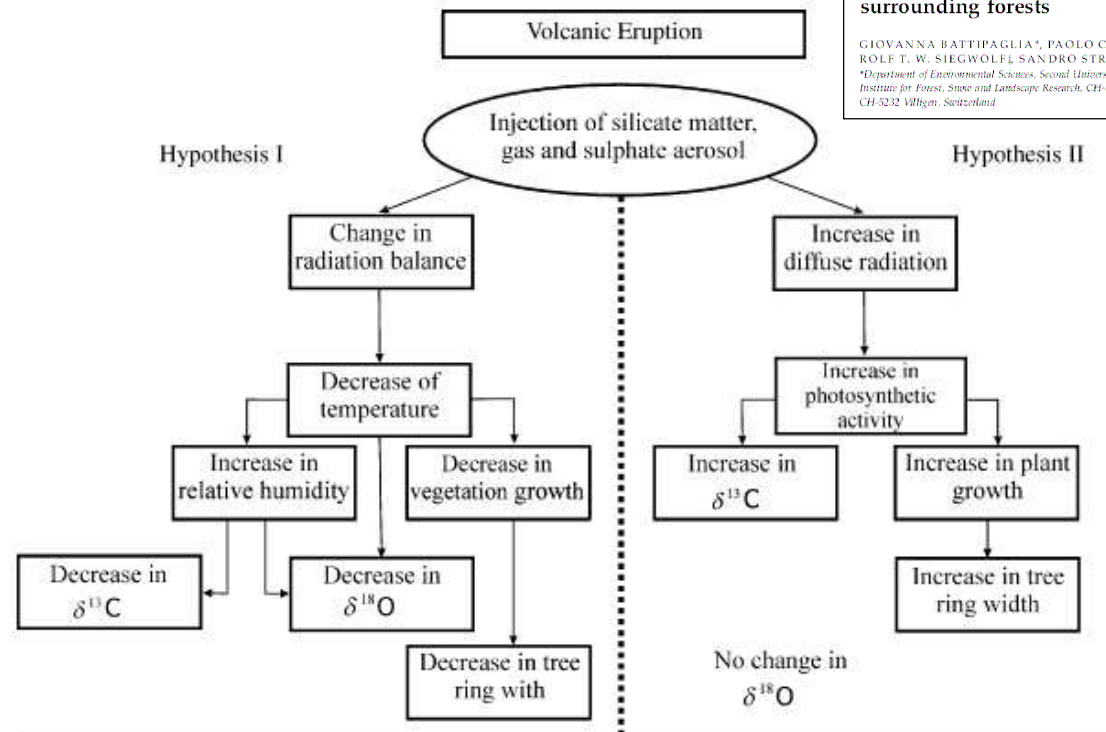


Fig. 1 Theoretical development of the work hypotheses, with two different scenarios following volcanic eruption. One hypothesis illustrates the cooling effect caused by aerosol, which decreases plant growth and enhances relative humidity, leading to a reduction of $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ in tree rings (Hypothesis 1). The second hypothesis proposes the increase in photosynthesis and plant growth, as a consequence of a better canopy light use efficiency under diffuse light, with an increase in $\delta^{13}\text{C}$ (Hypothesis 2).

Quelques applications de la dendrochronologie

Table 1 Main characteristic of all eruption events registered for the Vesuvio since 1838

Start date (d/m/y)	End date (d-m-y)	Duration (days)	Volcanological notes	$D \delta^{18}O$ (%)	D tree width (%)
01/01/1839	03/01/1839	2	Effusive-explosive; lava fountains up to 400 m; lava volume erupted: $10 \times 10^6 \text{ m}^3$	-8	-69
05/02/1850	16/02/1850	11	Effusive-explosive; two strong explosions; the cone collapses into two craters lava volume erupted: $20 \times 10^6 \text{ m}^3$	-1.4	-51
01/05/1855	27/05/1855	26	Effusive with lava emission and mild strombolian activity; lava volume erupted: $17 \times 10^6 \text{ m}^3$	-3.3	-63
13/04/1861	31/12/1861	261	Effusive mildly explosive lateral with strong earthquakes; lava volume erupted: $120 \times 10^6 \text{ m}^3$	-5.8	-32
01/06/1868	26/11/1868	177	Effusive-explosive with strong eruptive column; lava volume erupted: $6 \times 10^6 \text{ m}^3$	-4.1	-42
24/4/1872	30/4/1872	6	Effusive-explosive; ash emission with ejection up to 130 m; lava volume erupted: $20 \times 10^6 \text{ m}^3$	-5.7	-40
1/2/1884	01/05/1855	455	Effusive with consistent lava flow; lava volume erupted: $7 \times 10^6 \text{ m}^3$	-4.7	-51
27/08/1903	30/09/1904	400	Effusive-explosive with intracrateric lava, large amount of ash; lava volume erupted: $0.05 \times 10^6 \text{ m}^3$	-2.1	-38
03/02/1906	22/04/1906	77	Effusive-explosive: intense activity with strong explosions and lava emission; increase of seismicity; lava volume erupted: $22 \times 10^6 \text{ m}^3$	-1.5	-46
03/06/1929	08/06/1929	5	Effusive-explosive with injection of scoriae and lava fountain 400 m high; lava volume erupted: $12 \times 10^6 \text{ m}^3$	-1	-36
06/01/1944	04/04/1944	87	Effusive-explosive: lava fountains turn ashy with a column 6-7 km a.s.l. high, small glowing avalanches and several seismic activities; lava volume erupted: $10 \times 10^6 \text{ m}^3$	-2.7	-46

The start and end date of the volcanic activity (day-month-year); the duration of the eruptive event and the volcanological notes, describing the main features observed in the period and the volumes of lava erupted, are reported, together with the relative percent variation ($D\%$) recorded in $\delta^{18}O$ and tree-width. D indicates the % variation between individual tree-ring value of $\delta^{18}O$ and the mean curves calculated from all the tree-width measurements and the $\delta^{18}O$ data. The negative % values indicate the negative % change.

Quelques applications de la dendrochronologie

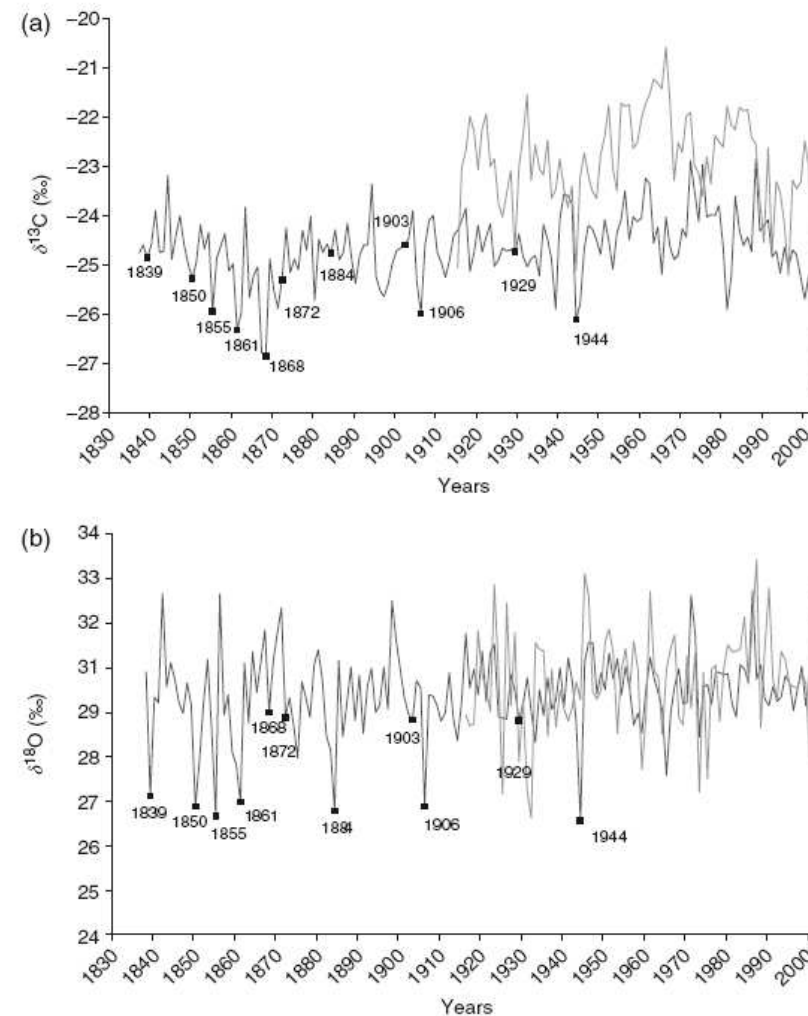


Fig. 5 (a) $\delta^{13}\text{C}$ time series of *Fagus sylvatica* and *Acer pseudoplatanus* trees. Each annual isotopic value is the result of pooled material of the same year, from different cores selected per each species. In this way a mean mass-weighted $\delta^{13}\text{C}$ value is produced. (b) Annual courses of $\delta^{18}\text{O}$ of tree-ring cellulose of *F. sylvatica* and *A. pseudoplatanus*. Each curve is obtained as described for (a).

Quelques applications de la dendrochronologie

Datation des éruptions volcaniques

Bristlecone pine tree rings and volcanic eruptions over the last 5000 yr Quaternary Research 67 (2007) 57–68

Matthew W. Salzer *, Malcolm K. Hughes

Eruptions => poussières => modification du climat (Ice cores) => moins de soleil, temp plus faible... croissance réduite... cernes plus fins

Table 4

Intervals of decreased tree growth and volcanic evidence

Interval	Yr	Volcano/ICE CORE evidence
1836–1842	7	Coseguina, 1835
1702–1705	4	None
1672–1681	10	Gamkonora, 1674; Tongkoko, 1680
1641–1647	7	Parker, 1641
1458–1474	17	Kuwaie, 1452; Pele, 1459; Kelut, 1463
1348–1360	13	GISP2 1344; DYE 1360; BIPOLAR 1348
1332–1336	5	GISP2 1328
899–903	5	GISP2 900, 902; GRIP 898; DYE 895
687–698	12	GISP2 691, 695, 696
536–547	12	Dust Veil of 536 *; GRIP 527, 532; DYE 530, 534
42–36 BC	7	Etna, 44 BC ^a ; GISP2 44 BC; GRIP 49 BC; DYE 50 BC
282–280 BC	3	None
425–419 BC	7	GRIP 421 BC
1135–1132 BC	4	GISP2 1128 BC
1909–1907 BC	3	GRIP 1910 BC; DYE 1911 BC
2036–2023 BC	14	GISP2 2034 BC

Volcanoes and dates: (Ammann and Naveau, 2003).

GISP2: (Zielinski et al., 1994); GRIP: (Clausen et al., 1997); DYE: (Clausen et al., 1997); BIPOLAR: (Langway et al., 1995).

^a See Stothers and Rampino (1983).

* See Baillie (1994); Stothers (1984); Stothers and Rampino (1983).

Quelques applications de la dendrochronologie

Volet 2

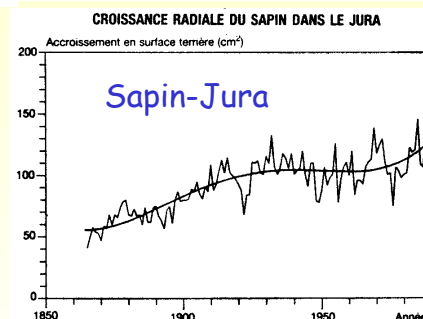
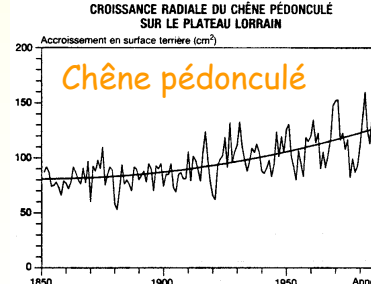
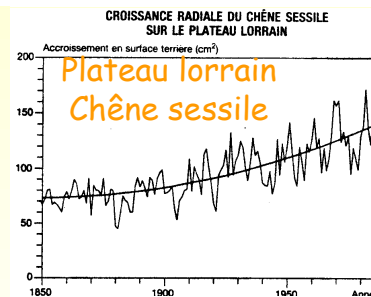
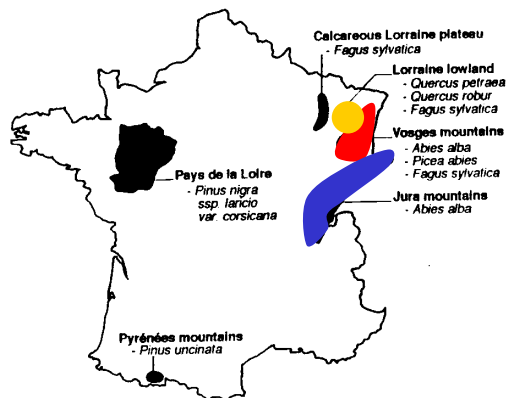
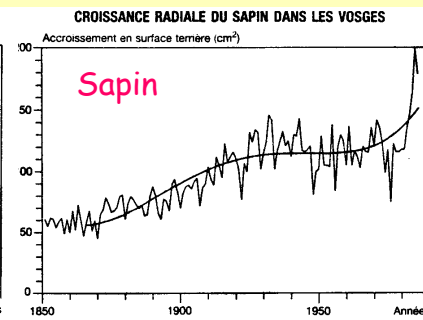
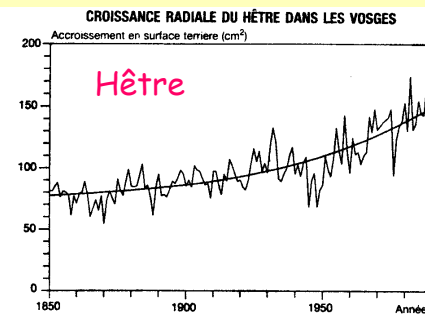
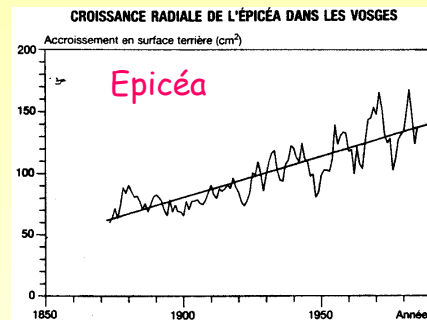
Analyses des modifications de l'environnement



Quelques applications de la dendrochronologie

Evolution de la vitesse de croissance radiale
En France...premiers travaux de **Becker (1987)** dans les
Vosges... dernière étude Bontemps (2006)

Vosges



(Synthèse dans Spiecker et al. 1995)

Quelques applications de la dendrochronologie

Evolution de la vitesse de croissance radiale
En France...premiers travaux de Becker (1987) dans les
Vosges... dernière étude **Bontemps (2006)**

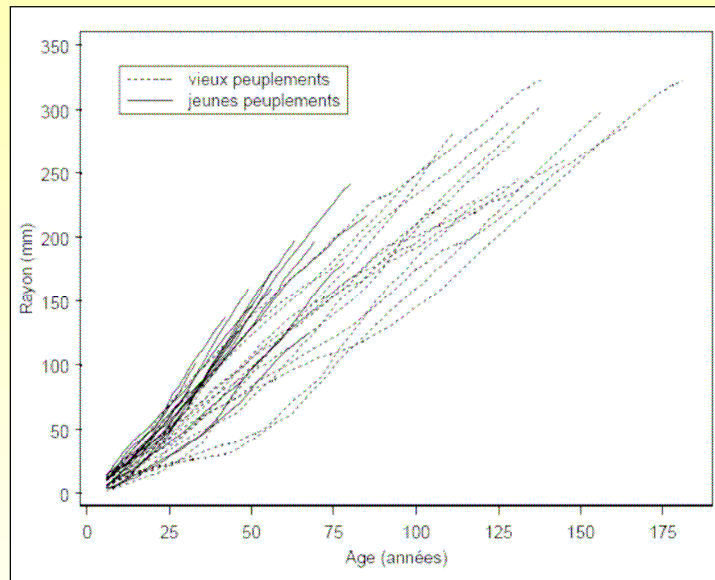


Figure 4.1 Courbes de croissance en rayon dominant à 1,30m des peuplements de l'échantillon Nord-Est.

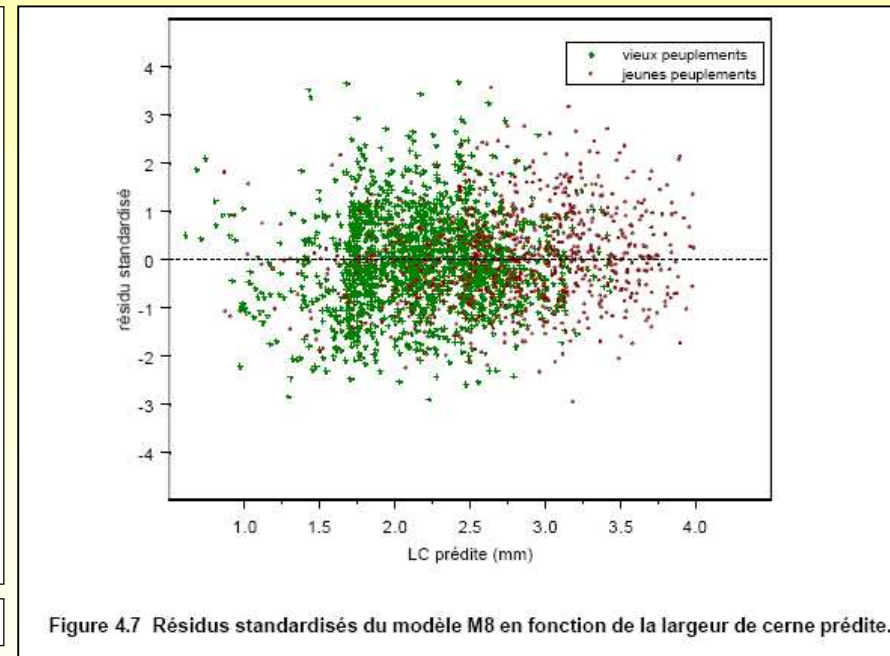
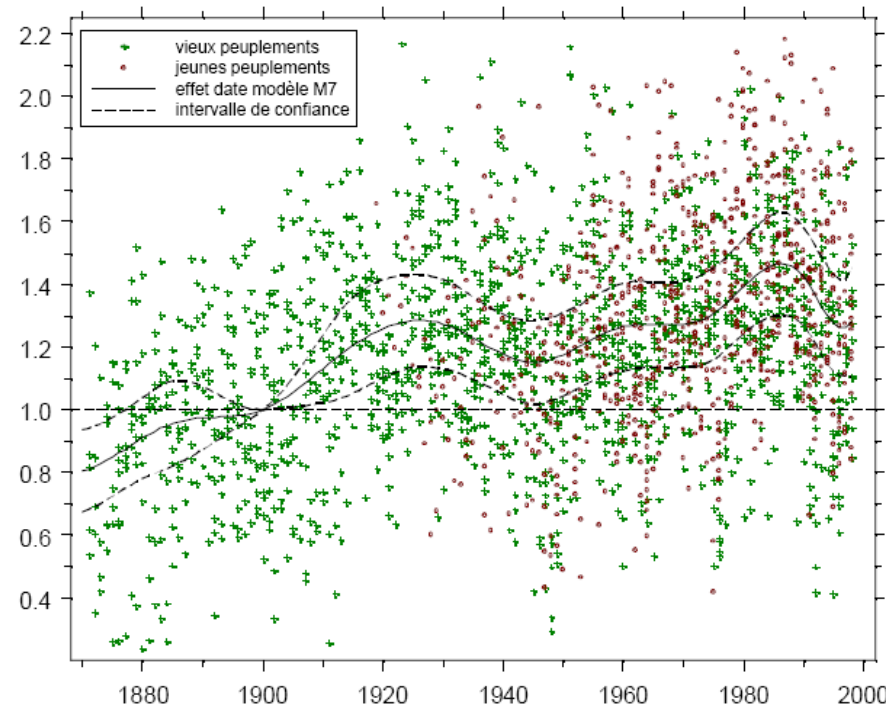


Figure 4.7 Résidus standardisés du modèle M8 en fonction de la largeur de cerne prédite.

Hêtre

Quelques applications de la dendrochronologie

Evolution de la vitesse de croissance radiale
En France...premiers travaux de Becker (1987) dans les Vosges... dernière étude **Bontemps (2006)**



Environ +50%

Figure 4.8 Evolution historique de la vitesse de croissance en rayon dominant (modèle M7).

Les accroissements ont été transformés selon la procédure indiquée dans le texte. L'intervalle de confiance à 95% pour l'estimation de l'effet date est conditionnel à la date courante (voir annexe 3).

Quelques applications de la dendrochronologie

Modification du fonctionnement des écosystèmes...

VARIATIONS OF WOOD $\delta^{13}\text{C}$ AND WATER-USE EFFICIENCY OF
ABIES ALBA DURING THE LAST CENTURY

Ecology, 78(5), 1997, pp. 1588–1596
© 1997 by the Ecological Society of America

DIDIER BERT,^{1,3} STEVEN W. LEAVITT,¹ AND JEAN-LUC DUPOUEY^{2,4}

¹Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona 85721 USA

²Ecophysiology Unit, INRA-Nancy, 54280 Champenoux, France

Relation entre $\delta^{13}\text{C}$ et WUE (A/g_s)... gain de biomasse / perte en eau
=> fonction du CO₂, de l'approvisionnement en eau...

Cernes => mesures $\delta^{13}\text{C}$ => calculs de WUE => variations selon l'âge, la date..

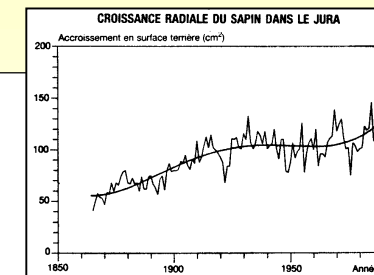
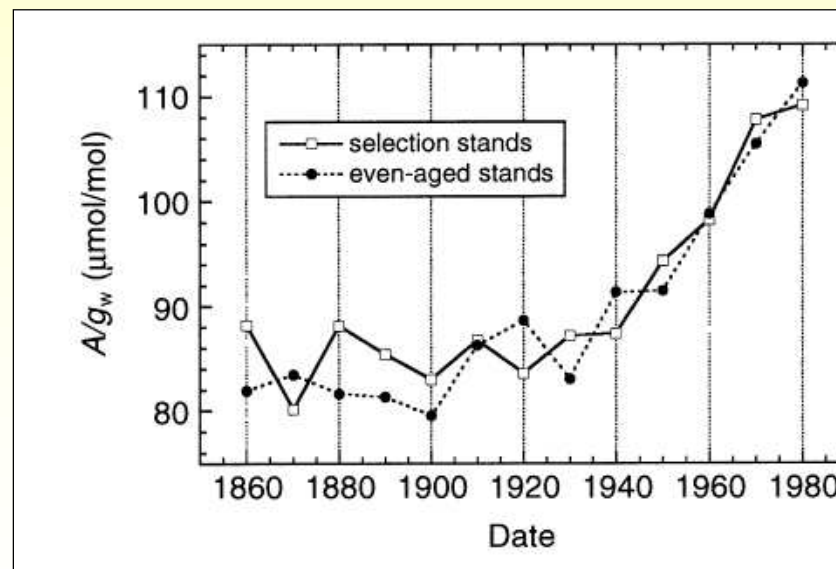


FIG. 6. Intrinsic water-use efficiency (A/g_w , the ratio of CO₂ assimilation rate to stomatal conductance for water vapor) calculated from 40-yr-old tree rings sampled in even-aged and selection stands according to the date.

+30%... relation avec CO₂

Quelques applications de la dendrochronologie

Volet 3

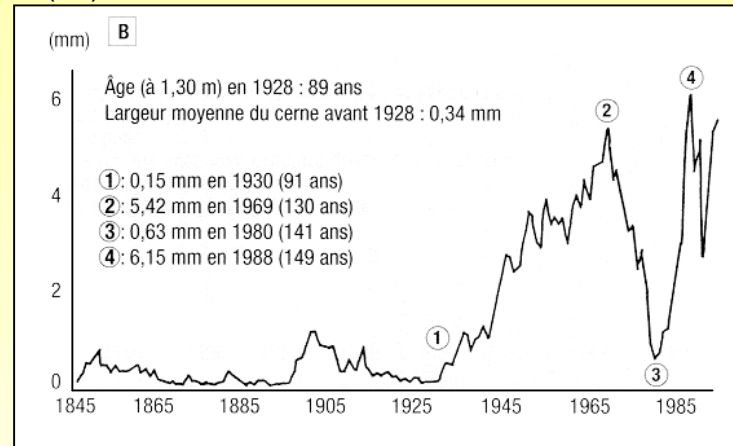
Analyses des effets de la gestion sylvicole et du milieu (*dendroécologie*)



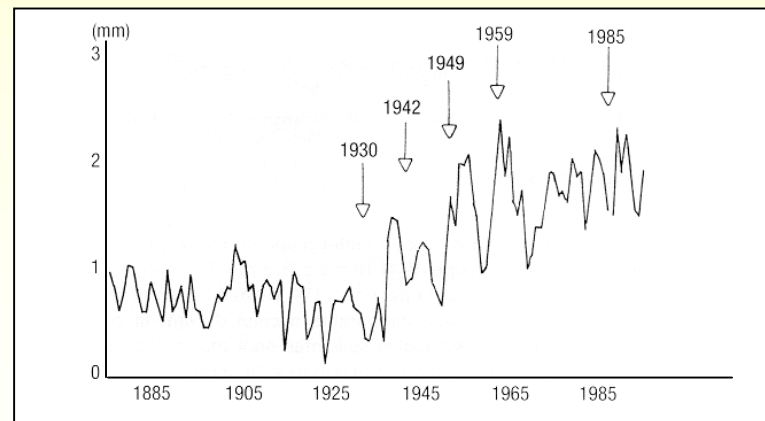
Quelques applications de la dendrochronologie

Utilisation des profils de croissance bruts... ex. effets des éclaircies

Sapin pectiné - FD de Ban (25)



Niveau d'accroissements
Réactivité des arbres
Comportement spécifique



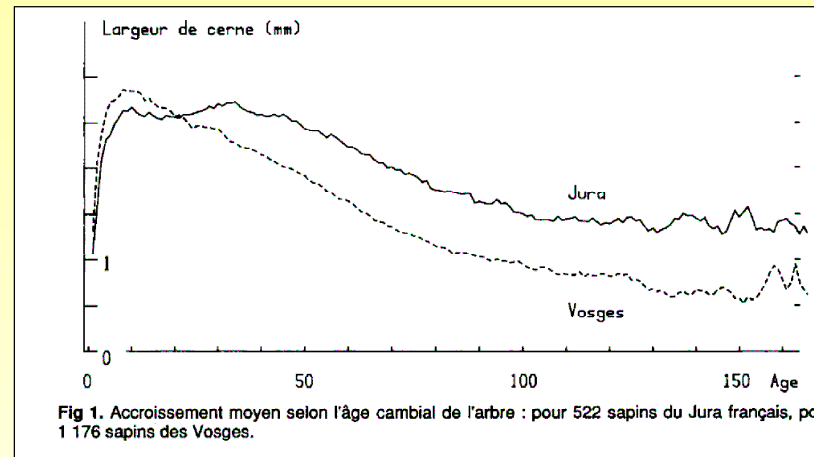
(Lebourgeois et al. 1998)

Hêtre - FD de l'Aigoual (30)

Quelques applications de la dendrochronologie

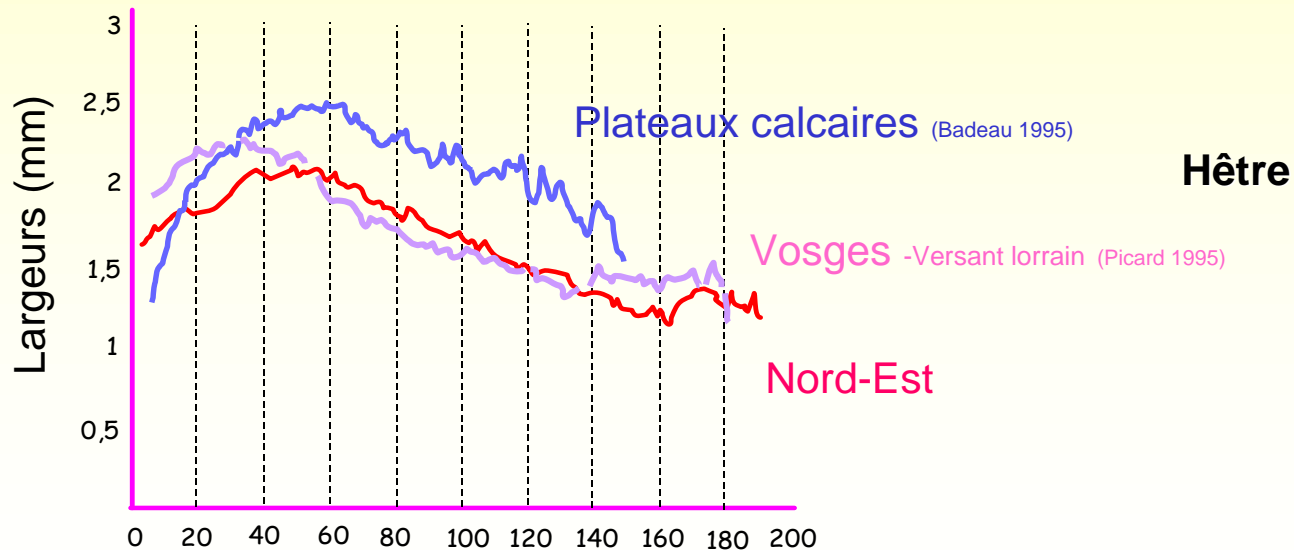
Utilisation des profils de croissance bruts...

ex. courbes âges régionales (=> voir interdatation)



80 ans **Vosges** **1.1 mm**
 Jura **1.5 mm**

Sapin (Bert et Becker 1990)



Quelques applications de la dendrochronologie

Etude des dépérissements forestiers...

Programme DEFORPA dans les années 1980-1990...

Evolution de la croissance radiale ($I_c\%$) selon le degré de défoliation des sapins (Vosges)

(Becker 1985, 1988, 1989...)

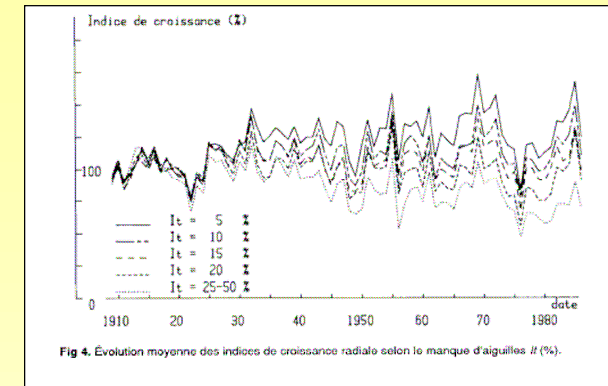
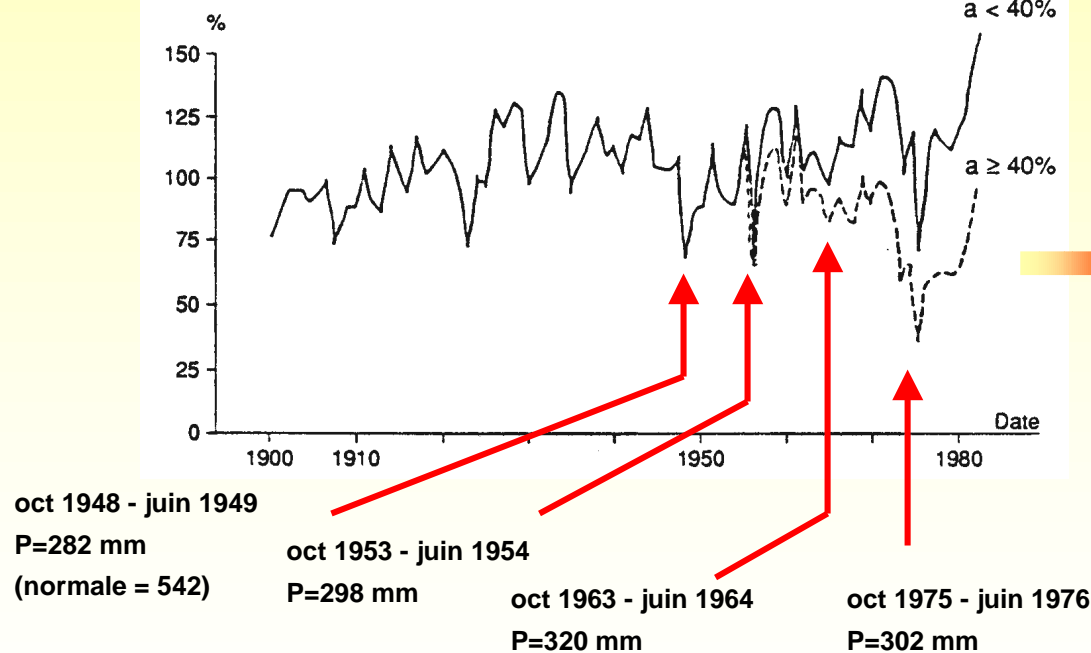


Fig 4. Evolution moyenne des indices de croissance radiale selon le manque d'aiguilles H (%).

(Sapin-Jura Bert et Becker 1990)



(F. Dej)

Perte de vigueur correspondant à des périodes sèches (octobre $n-1$ à juin n)

Quelques applications de la dendrochronologie

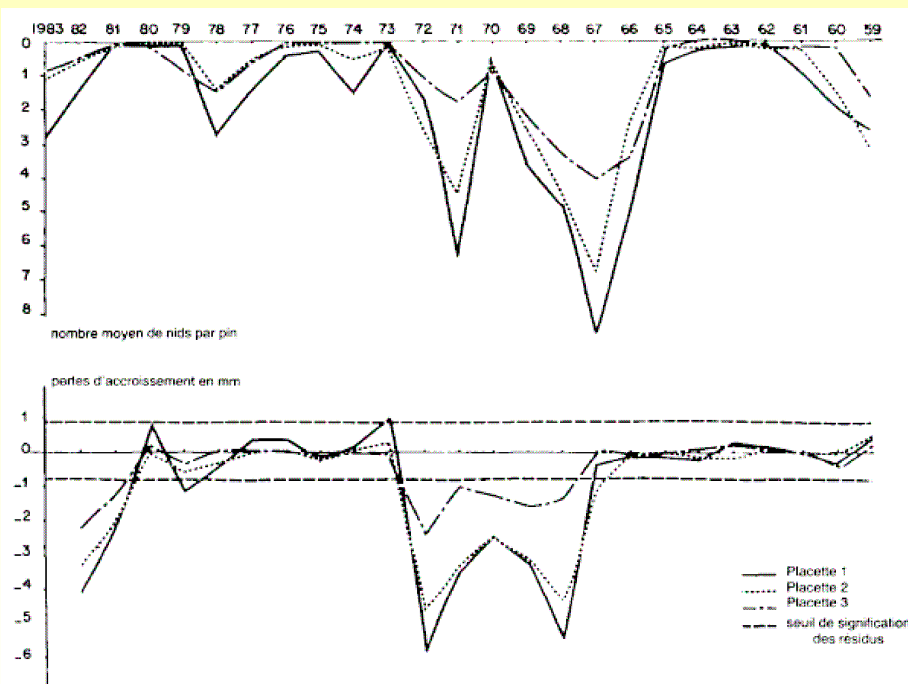
Etude des dépérissements forestiers...

Mesure des pertes de croissance radiale sur quelques espèces de *Pinus* dues à deux défoliateurs forestiers.

Ann. Sci. For., 1986, 43 (2), 239-262
Nathalie LAURENT-HERVOUËT

Au Ventoux, on a pu détecter un cerne nul en 1968 dans deux placettes après la forte attaque de 1966-1967. L'étude des vingt-cinq dernières années montre les faits suivants :

- 1) l'accroissement est davantage influencé par les attaques de processionnaires que par le climat ;
- 2) une défoliation à l'automne $n-1$ et au printemps n est répercutée sur l'accroissement de l'année $n+1$;
- 3) la perte globale enregistrée est de 35 p. 100 dans la placette la plus attaquée.



Comparaison entre les pertes d'accroissement radial annuelles et le nombre moyen de nids par pin au Ventoux.

Relations entre les nids de processionnaire du pin et la croissance du pin noir dans le Ventoux

Quelques applications de la dendrochronologie

Effets d'une fertilisation...

Radial growth of mature pedunculate and sessile oaks in response to drainage, fertilization and weeding on acid pseudogley soils

Ann Sci For (1996) 53, 585-594
© Elsevier/INRA

M Becker, G Lévy, Y Lefèvre

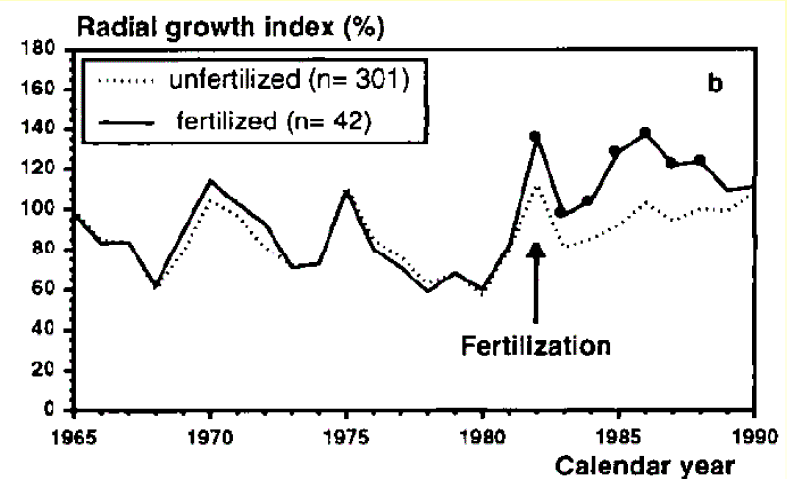
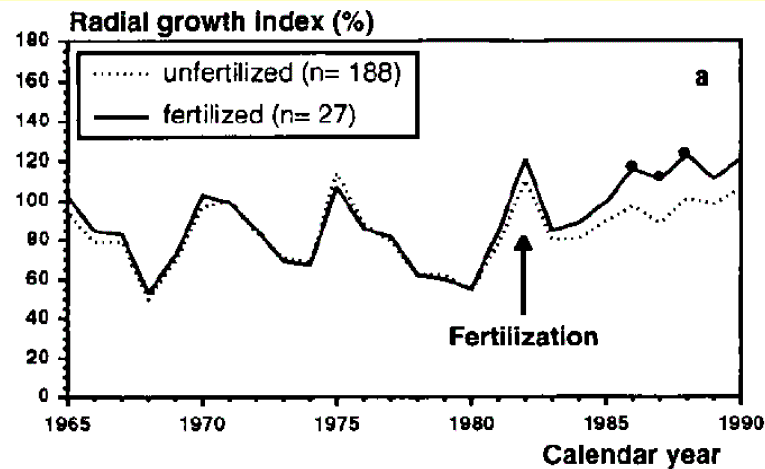


Fig 3. Effect of fertilization on pedunculate oak radial growth whatever the site type and the other experimental treatments. Black dots indicate the significant (at $P = 0.05$) yearly differences between the treated and the control trees. (a) Young trees (≤ 110 years); (b) old trees (> 110 years).

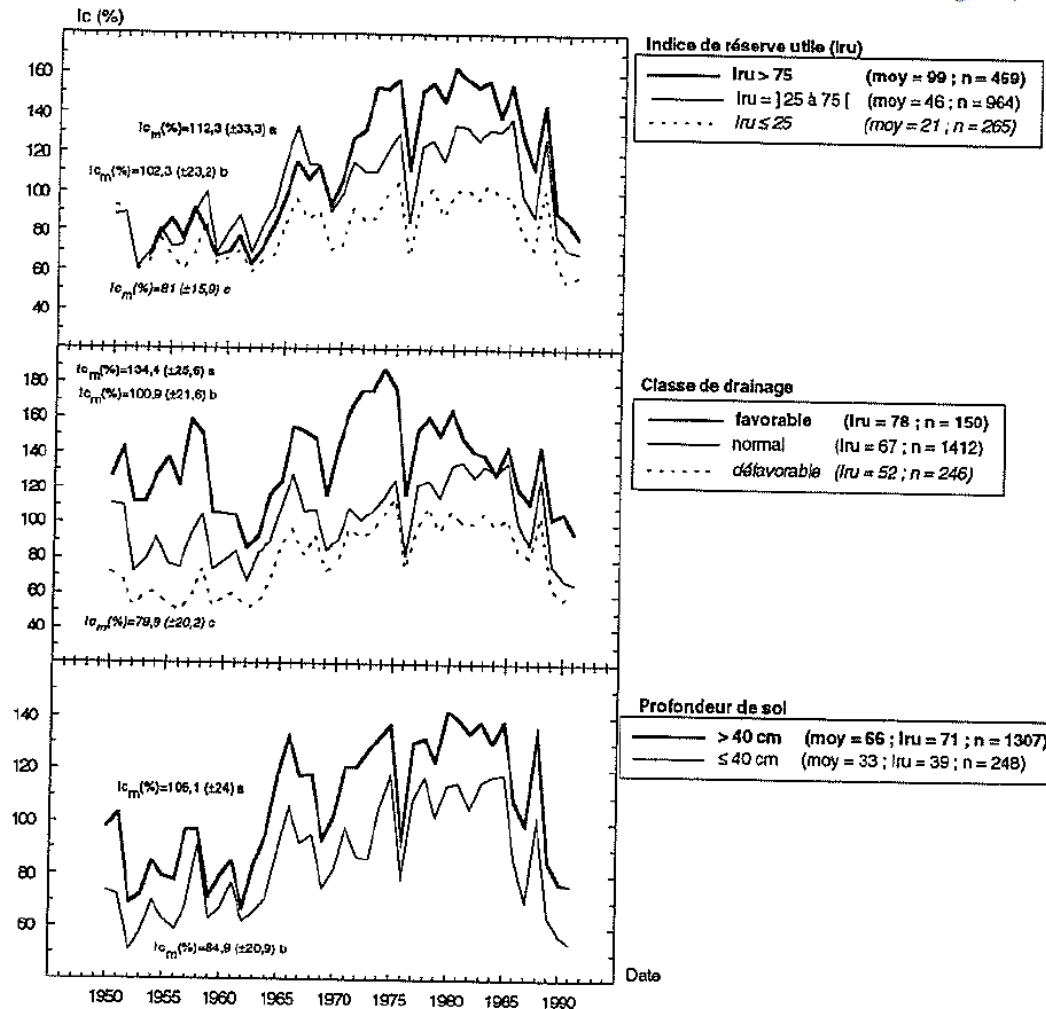
Quelques applications de la dendrochronologie

Effets de l'alimentation locale en eau

Rôle de la nutrition minérale
et de l'approvisionnement en eau sur la croissance
du pin laricio de Corse dans l'ouest de la France

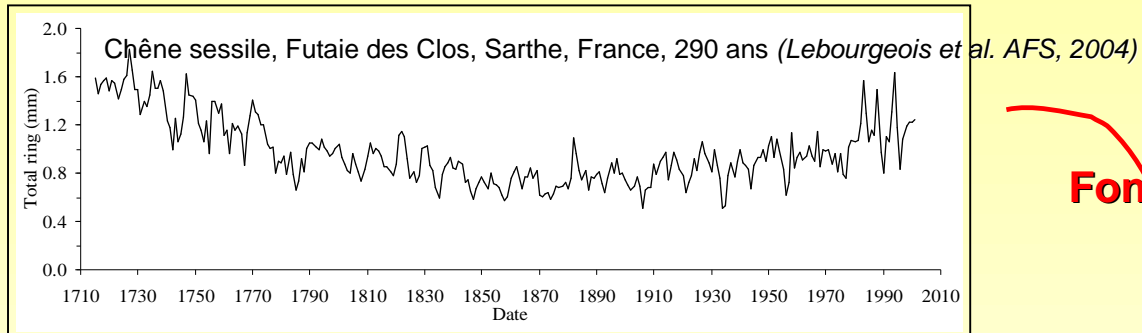
F Lebourgeois¹*, G Lévy², M Becker¹, Y Lefevre²

Ann Sci For (1997) 54, 279-300
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Quelques applications de la dendrochronologie

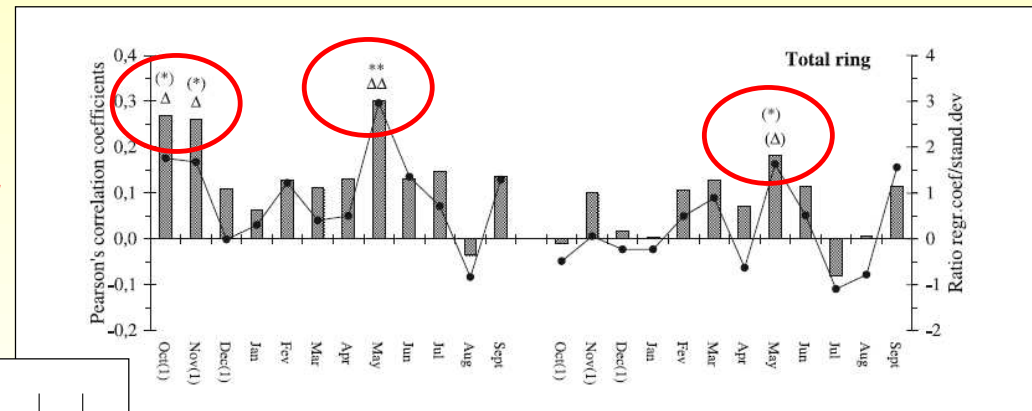
Relations croissance et climat (voir modélisation climatique)



Fonctions de réponse

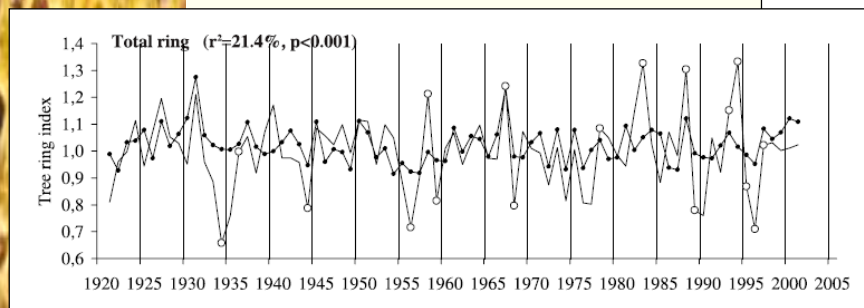
1921-2001

Reconstruction



T min

(P-ETP)



Quelques applications de la dendrochronologie

Relations croissance, climat et statut social...

A quantitative analysis of the interactions between climatic response and intraspecific competition in European beech

E. Piutti and A. Cescatti

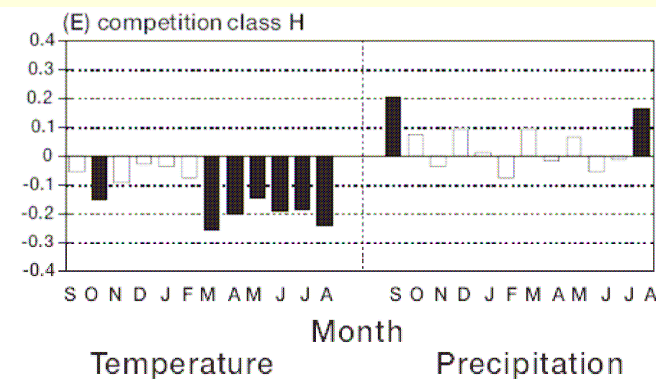
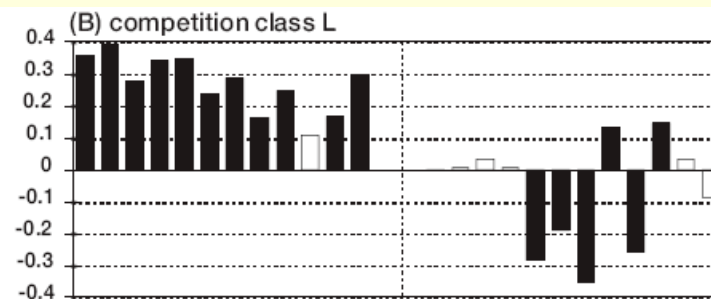
Can. J. For. Res. 27: 277-284 (1997)

Hêtre - Italie - 1250 à 1425 m

Table 2. Descriptive statistics of cored trees categorized by competition index.

Competition class	Abbrev.	No. of trees ^a	Mean CI	Mean DBH (m)	Avg. height (m)	Height/DBH ratio	Crown ratio
CI≤0.5	L	13	0.226	46.2	26.1	0.576	0.629
0.5<CI≤1.7	ML	13	1.295	37.1	23.0	0.633	0.503
1.7<CI≤3	MH	16	2.187	32.2	23.5	0.761	0.410
CI>3	H	12	5.076	21.3	22.5	1.144	0.341

^aNumber of trees in each competition class.



**Effet majeur des Températures mais effet inverse selon la compétition
effet + en cas de faible compétition et effet - en cas de forte compétition**

Quelques sites sur la dendrochronologie

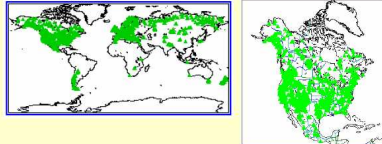
Quelques sites importants...

- <http://www.tree-ring.org/> (tree ring research)
- <http://www.wsl.ch/dbdendro/> (biblio dendro)
- <http://www.ltrr.arizona.edu/resources.html> (laboratoire Tree Ring Research)
- <http://www.treeringsociety.org/>

Data selection and evaluation

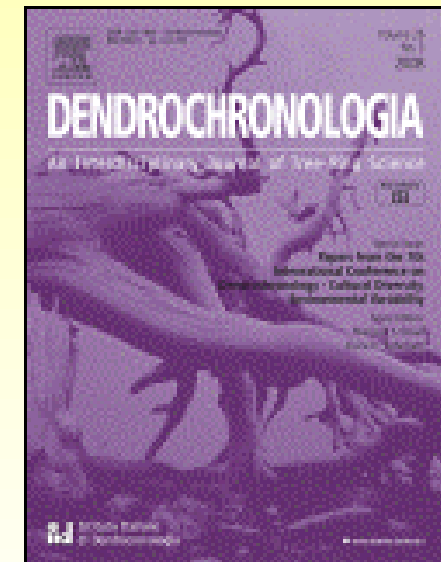
Tree-ring data: Sources for chronologies

International Tree-Ring Data Bank (ITRDB)
<http://www.ncdc.noaa.gov/paleo/treering.html>



- ~2500 chronologies contributed from all over the world
- Can be searched by moisture-sensitive species, location, years

La revue...



Ouvrages de référence

- Fritts H.C., 1976, Tree Rings and Climate, 567 pages
- Cook E.R. and Kairiukstis L.A. (eds), 1989 (reprinted 1992), Methods of dendrochronology, Kluwer Academic Publishers, 392 pages
- Winner R. and Vetter R.E. (eds), 1999, Tree-Ring analysis. Biological, methodological and environmental aspects, CABI Publishing, 302 pages