Written in the Trees: Exploring the Past Through Tree-Ring Records

LFPL's MyLibraryU Short Course

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University of Louisville Geographic and Environmental Sciences

A bit about me

"To me, an experiment is a kind of conversation with plants: I have a question for them, but since we don't speak the same language, I can't ask them directly and they won't answer verbally. But plants can be eloquent in their physical responses and behaviors. Plants answer questions by the way they live, by their responses to change; you just need to learn how to ask."

-Robin Wall Kimmerer

Braiding Sweetgrass

So, what is dendrochronology?

Discussion

- Have you heard of tree rings before?
- What can you tell about a tree's environment by looking at tree rings – how much a tree grew in one year?

Tree-Ring Science

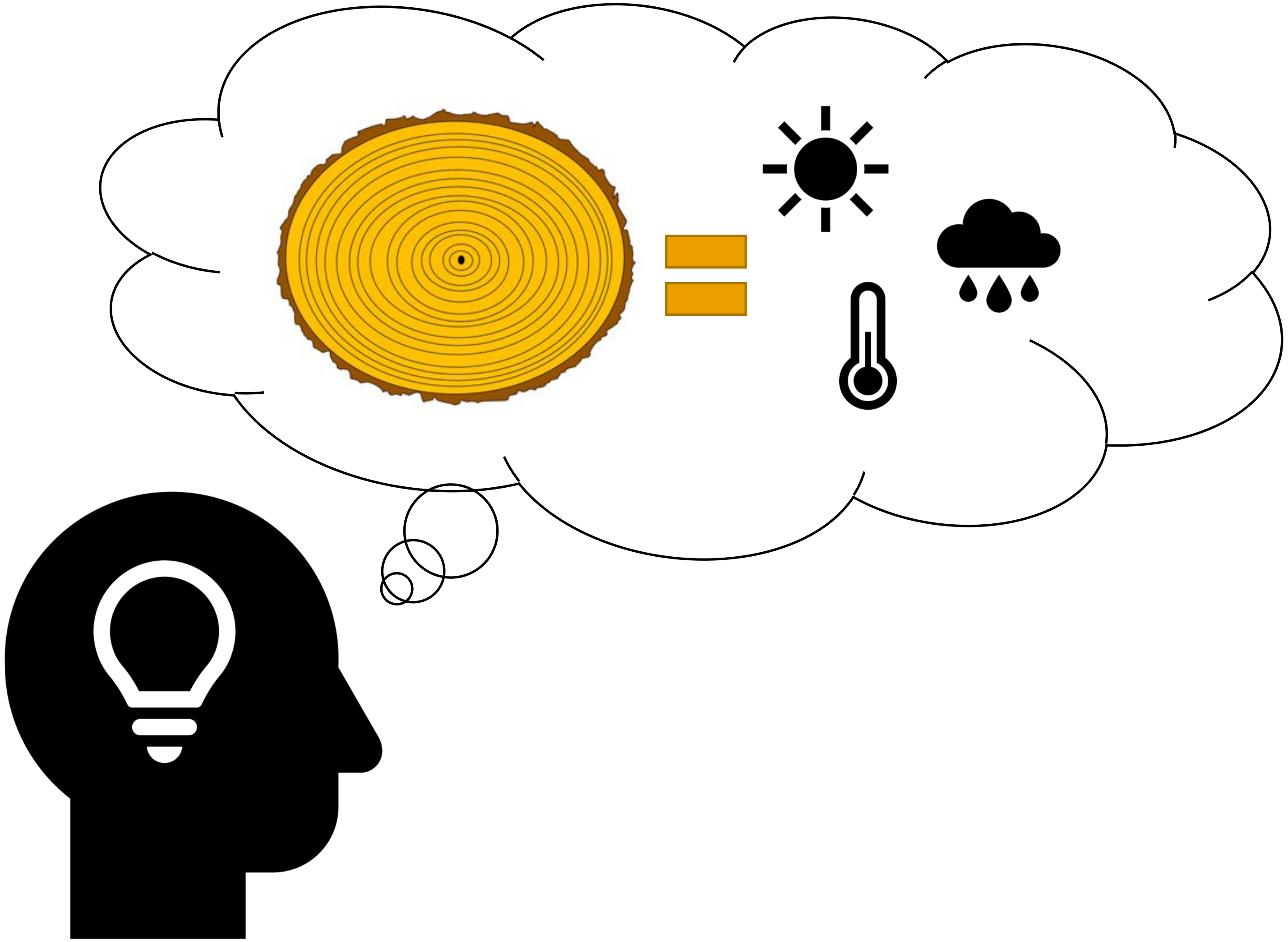
Also known as ***dendrochronology***

- Dendro = tree
- Chrono = time

Defined as:

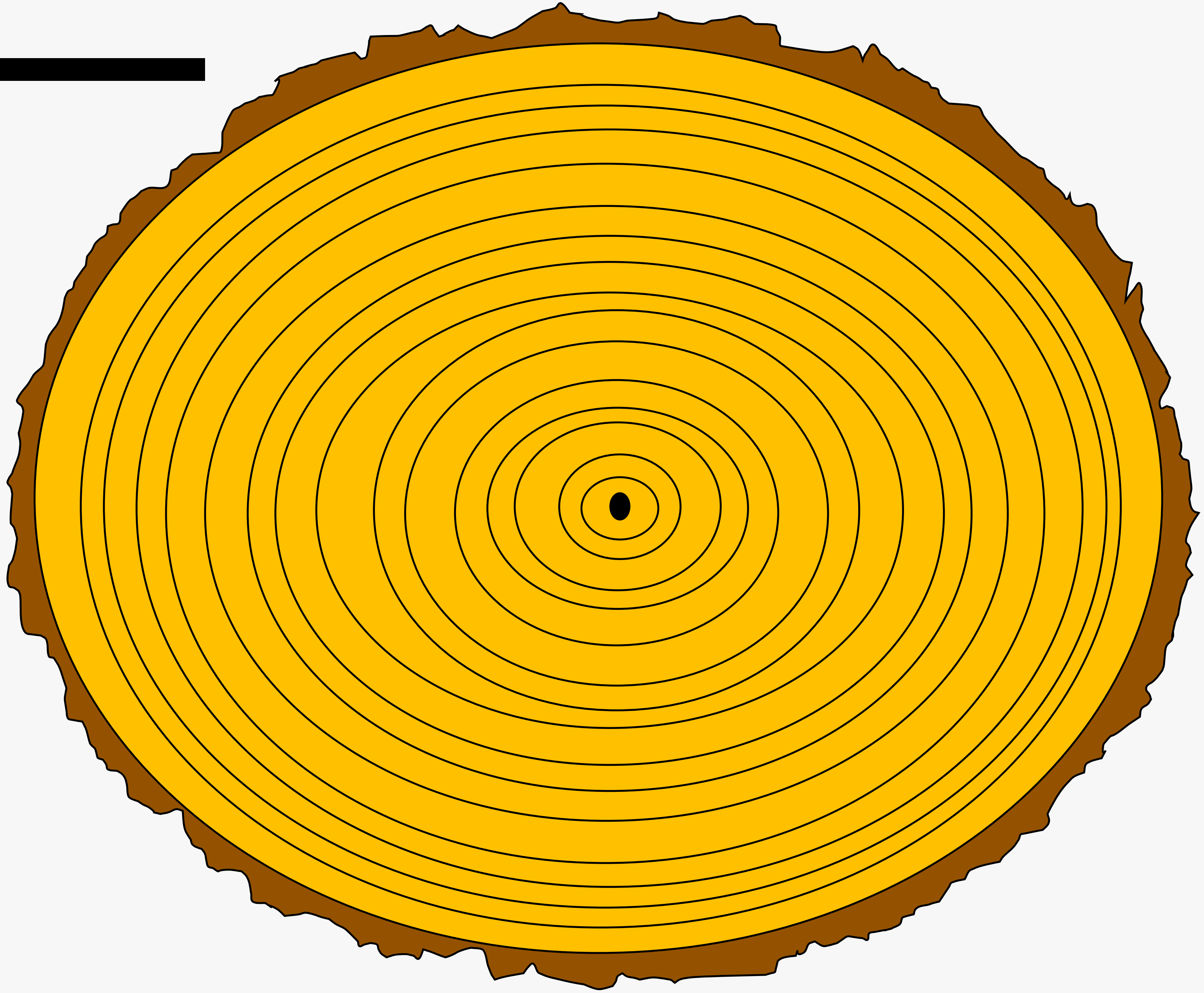
the science or technique of dating events, environmental change, and archaeological artifacts by using the characteristic patterns of annual growth rings in timber and tree trunks.

Tree-ring scientists use *patterns* in tree growth to understand past environmental conditions.



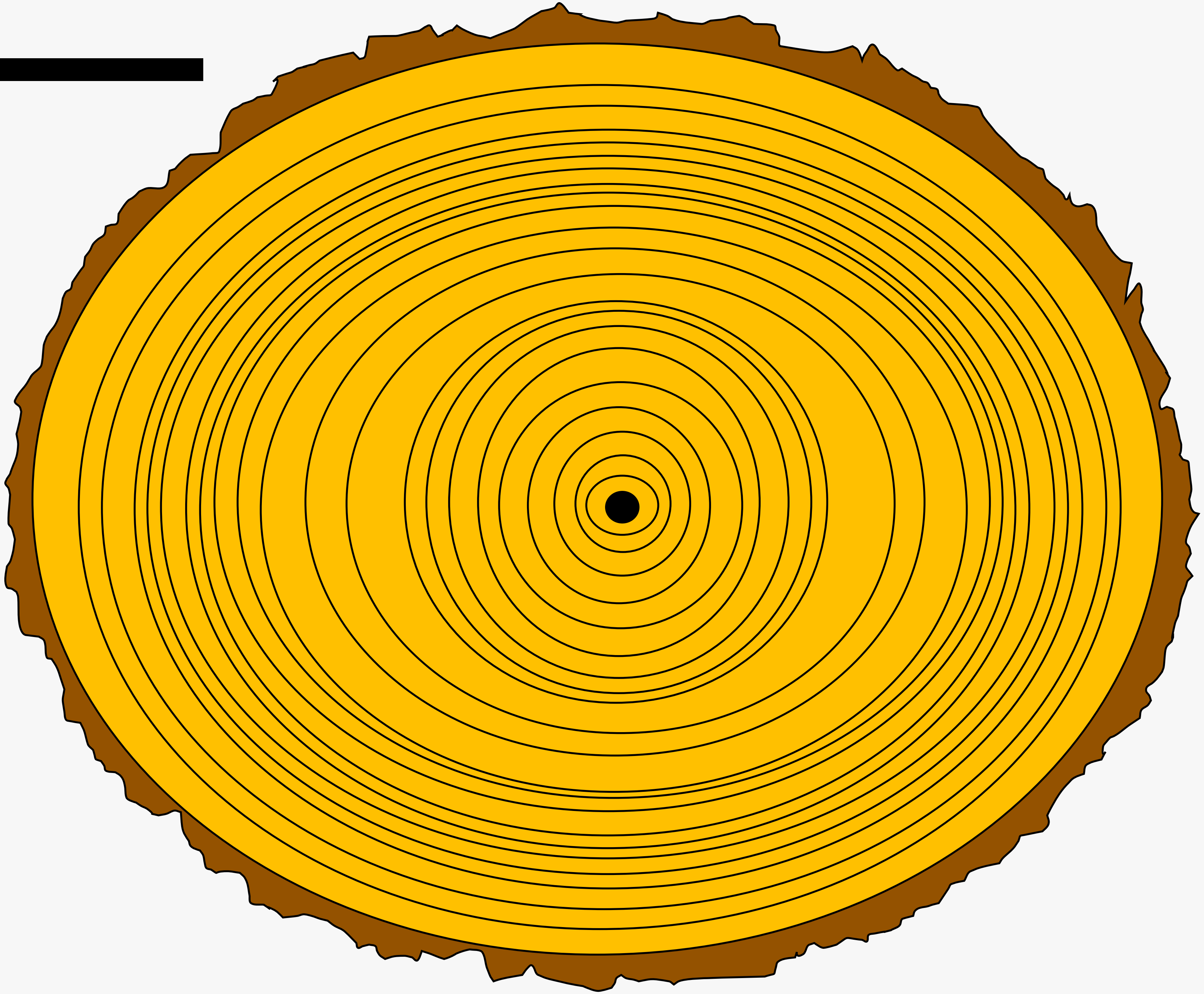
This tree had good growing conditions its whole life.

What sorts of conditions would allow a tree to grow well?



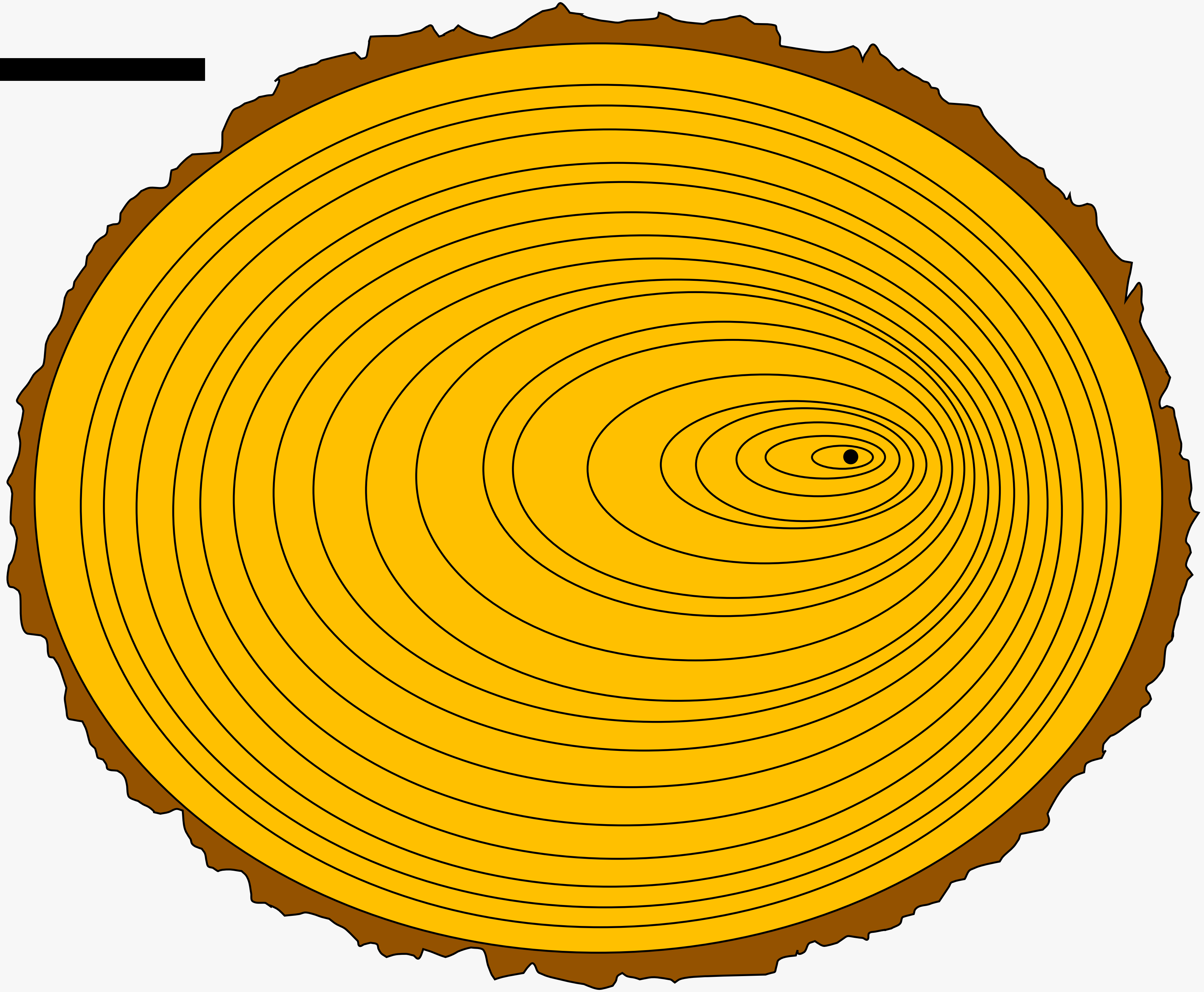
This tree ***did not*** have good growing conditions its whole life.

What sorts of conditions would reduce the growth of a tree?



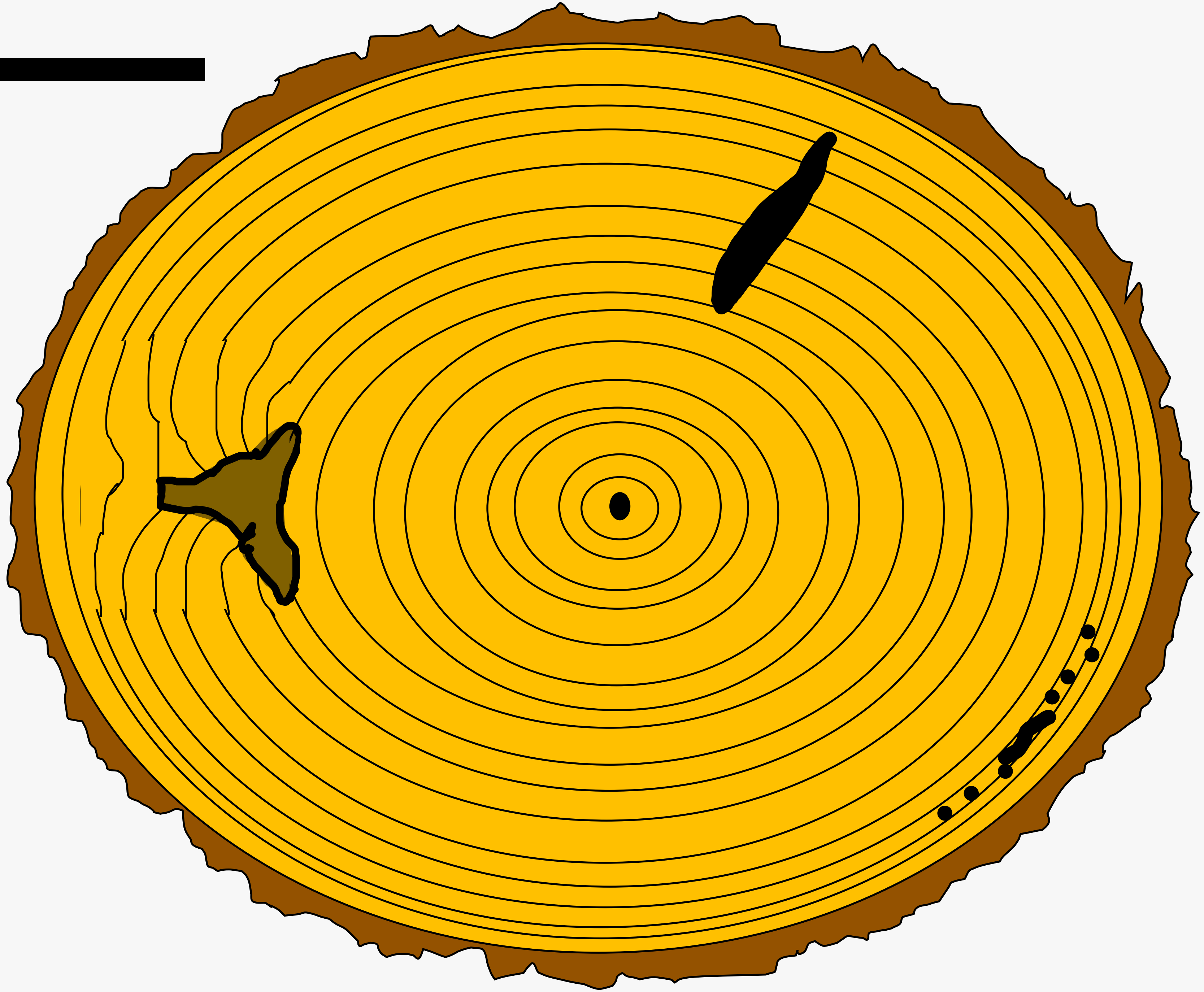
This tree grew unevenly.

What sorts of conditions would cause a tree to grow this way?



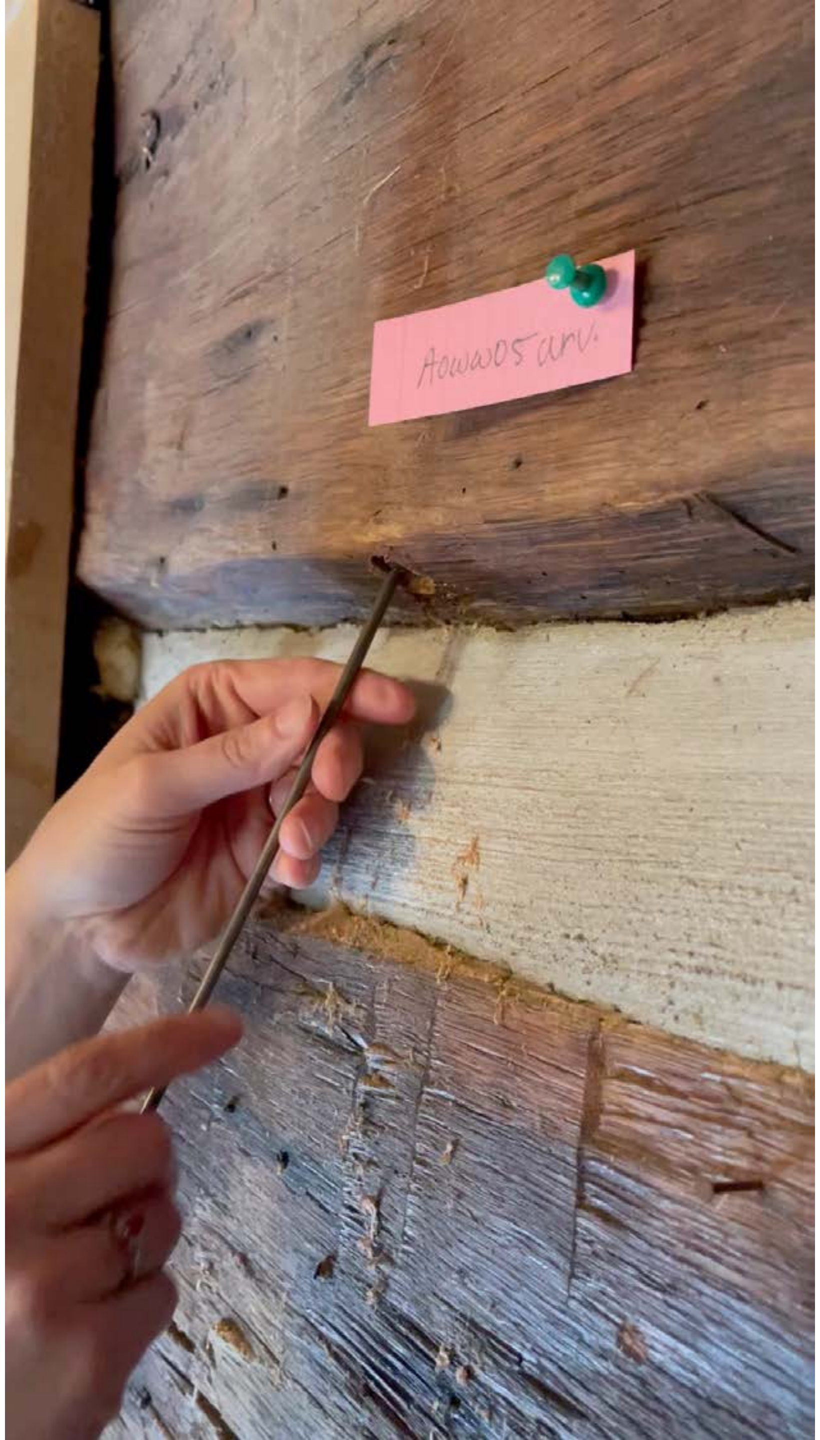
This tree experienced injuries.

What sorts of things would injure a tree, leaving a scar?

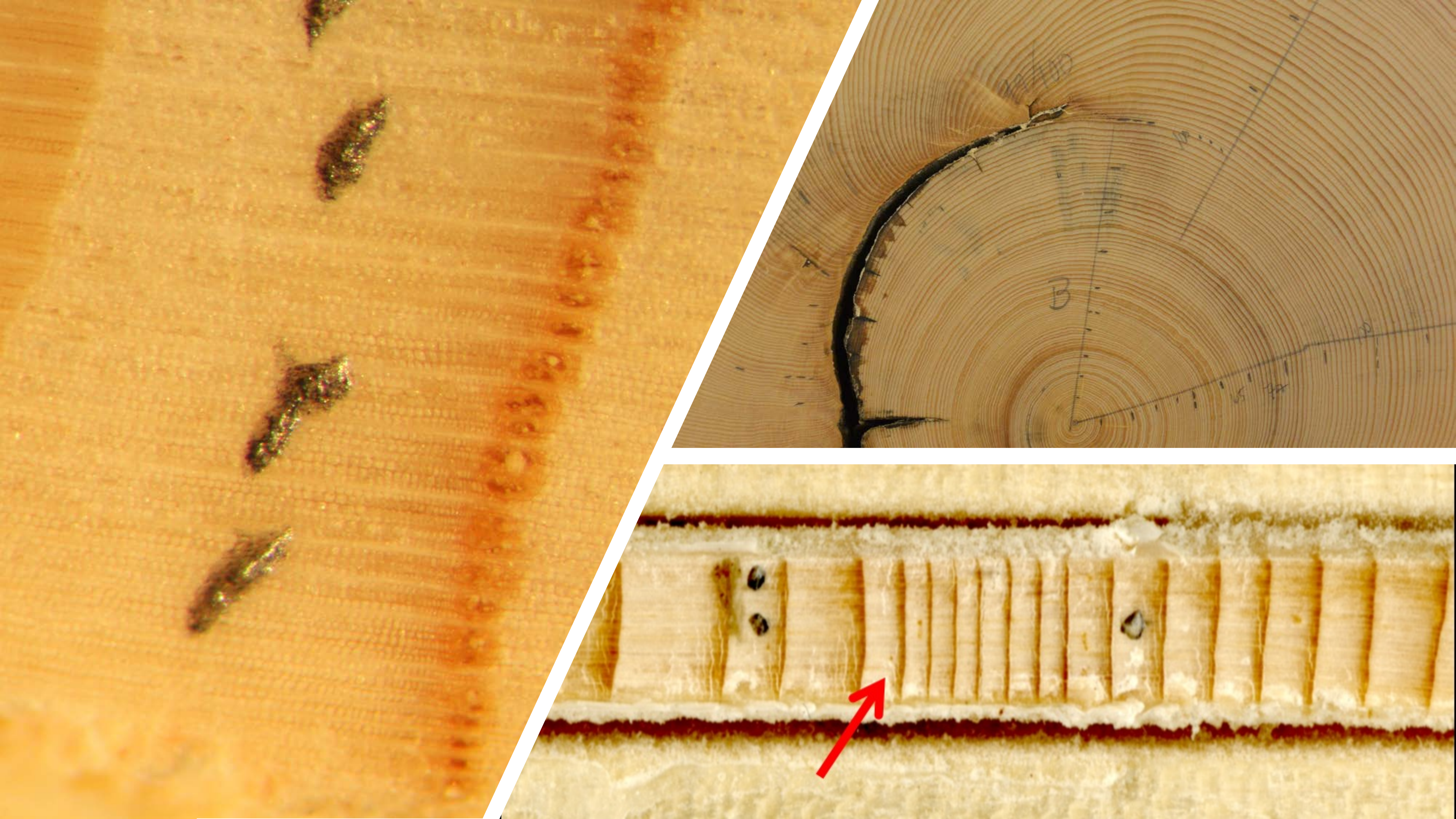


Tree rings are ***proxies***, natural recorders of events and change.


McB 04


Aowa05 arv.





Trees help us understand the past.

Understanding how trees respond to change.

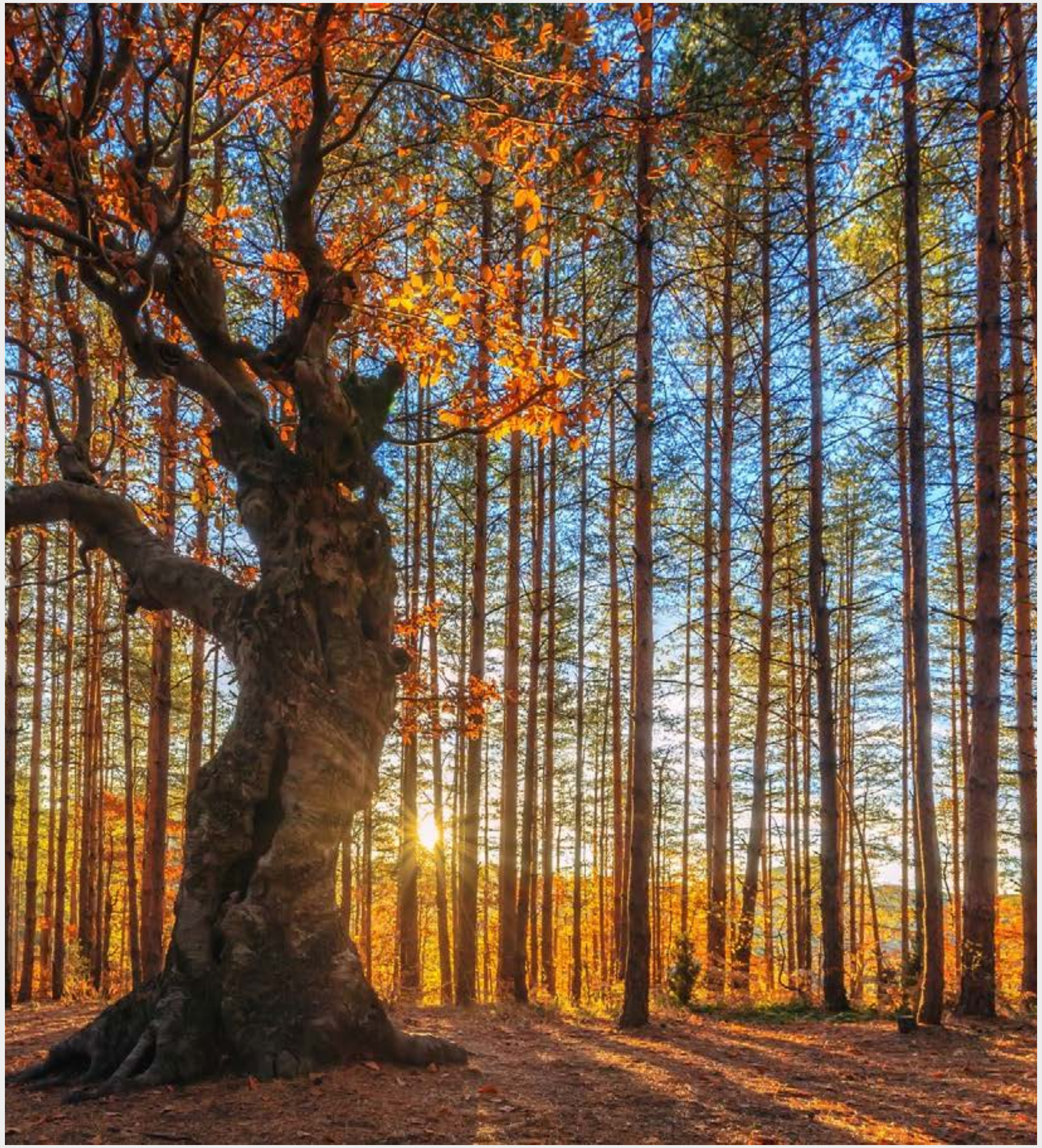
Understanding how this varies by species and environments.

Understanding climate and environmental extremes.

Understanding how often environmental events occur.

Understanding how current conditions compare to the past.

To help us better predict the future.



Let's Dig a Little Deeper

Foundational Principles in Dendrochronology/Tree-Ring Science

You can't just count the rings. . .

Important Principles in Dendrochronology

Uniformitarianism

Limiting Factors

Ecological Amplitude and Site Selection

Aggregate Tree Growth

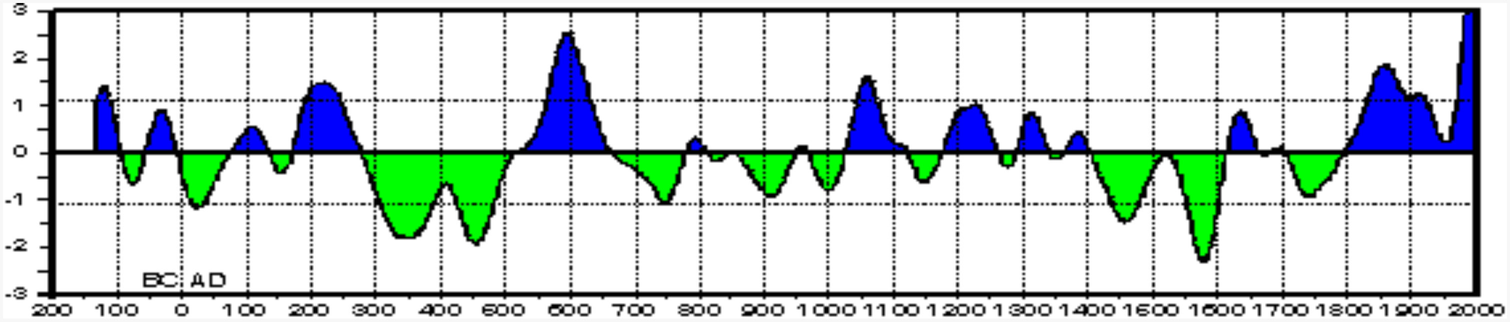
Uniformitarianism

"The Present is the Key to the Past"

Why is this important to tree-ring scientists?

An important assumption for reconstructing past conditions

- Climate Reconstructions
- Disturbance



Future?

Past

Present

Limiting Factors

"Tree growth can proceed only as fast as allowed by the primary environmental and physiological mechanisms that restrict growth."

Why is this important to tree-ring scientists?

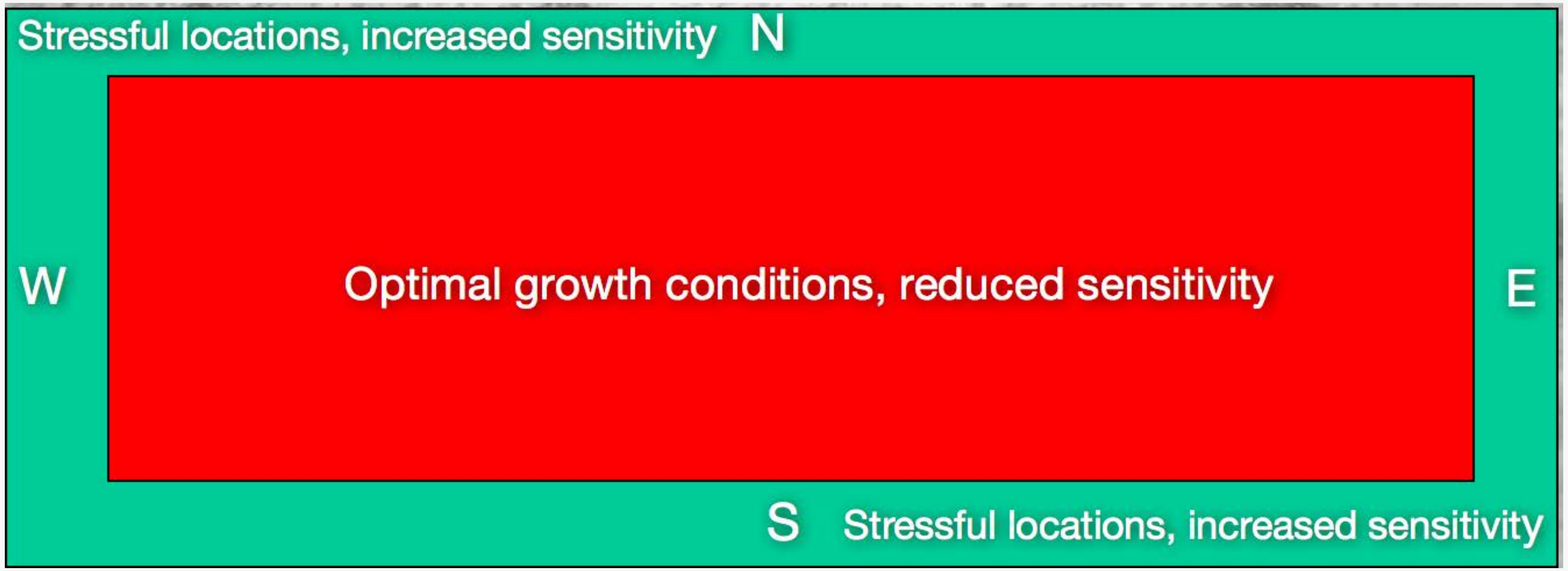
<u>We need variability!</u>

Ecological Amplitude and Site Selection

A tree species will be more responsive and sensitive to changes in environmental conditions in the outer limits of its range.

Why is this important to tree-ring scientists?

<u>We need sensitive trees!</u>



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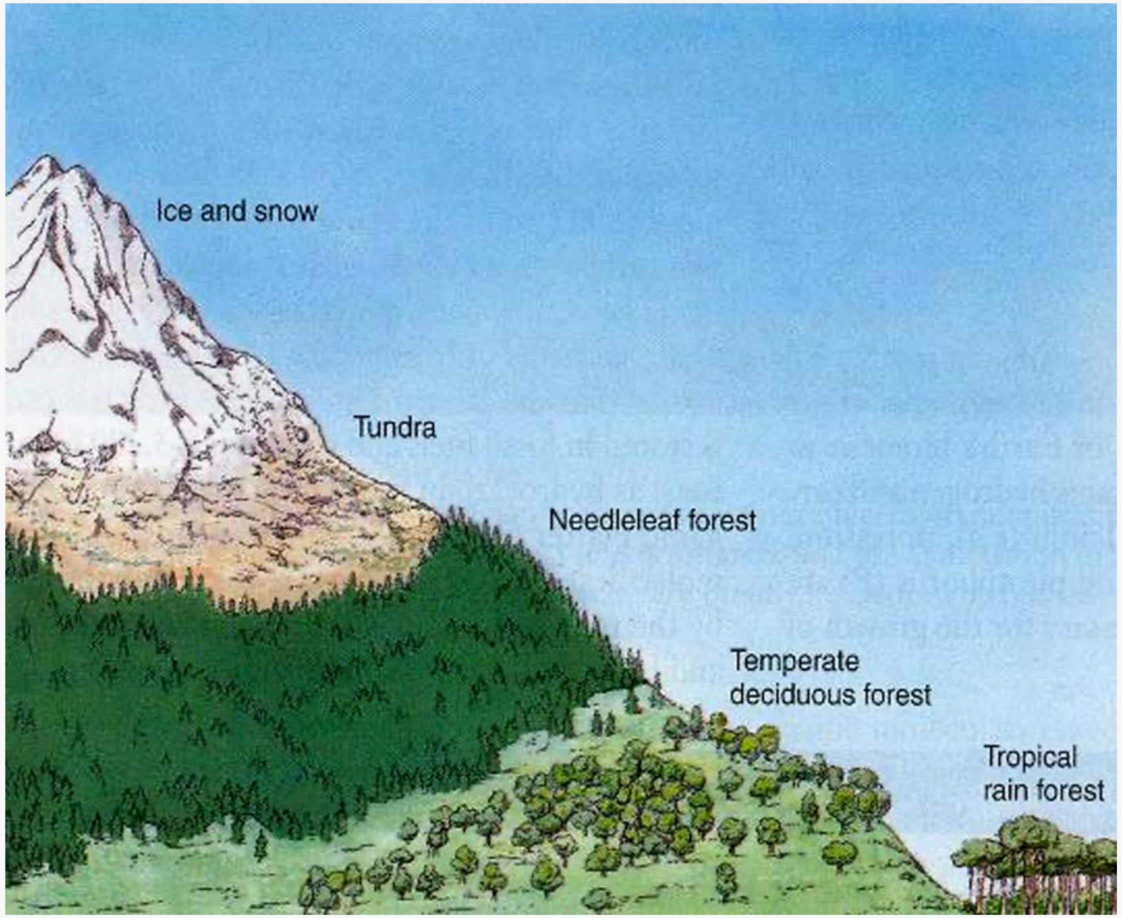
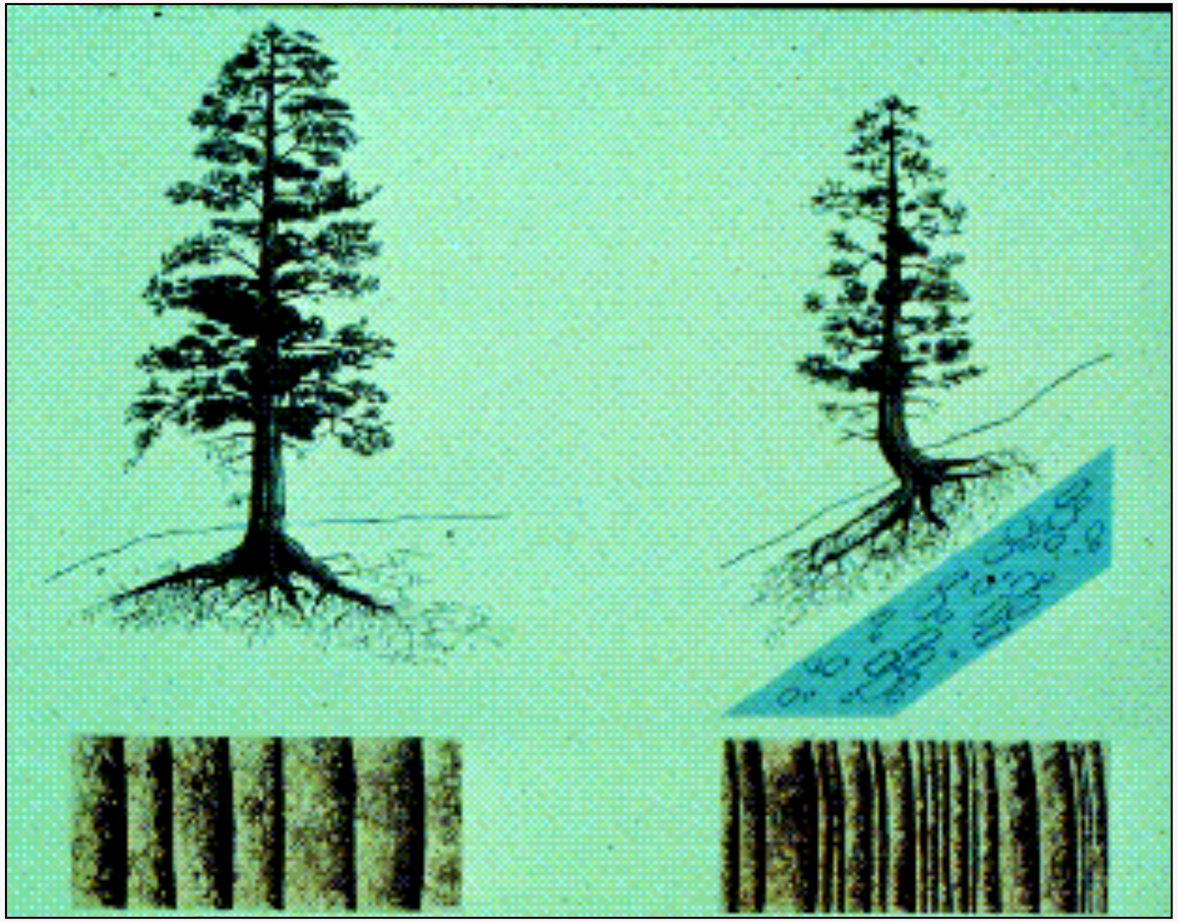
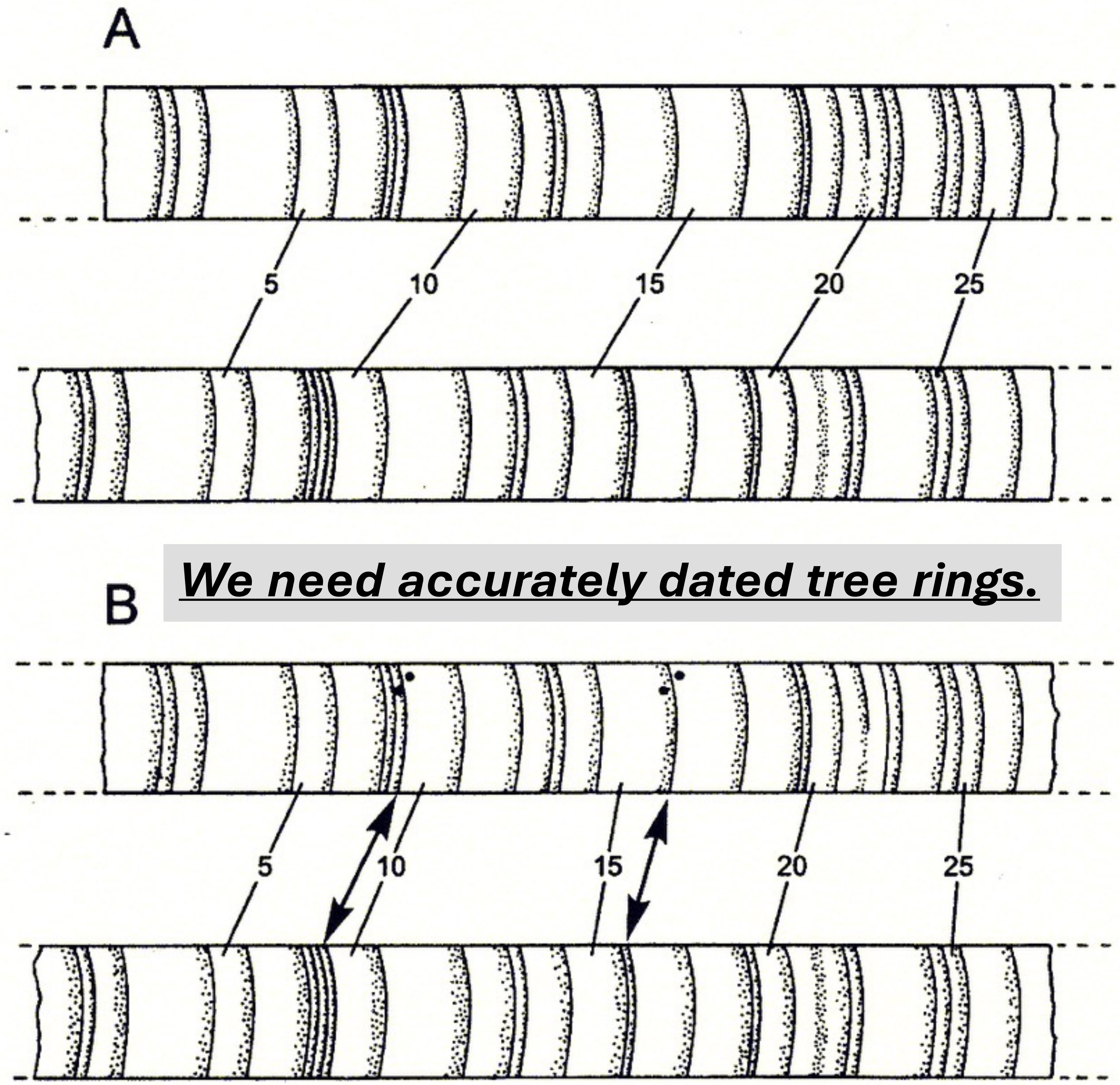

Ice and snow
Tundra
Needleleaf forest
Temperate
deciduous forest
Tropical
rain forest





We need accurately dated tree rings.

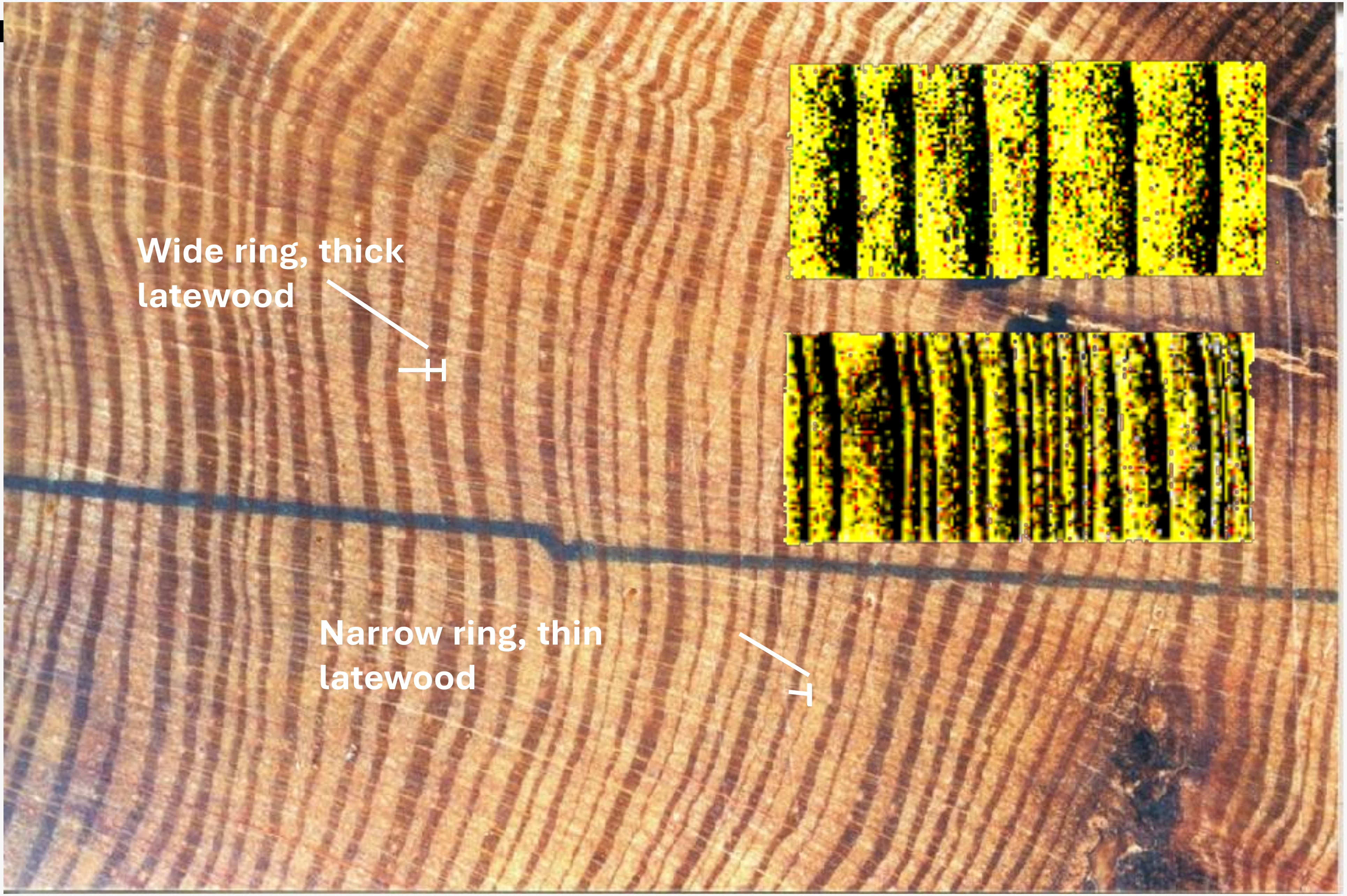
Crossdating

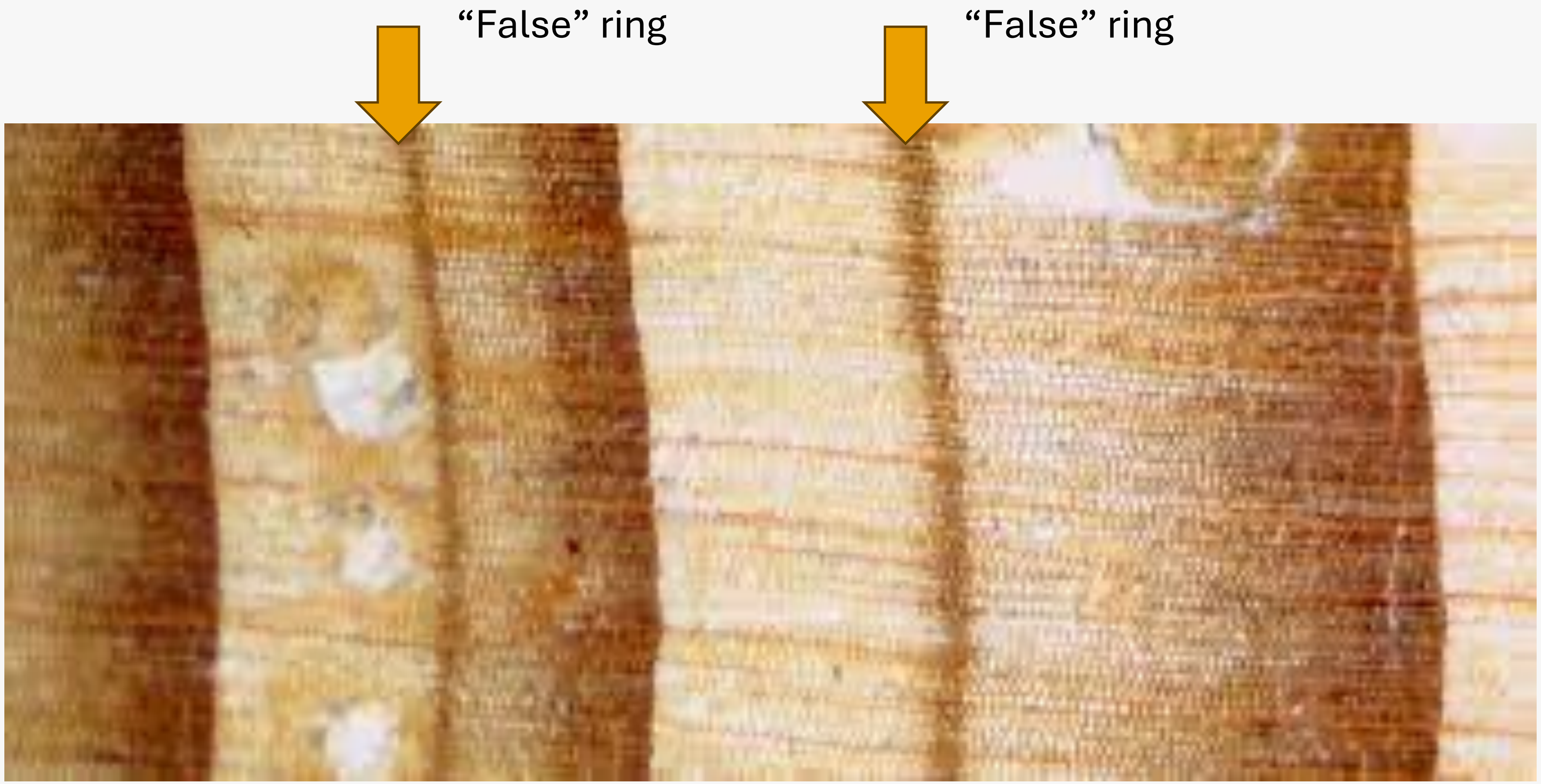
Variability in tree-ring widths is necessary for the primary principle of dendrochronology

Pattern matching, visually and statistically confirms absolute dating, helps us to identify true anomalies vs. human error

Anomalies like:

- False rings
- Locally absent rings


Wide ring, thick latewood
Narrow ring, thin latewood



http://www.rmtrr.org/basics.html

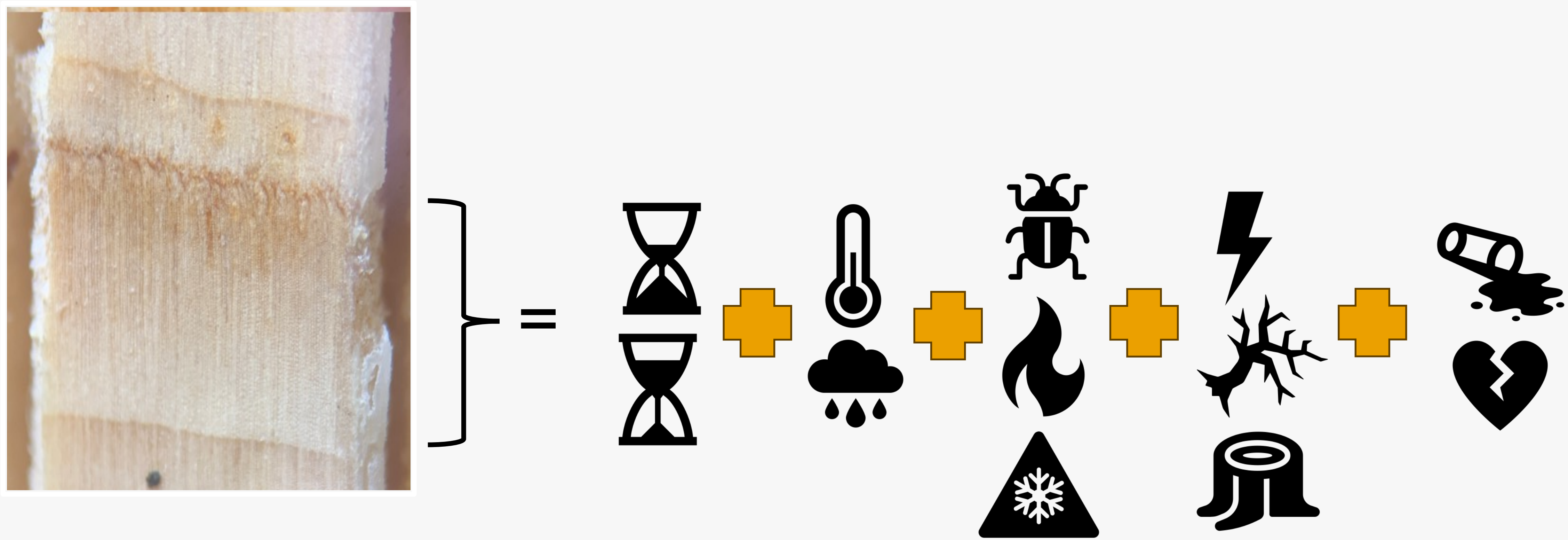
Aggregate Tree Growth

Tree growth can be "decomposed" into five basic parts:

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

R = ring width, t = the current year, and δ = presence (1) or absence (0) indicator

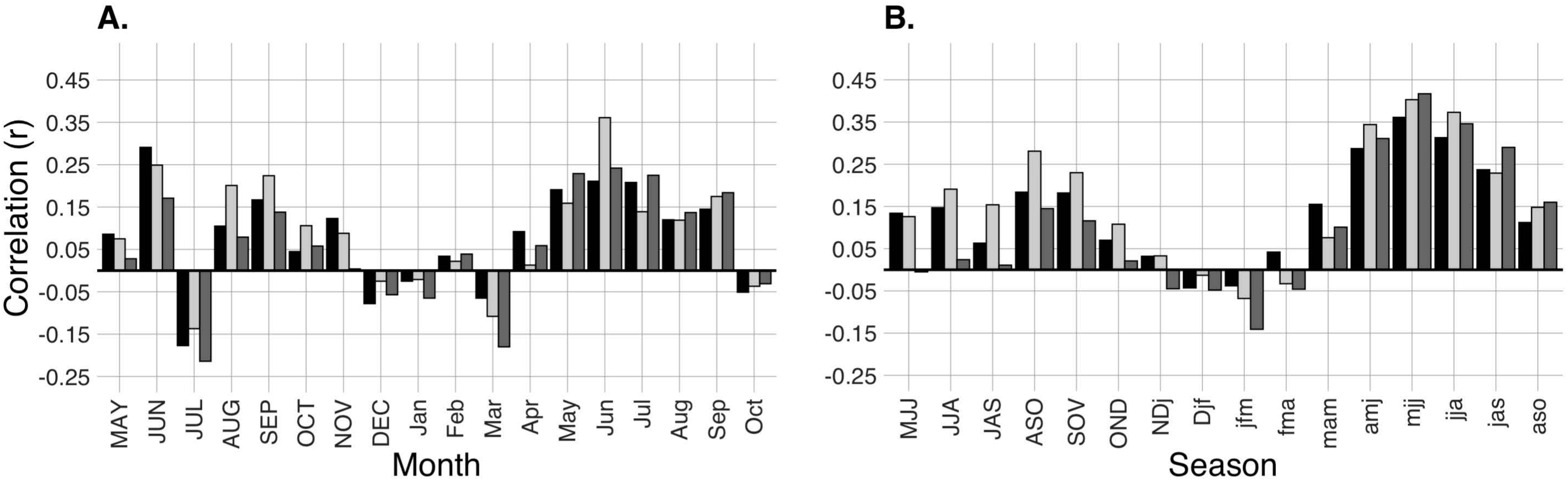
1. A = age-related trend
2. C = climate
3. D1 = exogenous (external) disturbance processes (examples?)
4. D2 = endogenous (internal) disturbance processes (examples?)
5. E = random error



<u>Tree-ring scientists sort out the SIGNAL from the NOISE.</u>

Using tree rings to reconstruct climate

- We start by finding out IF trees are responding to climate variables
  - Climate-Growth Correlation Analyses
- Then we must check to see if this signal is temporally stable
  - We can no longer assume uniformitarianism!
- If a signal is strong, we can use it to build a model to reconstruct climate



A.
0.45
0.35
0.25
0.15
0.05
-0.05
-0.15
-0.25
Correlation (r)
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Month
B.
0.45
0.35
0.25
0.15
0.05
-0.05
-0.15
-0.25
MJJ
JJA
JAS
ASO
SOV
OND
NDj
Djf
jfm
fma
mam
amj
mjj
jja
jas
aso
Season

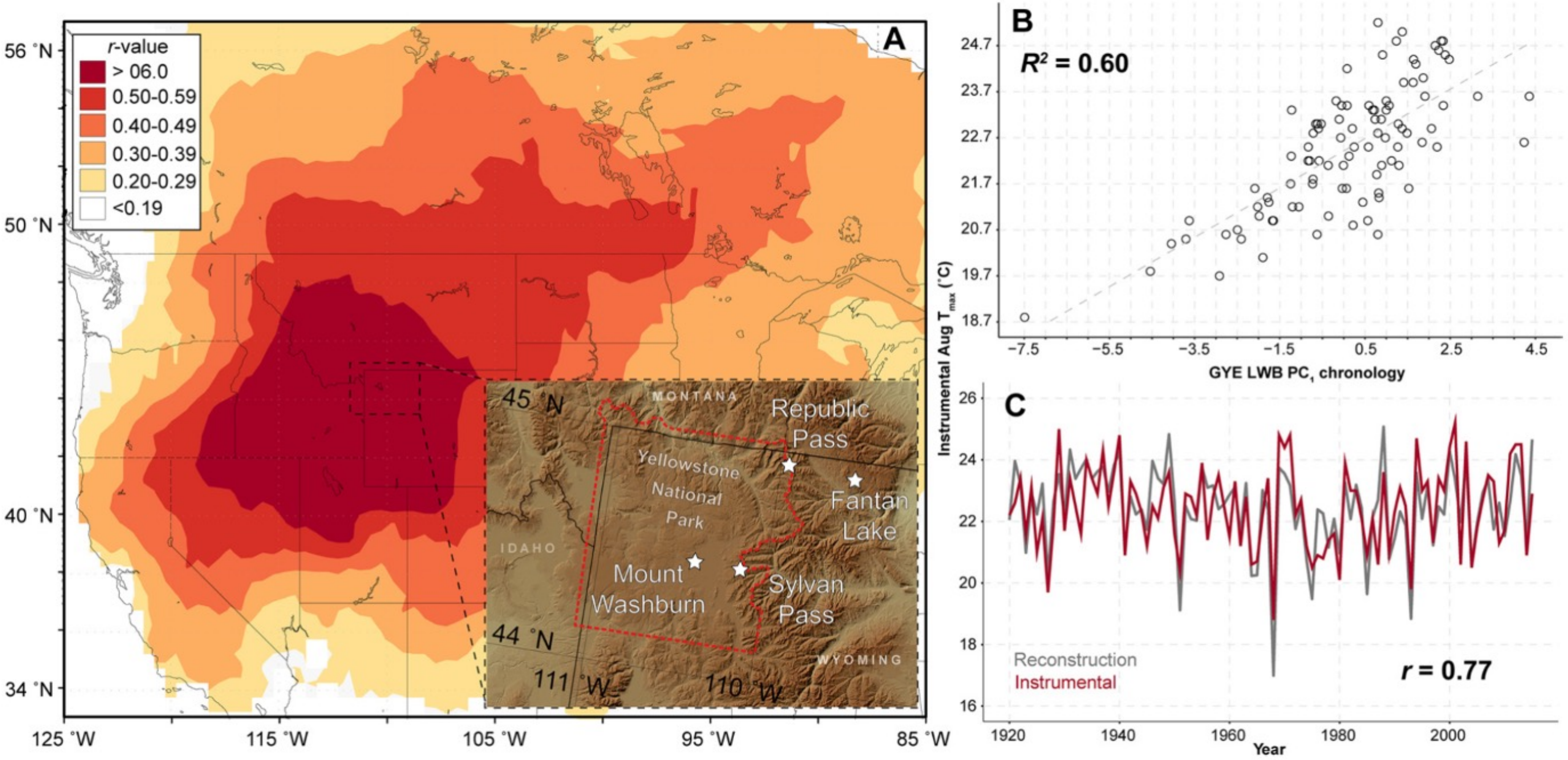
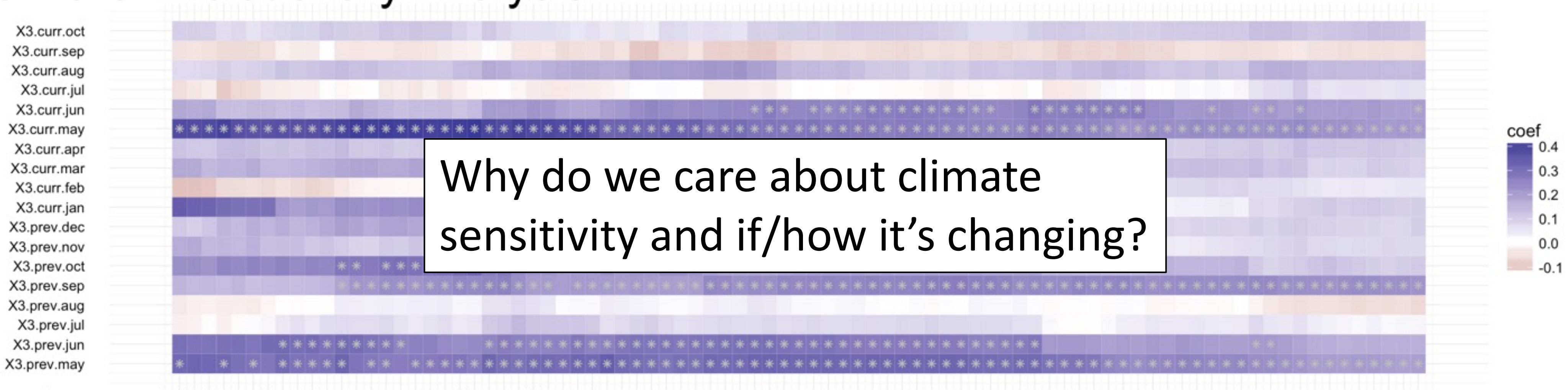


Figure 7: From Heeter et al. (2021): A) Spatial correlation between the GYE T_{max} reconstruction and mean August CRU 0.5 T_{max} (Harris et al., 2014) plotted with study site locations; (B) Scatter of instrumental August T_{max} and the GYE latewood blue (LWB) PC1 chronology, 1920–2015; (C) Instrumental (red) and reconstructed (gray) values for the GYE Tmax reconstruction model 1920–2015. Higher correlation coefficients (increasing darkness of red) indicate a stronger relationship ($p < 0.001$).

Heeter, K.J., Rochner, M.L., and Harley, G.L. 2021. Summer air temperature for the Greater Yellowstone Ecoregion (770–2019 CE) over 1,250 years. *Geophysical Research Letters*, 48 (7), e2020GL092269. https://doi.org/10.1029/2020GL092269

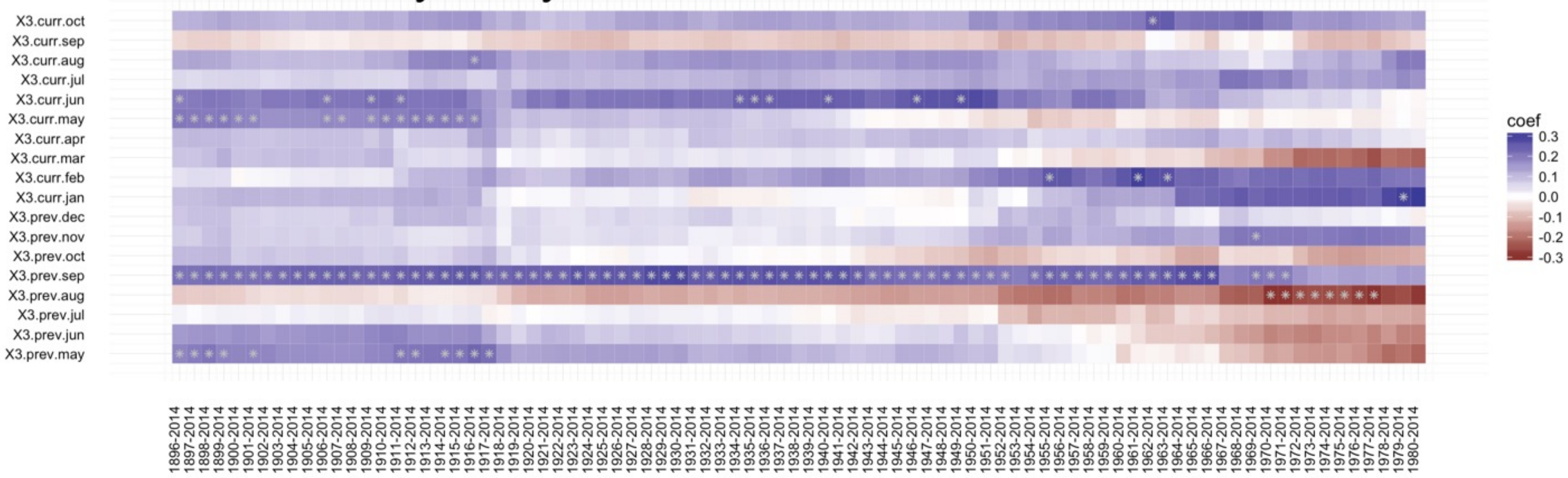
Whitebark Pine Growth and Temperature

Forward Evolutionary Analysis



Why do we care about climate sensitivity and if/how it’s changing?

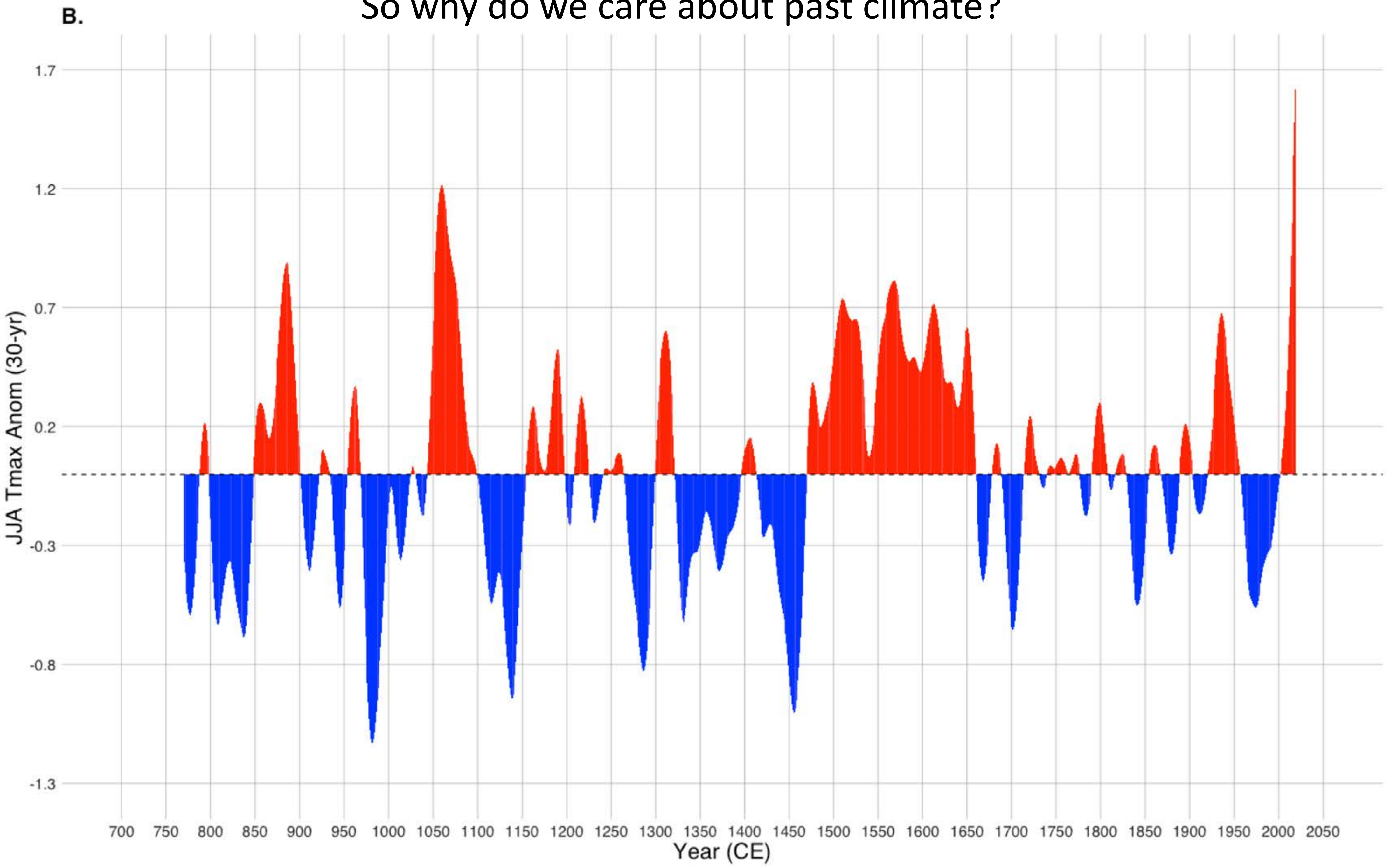
Backward Evolutionary Analysis



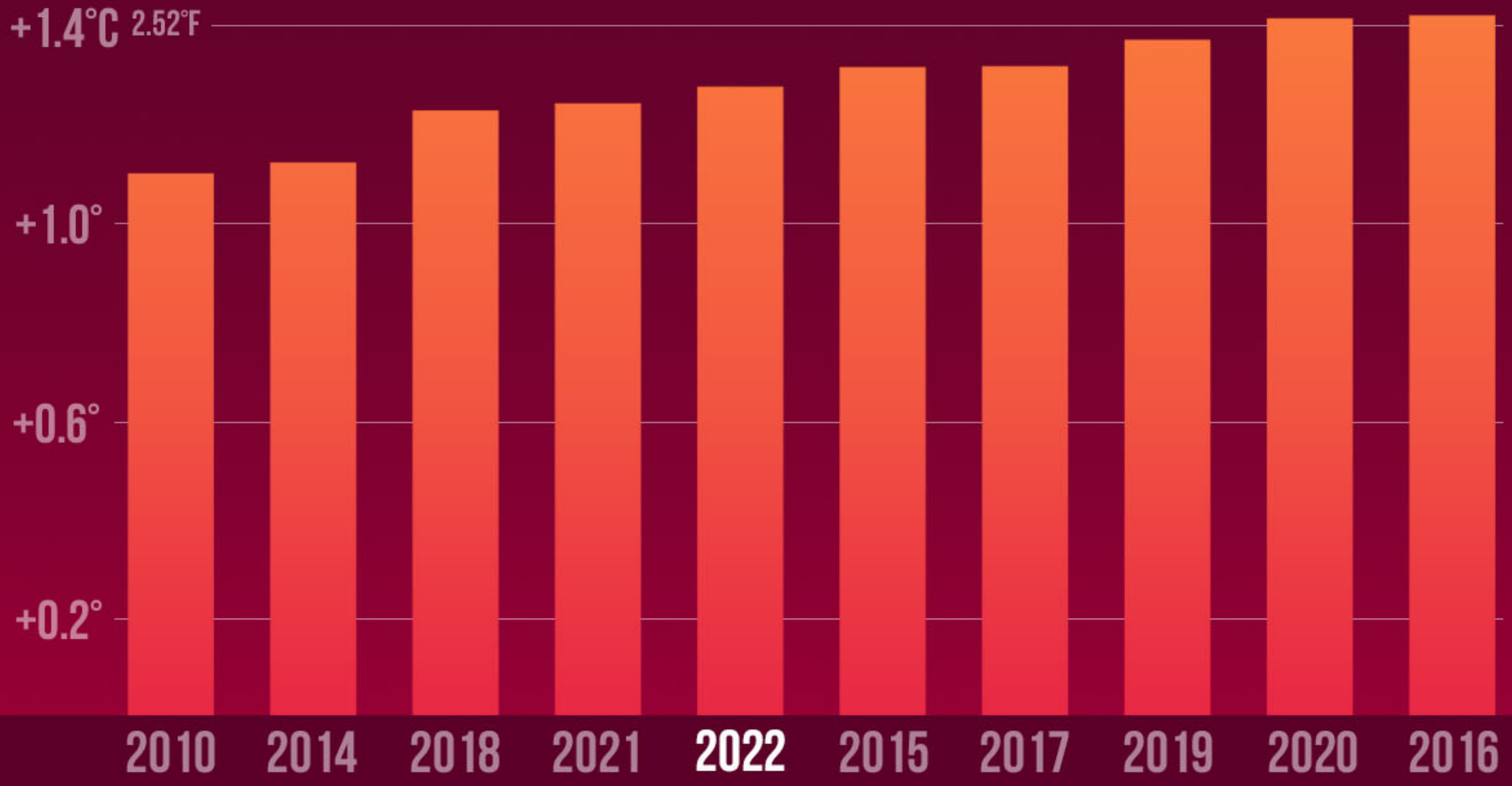
Climate Reconstruction

- We use correlation and temporal stability analyses to choose ONE variable to reconstruct
- Tree growth is a function of climate
- Build a model where climate is a function of tree growth

So why do we care about past climate?



10 HOTTEST GLOBAL YEARS ON RECORD



Source: NASA GISS & NOAA NCEI global temperature anomalies averaged and adjusted to early industrial baseline (1881-1910). Data as of 1/12/2023.

CLIMATE CENTRAL

Drought

RESEARCH

PALEOCLIMATOLOGY

Quantification of drought during the collapse of the classic Maya civilization

Nicholas P. Evans[1]*, Thomas K. Bauska[1], Fernando Gázquez-Sánchez[1], Mark Brenne Jason H. Curtis[2], David A. Hodell[1]

The demise of Lowland Classic Maya civilization during the Terminal Classic Period (~800 to 1000 CE) is a well-cited example of how past climate may have affected ancient societies. Attempts to estimate the magnitude of hydrologic change, howev have met with equivocal success because of the qualitative and indirect nature of available climate proxy data. We reconstructed the past isotopic composition ($\delta^{18}O$, δD, ^{17}O-excess, and d-excess) of water in Lake Chichancanab, Mexico, using a technique that involves isotopic analysis of the structurally bound water in sedimentary gypsum, which was deposited under drought conditions. The triple oxygen and hydrogen isotope data provide a direct measure of past changes in lake hydrology. We modeled the data and conclude that annual precipitation decreased between 41 and 54% (with intervals of up to 70% rainfall reduction during peak drought conditions) and that relative humidity declined by 2 to 7% compared to present-day conditions.

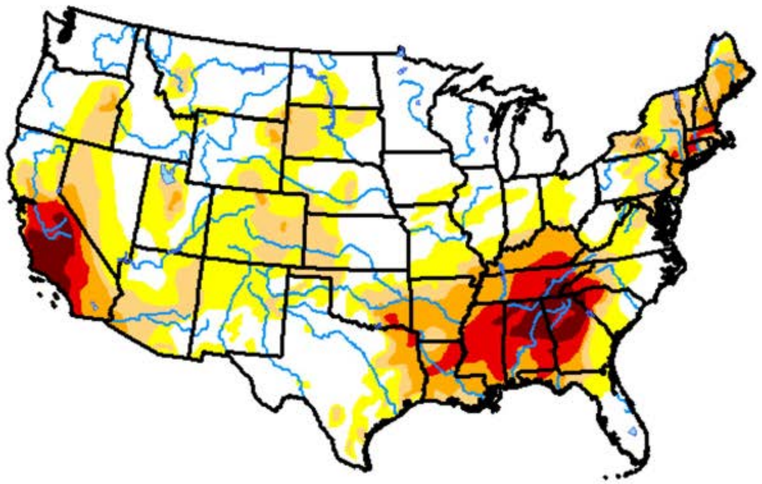
U.S. Drought Monitor

CONUS

November 22, 2016

(Released Wednesday, Nov. 23, 2016)

Valid 7 a.m. EST



Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	45.00	55.00	31.14	17.07	8.26	2.73
Last Week *11-15-2016*	48.01	51.99	30.13	14.44	6.40	2.36
3 Months Ago *08-23-2016*	54.63	45.37	19.42	7.41	2.70	1.11
Start of Calendar Year *12-29-2015*	66.99	33.01	18.74	11.56	6.28	2.70
Start of Water Year *09-27-2016*	53.60	46.40	18.96	8.10	3.20	1.16
One Year Ago *11-24-2015*	61.55	38.45	21.90	14.83	8.42	2.70

Intensity:

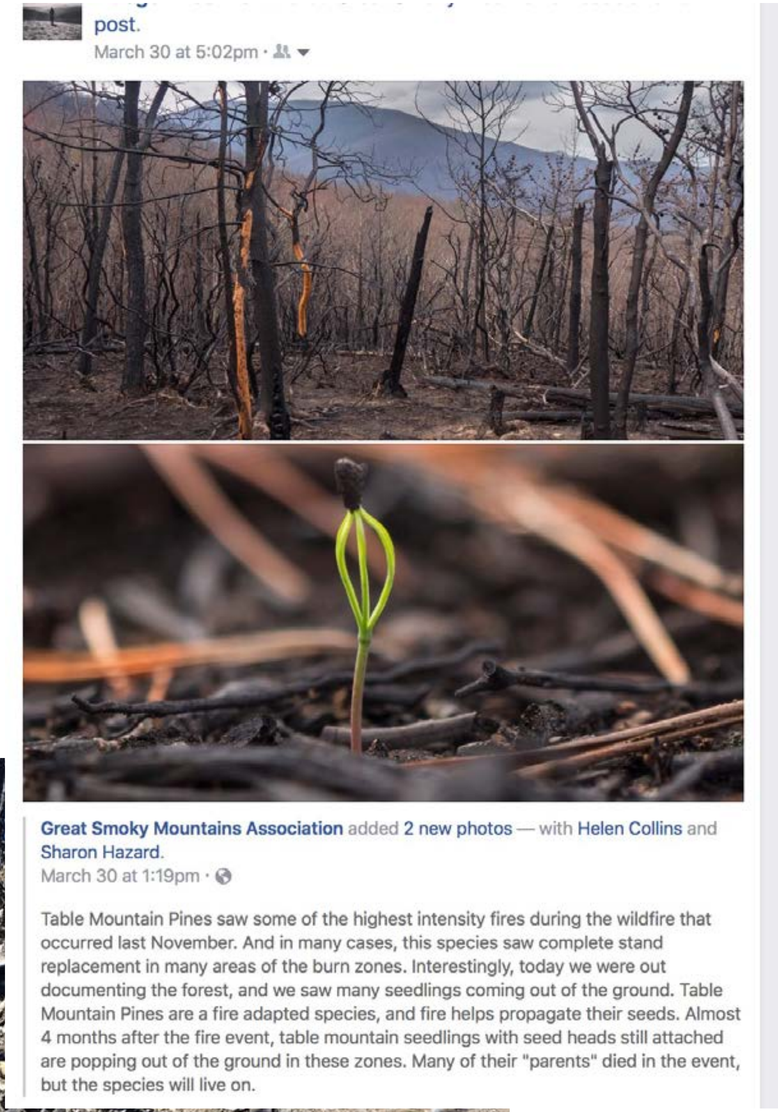
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:

Richard Heim
NCEI/NOAA

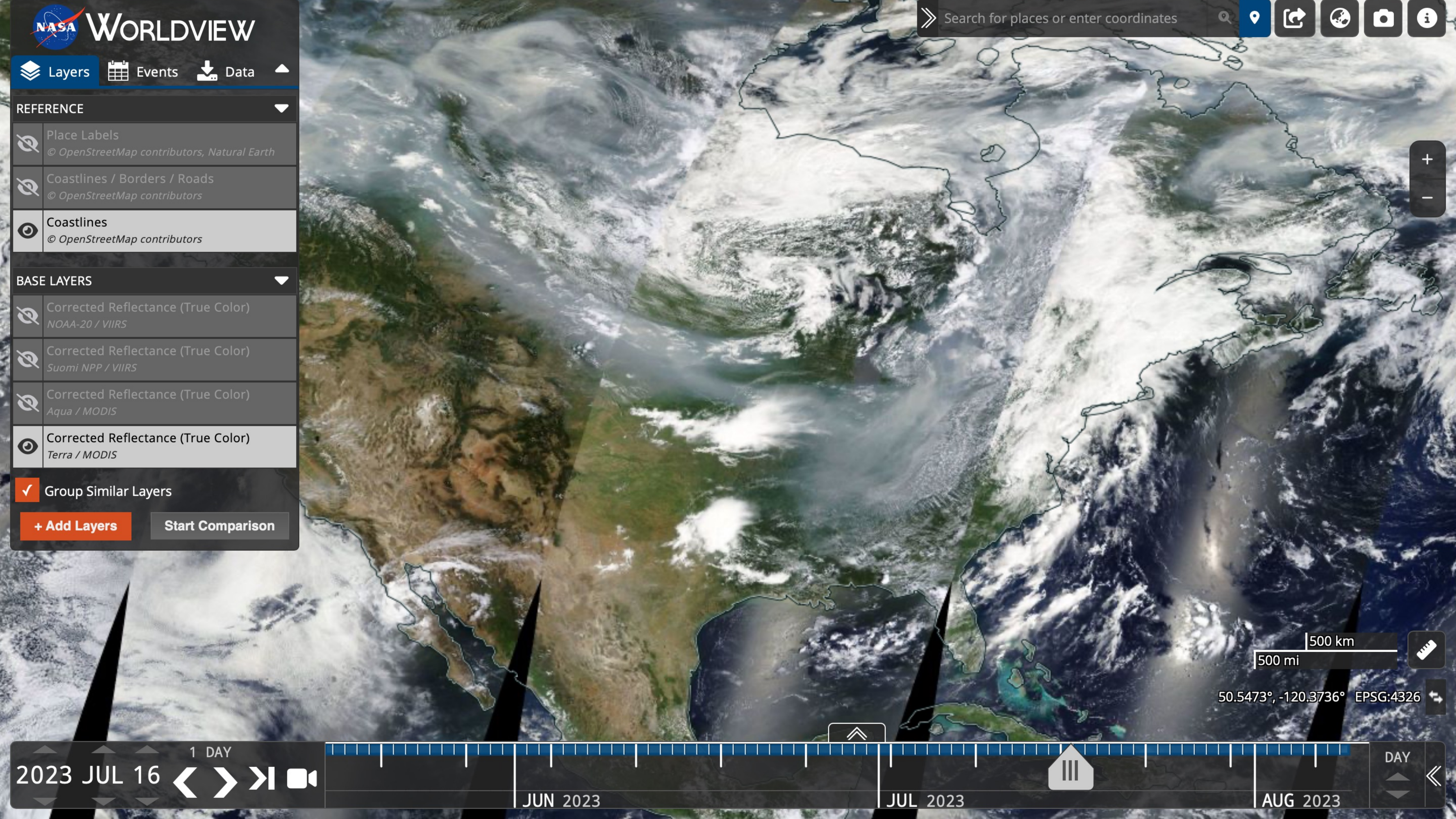
http://droughtmonitor.unl.edu/



post.
March 30 at 5:02pm

Great Smoky Mountains Association added 2 new photos — with Helen Collins and Sharon Hazard.
March 30 at 1:19pm

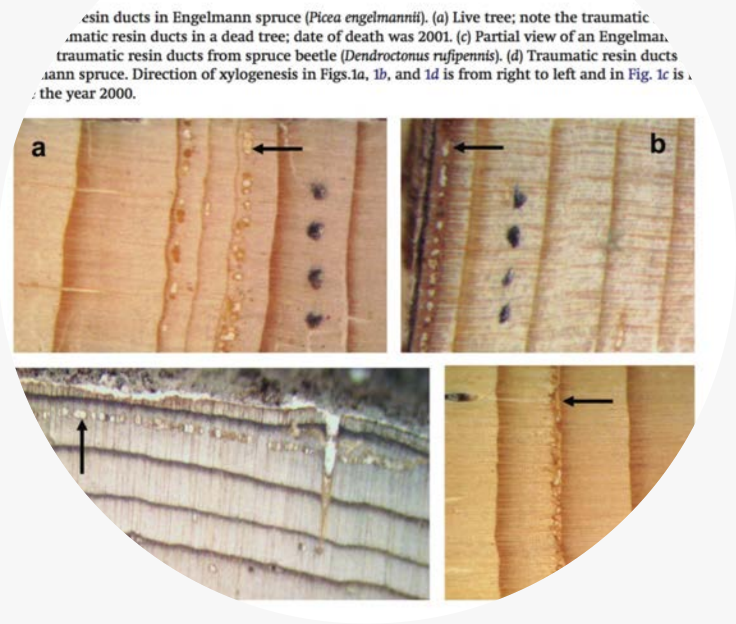
Table Mountain Pines saw some of the highest intensity fires during the wildfire that occurred last November. And in many cases, this species saw complete stand replacement in many areas of the burn zones. Interestingly, today we were out documenting the forest, and we saw many seedlings coming out of the ground. Table Mountain Pines are a fire adapted species, and fire helps propagate their seeds. Almost 4 months after the fire event, table mountain seedlings with seed heads still attached are popping out of the ground in these zones. Many of their "parents" died in the event, but the species will live on.

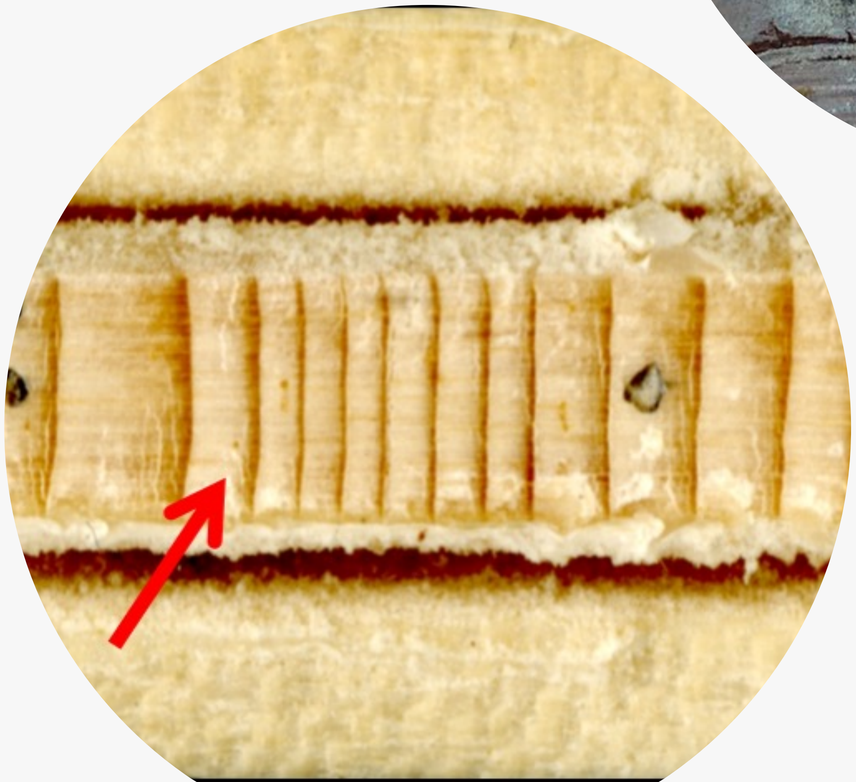

NASA
WORLDVIEW
Layers
Events
Data
REFERENCE
Place Labels
© OpenStreetMap contributors, Natural Earth
Coastlines / Borders / Roads
© OpenStreetMap contributors
Coastlines
© OpenStreetMap contributors
BASE LAYERS
Corrected Reflectance (True Color)
NOAA-20 / VIIRS
Corrected Reflectance (True Color)
Suomi NPP / VIIRS
Corrected Reflectance (True Color)
Aqua / MODIS
Corrected Reflectance (True Color)
Terra / MODIS
Group Similar Layers
+ Add Layers
Start Comparison
Search for places or enter coordinates
500 km
500 mi
50.5473°, -120.3736° EPSG:4326
1 DAY
2023 JUL 16
JUN 2023
JUL 2023
AUG 2023
DAY

Tree Rings also tell us about disturbance and environmental history

Multiple lines of evidence:

- Scars and Growth Anomalies
- Growth Changes
- Growth Suppression and Release
- Reaction Wood
- Traumatic Resin Ducts
- Mortality
- Recruitment/Secondary Succession





Scars

Fire Scars in the FL Keys

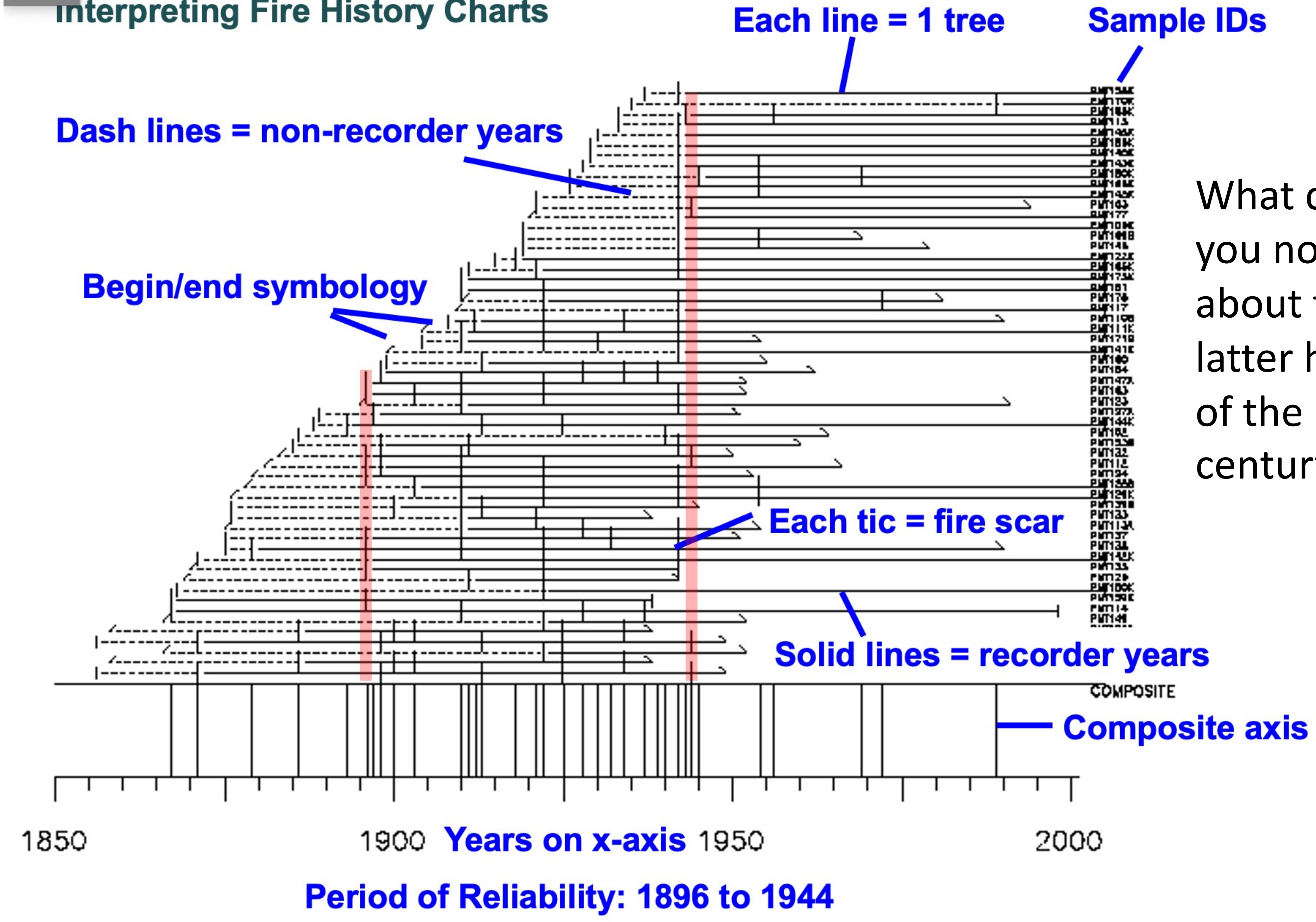
[redacted]

Fire scar from Engelmann spruce, Greater Yellowstone

Scars can mark the annual or even sub-annual dates for injuries, which can connect with environmental events like fires, rock falls, windthrow, tornadoes, and more.

Section

Interpreting Fire History Charts

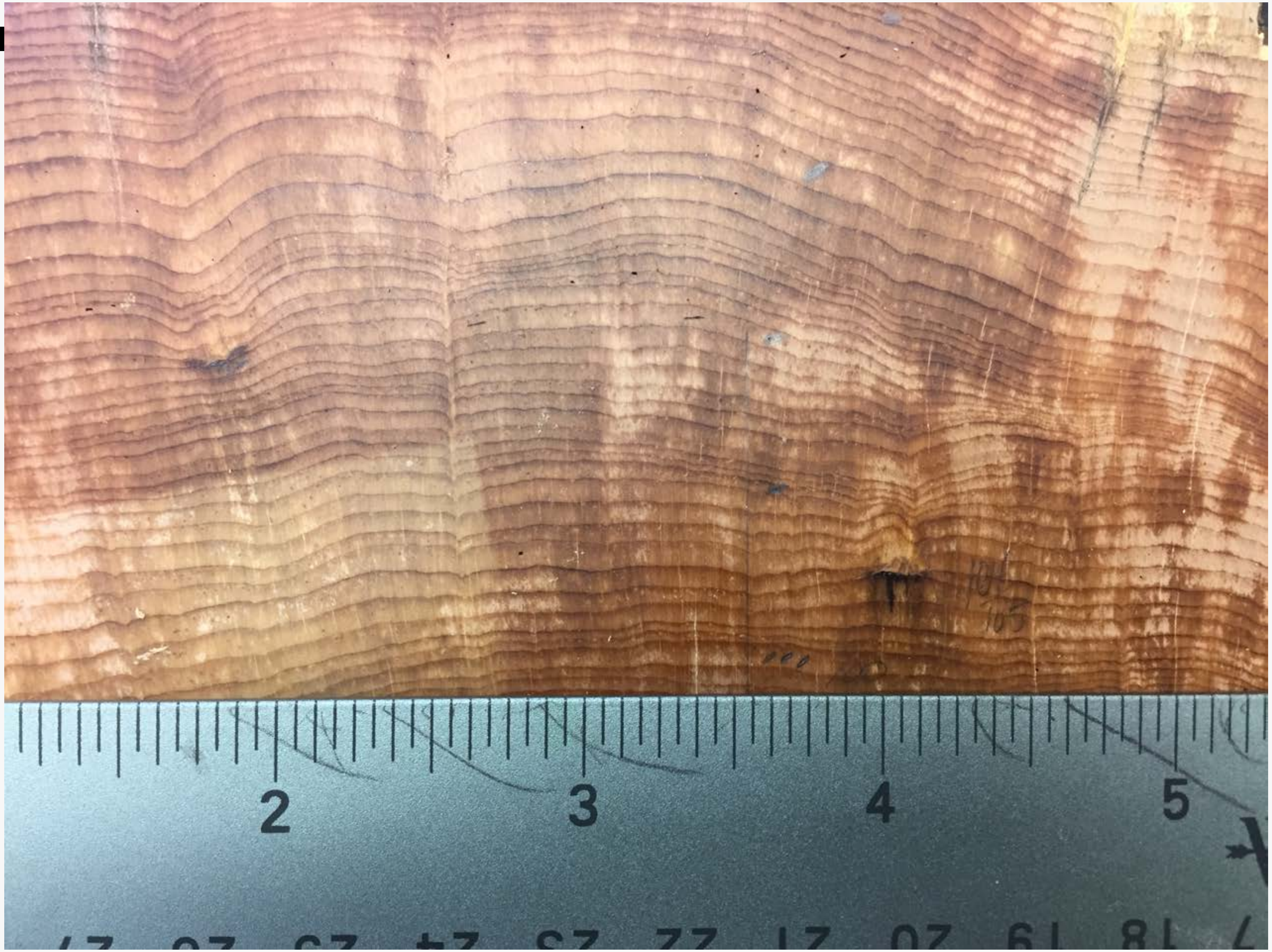


What do you notice about the latter half of the century?

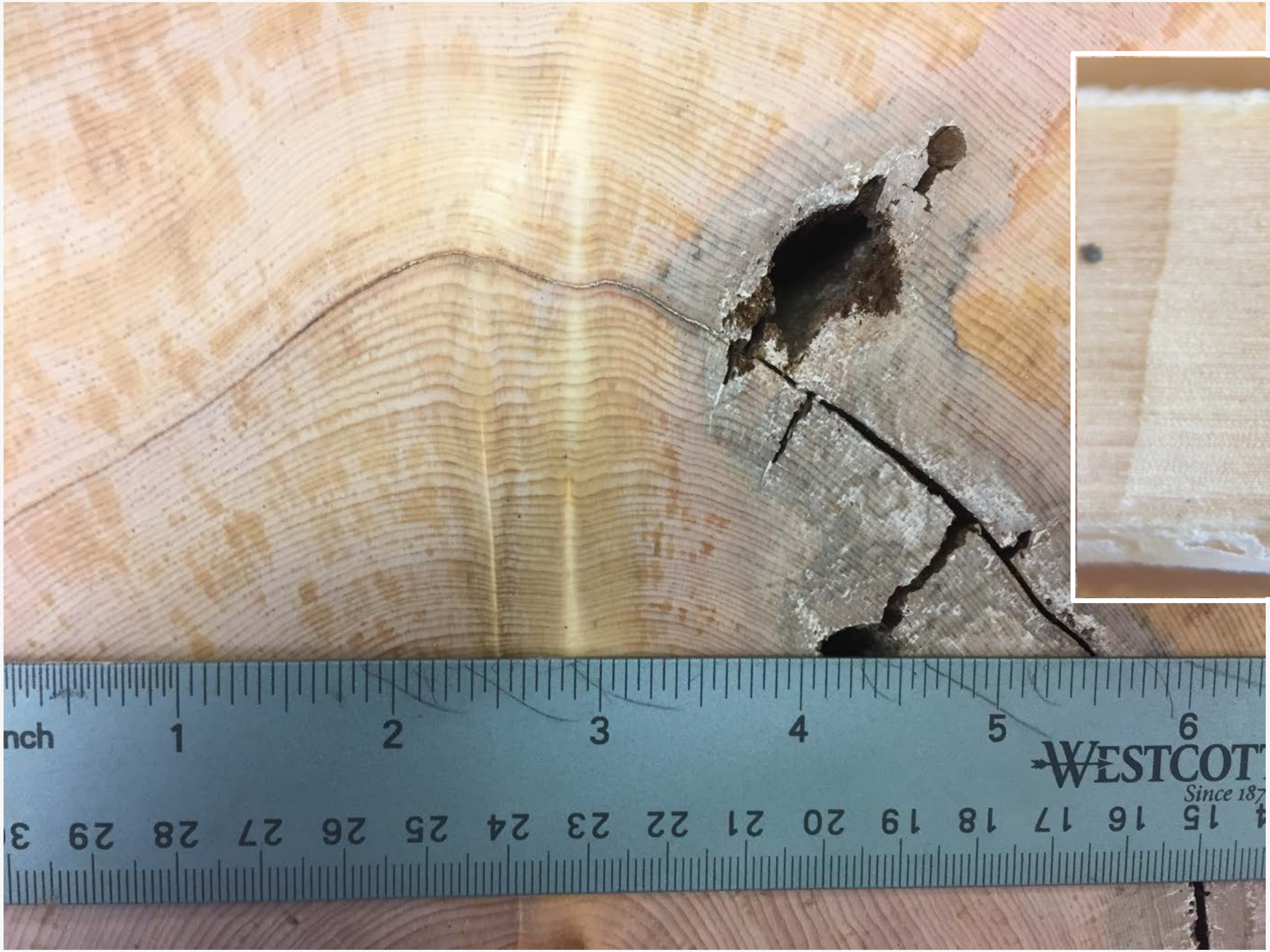
Avalanche scars, Greater Yellowstone

Growth Anomalies

Growth anomalies, like "pitch tubes" observed here can mark injuries and infestations.

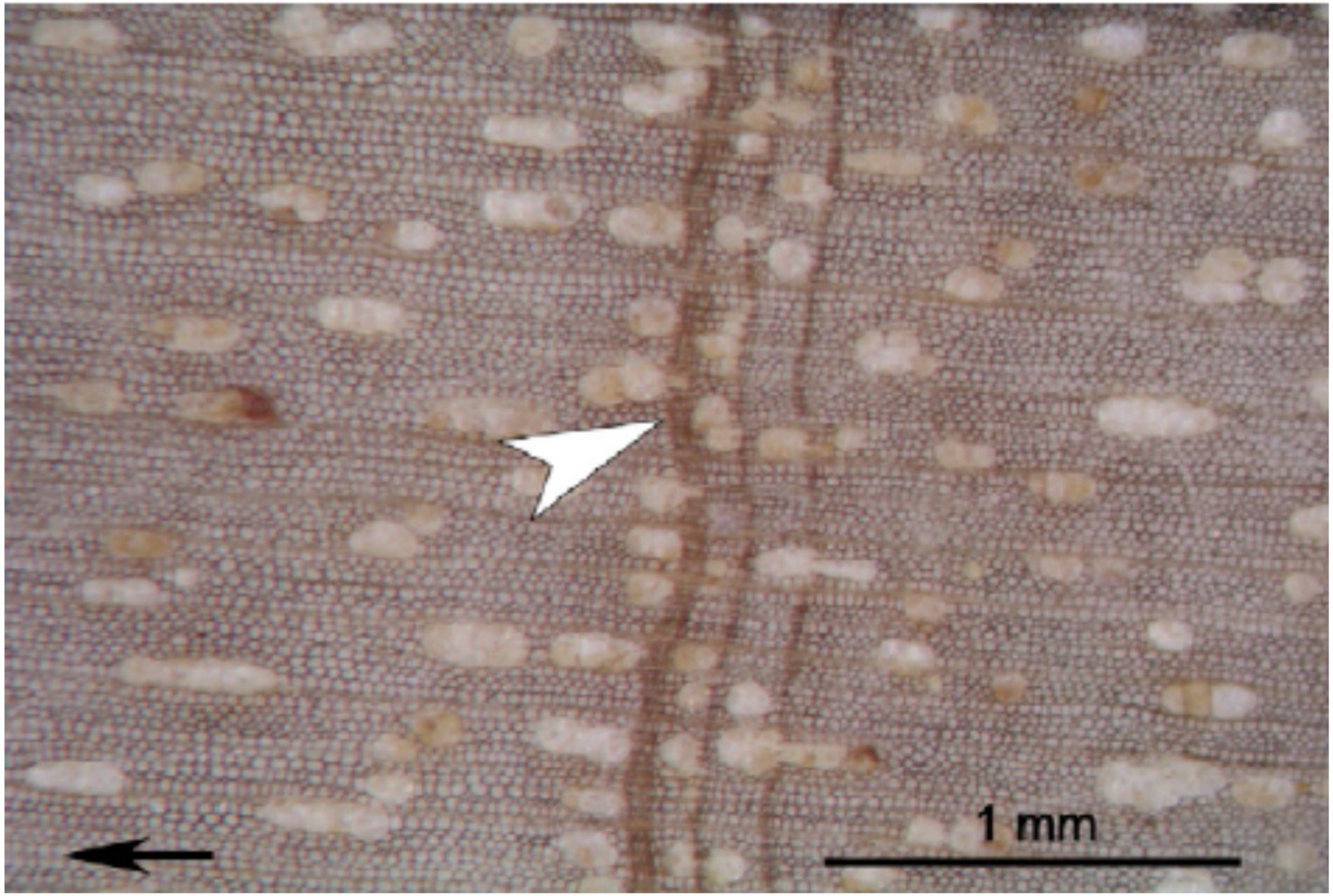


Evidence of pitch tubes in Whitebark Pine, Greater Yellowstone



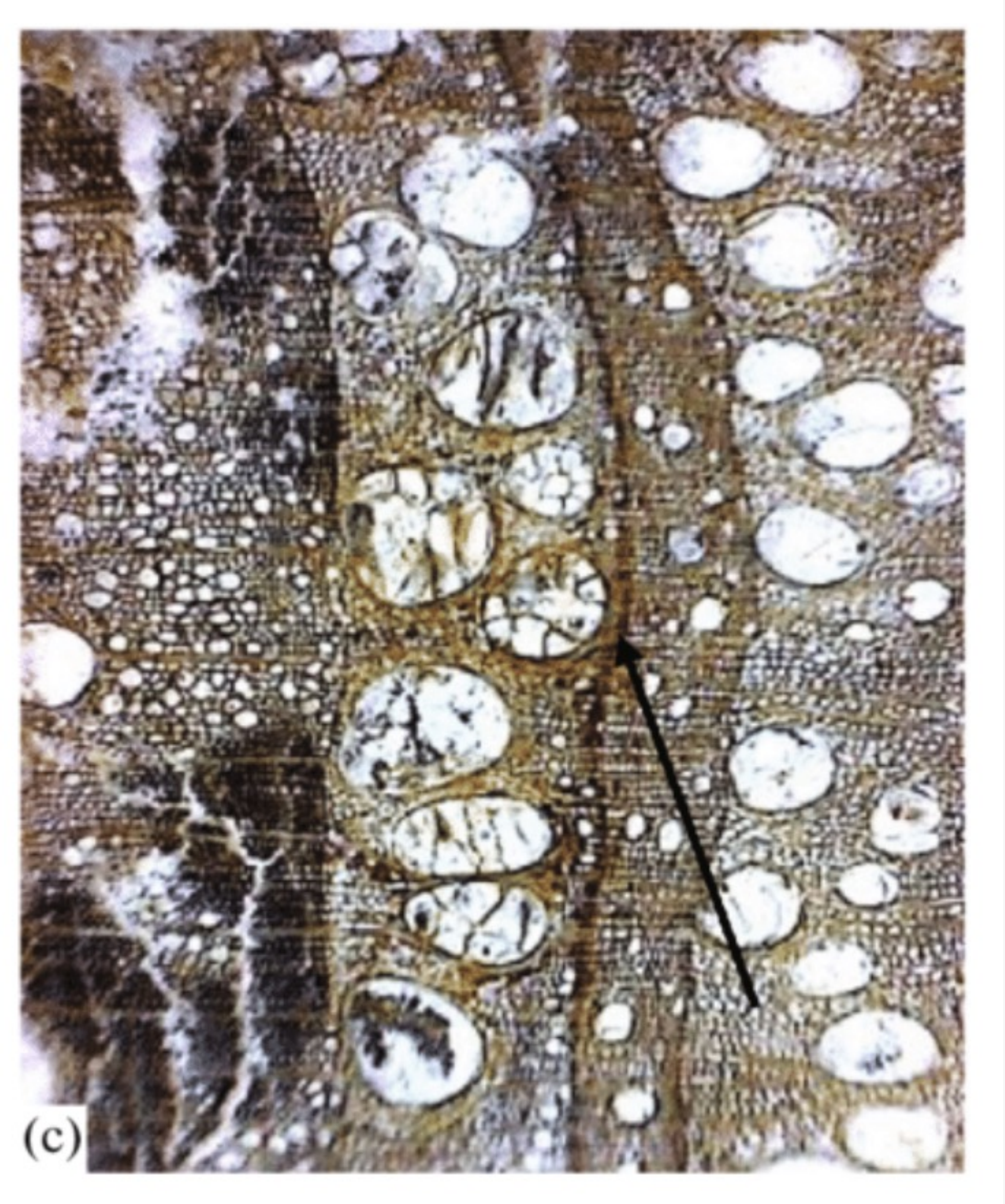
Frost ring in Whitebark Pine, Greater Yellowstone

Frost rings mark sudden and significant cooling during the growing season.



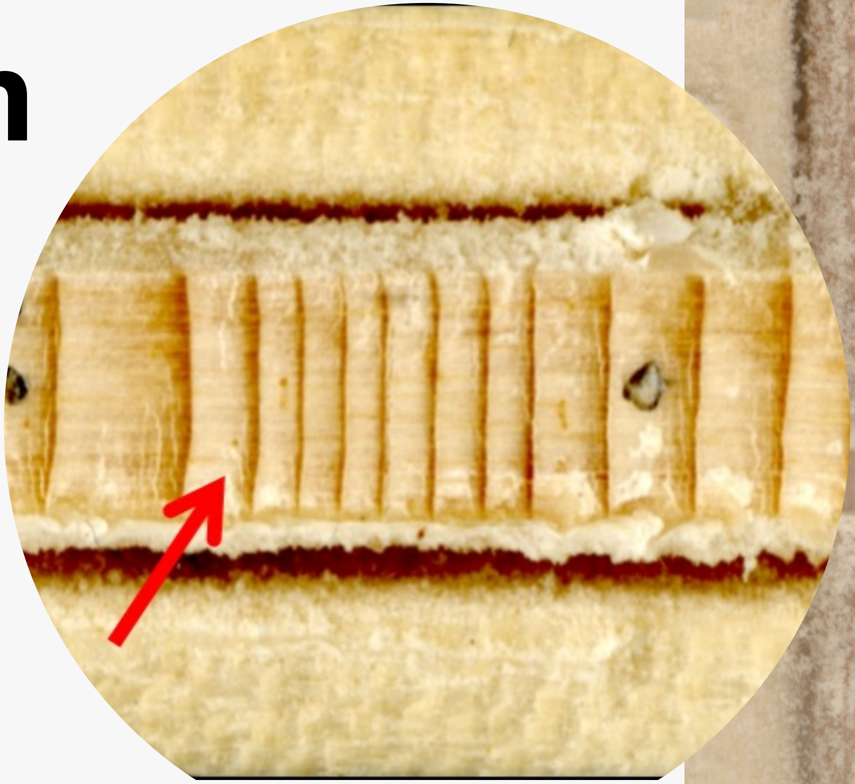
Frost ring in 1906 (white arrowhead) – this type of ring is caused by very cold weather (severe night frost) at the beginning of the growing season, e.g. middle of June. Severe night frost during the growing season can damage the cambium, causing frost ring features as seen in the figure. It is important to be able to identify wood anatomical features like this when you are working with tree rings of birch. The black arrow shows the direction of growth.

Levanič, T., & Eggertsson, O. (2008). Climatic effects on birch (Betula pubescens Ehrh.) growth in Fnjoskadalur valley, northern Iceland. *Dendrochronologia*, *25*(3), 135-143.



Kucherov, S. E. (2021). Identification of Calendar Years with Late Spring Frosts on the Basis of Anatomical Structure of Annual Rings of the Common Oak on the Zilair Plateau (Southern Urals). *Russian Journal of Ecology*, *52*(5), 383-390.

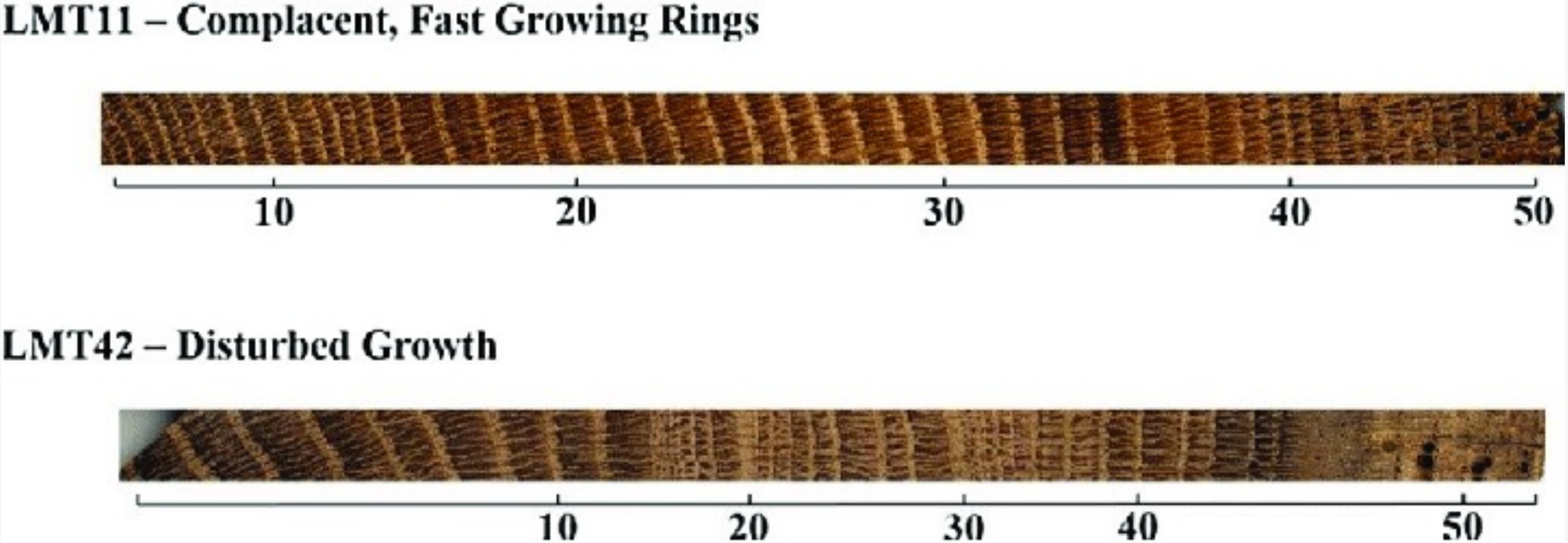
Changes in Growth

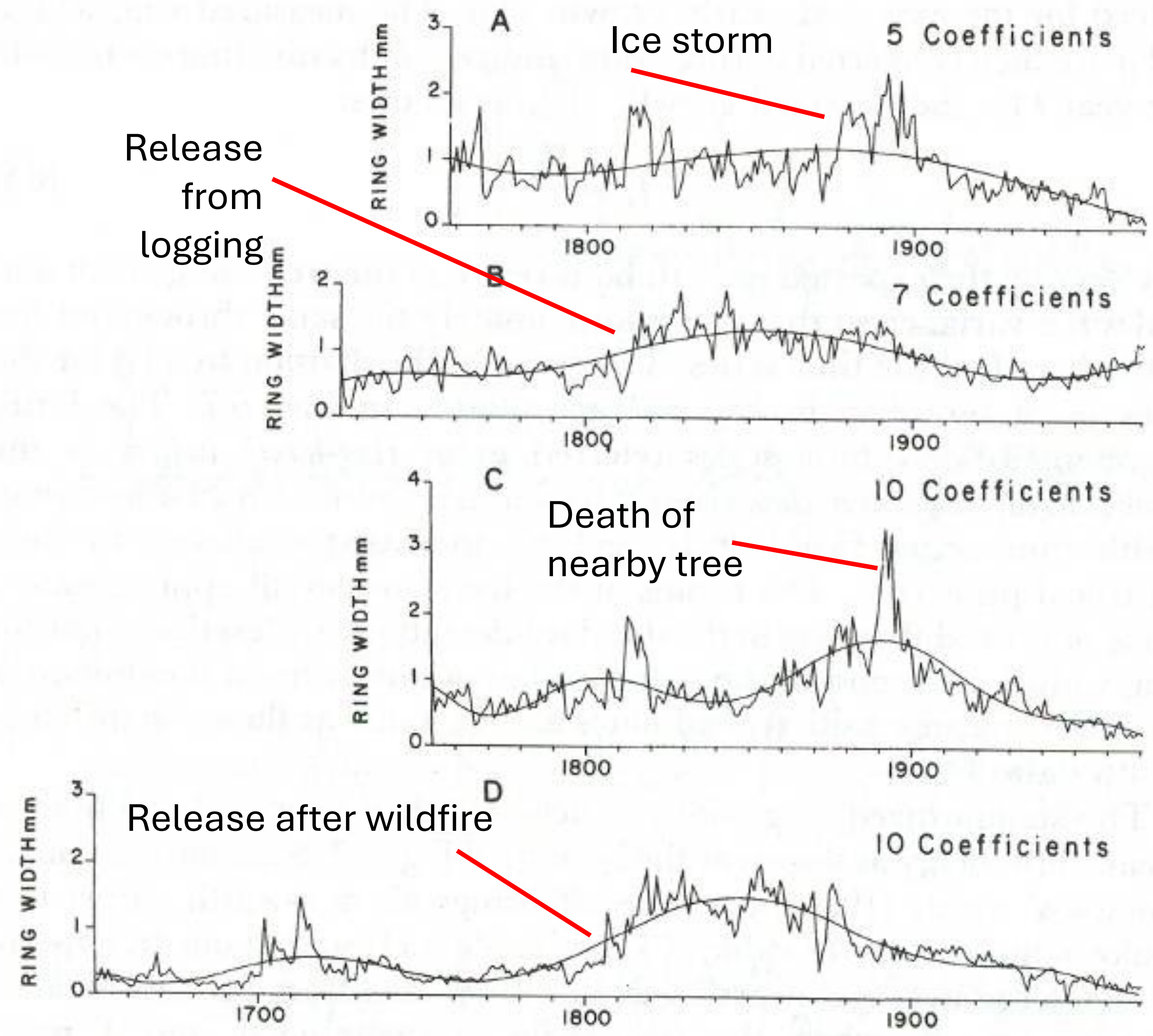


Growth Release – Relatively sudden and sustained increase in growth

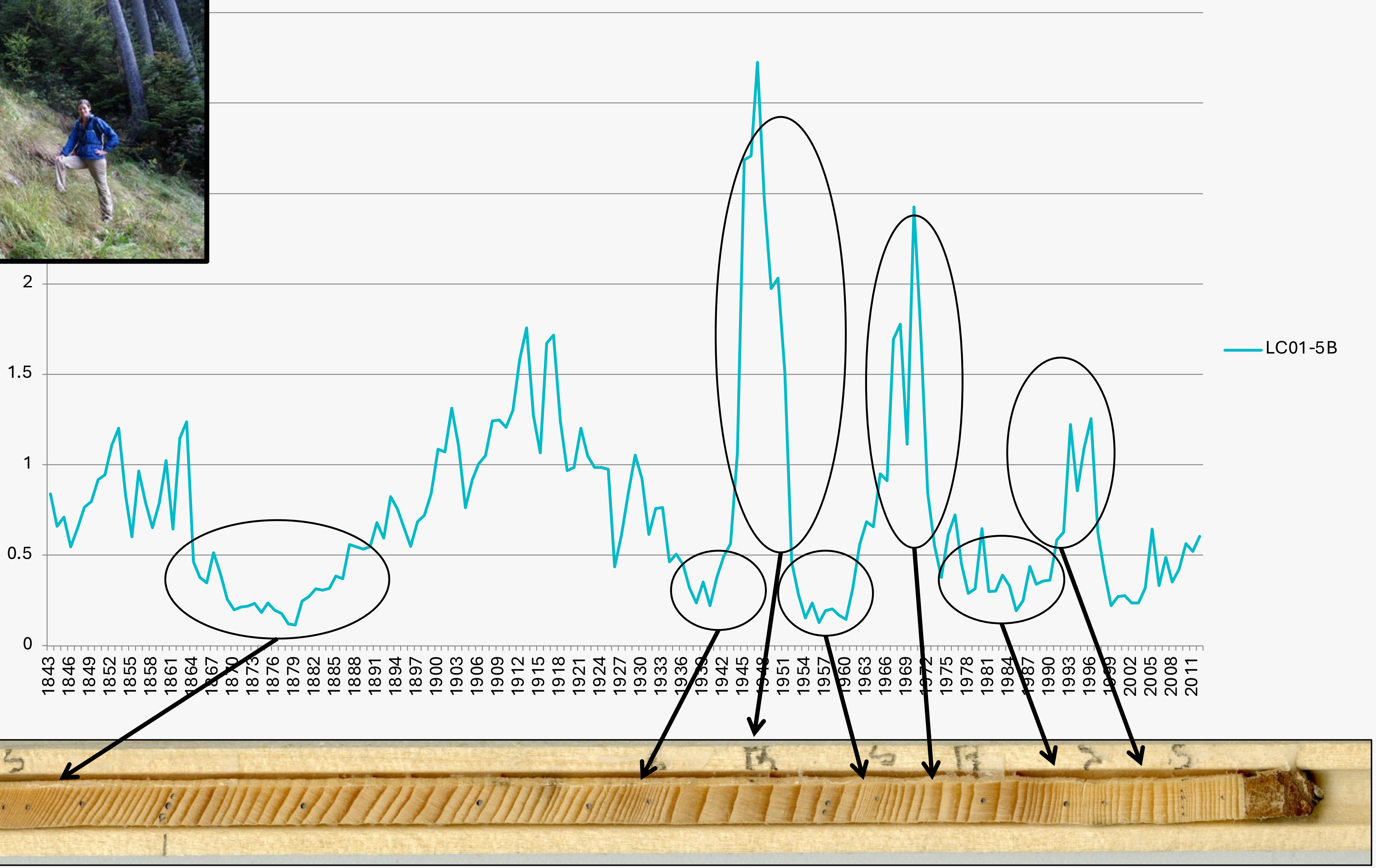
Growth Suppression – Relatively sudden and sustained decrease in growth

[redacted]


LMT11 – Complacent, Fast Growing Rings
10
20
30
40
50
LMT42 – Disturbed Growth
10
20
30
40
50


Ice storm
Release from logging
Death of nearby tree
Release after wildfire
A
5 Coefficients
B
7 Coefficients
C
10 Coefficients
D
10 Coefficients
RING WIDTH mm
0
1
2
3
4
1700
1800
1900

LC01-5B



2
1.5
1
0.5
0
1843
1846
1849
1852
1855
1858
1861
1864
1873
1876
1879
1882
1885
1888
1891
1894
1897
1900
1903
1906
1909
1912
1915
1918
1921
1924
1927
1930
1933
1936
1942
1945
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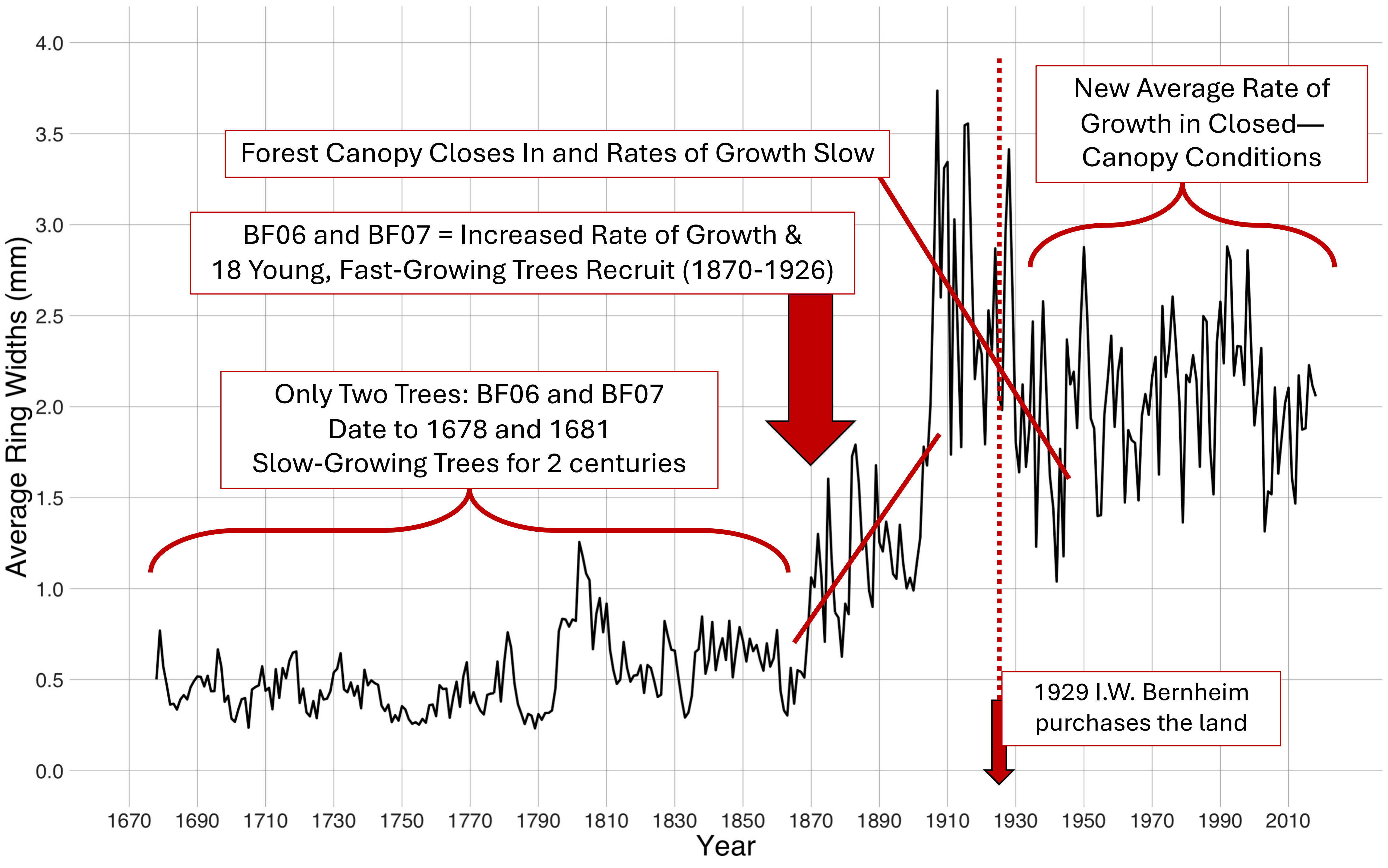
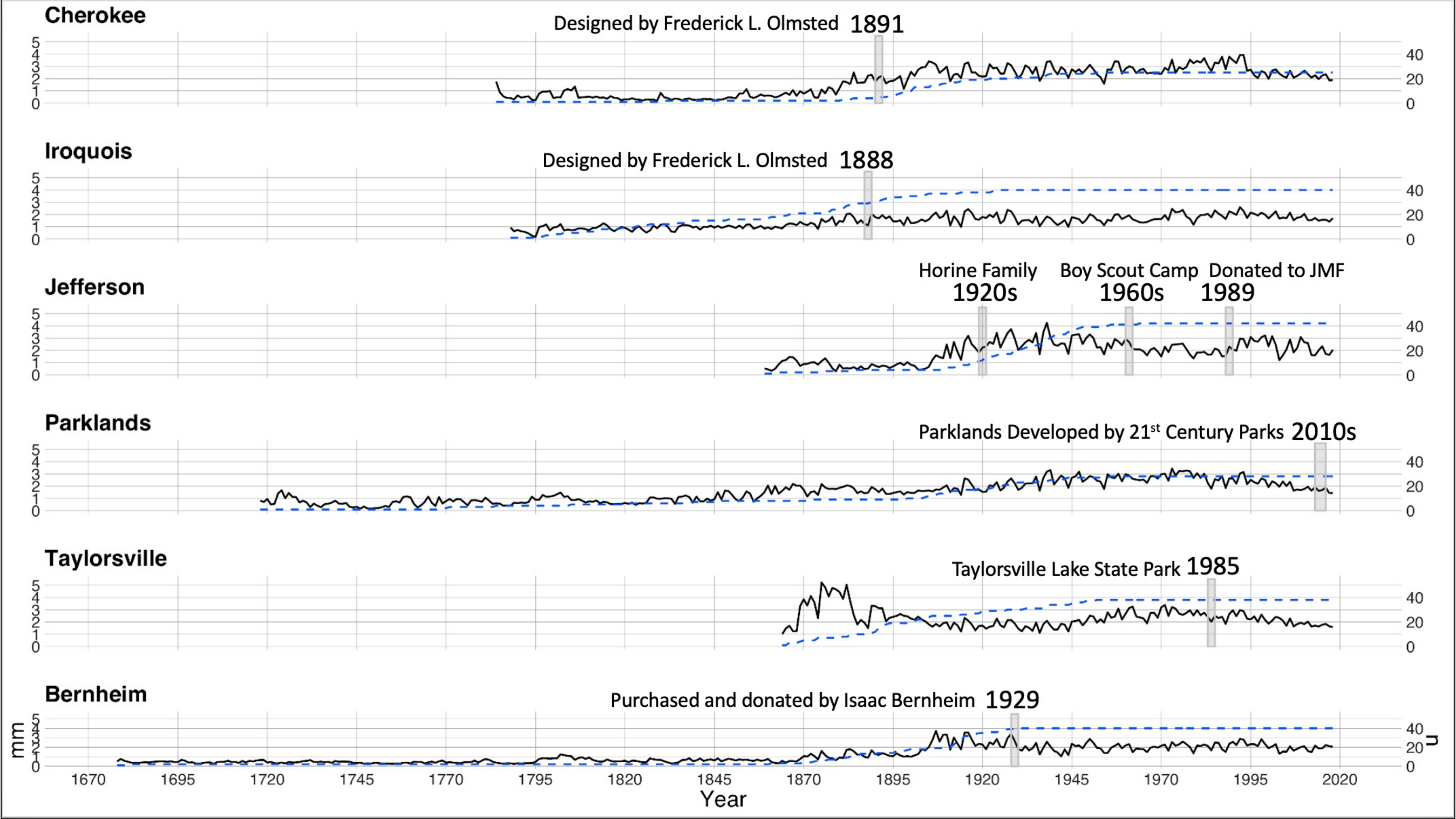
2005
2008
2011
LC01-5B

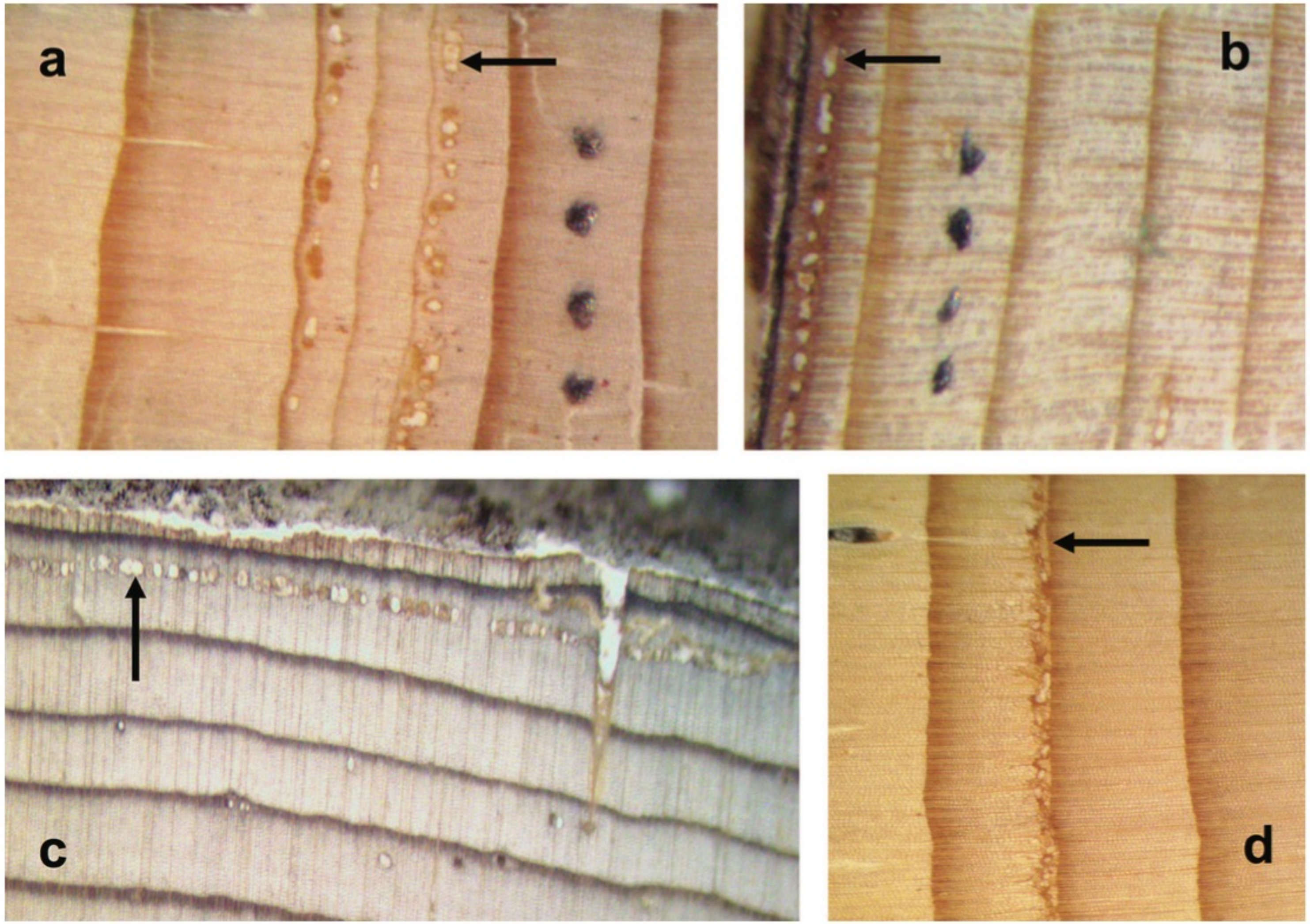

Forest Canopy Closes In and Rates of Growth Slow
BF06 and BF07 = Increased Rate of Growth &
18 Young, Fast-Growing Trees Recruit (1870-1926)
Only Two Trees: BF06 and BF07
Date to 1678 and 1681
Slow-Growing Trees for 2 centuries
New Average Rate of
Growth in Closed—
Canopy Conditions
1929 I.W. Bernheim
purchases the land
Average Ring Widths (mm)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1670
1690
1710
1730
1750
1770
1790
1810
1830
1850
1870
1890
1910
1930
1950
1970
1990
2010
Year



Cherokee
Designed by Frederick L. Olmsted 1891
Iroquois
Designed by Frederick L. Olmsted 1888
Jefferson
Horine Family 1920s
Boy Scout Camp 1960s
Donated to JMF 1989
Parklands
Parklands Developed by 21st Century Parks 2010s
Taylorsville
Taylorsville Lake State Park 1985
Bernheim
Purchased and donated by Isaac Bernheim 1929
mm
n
Year
1670 1695 1720 1745 1770 1795 1820 1845 1870 1895 1920 1945 1970 1995 2020

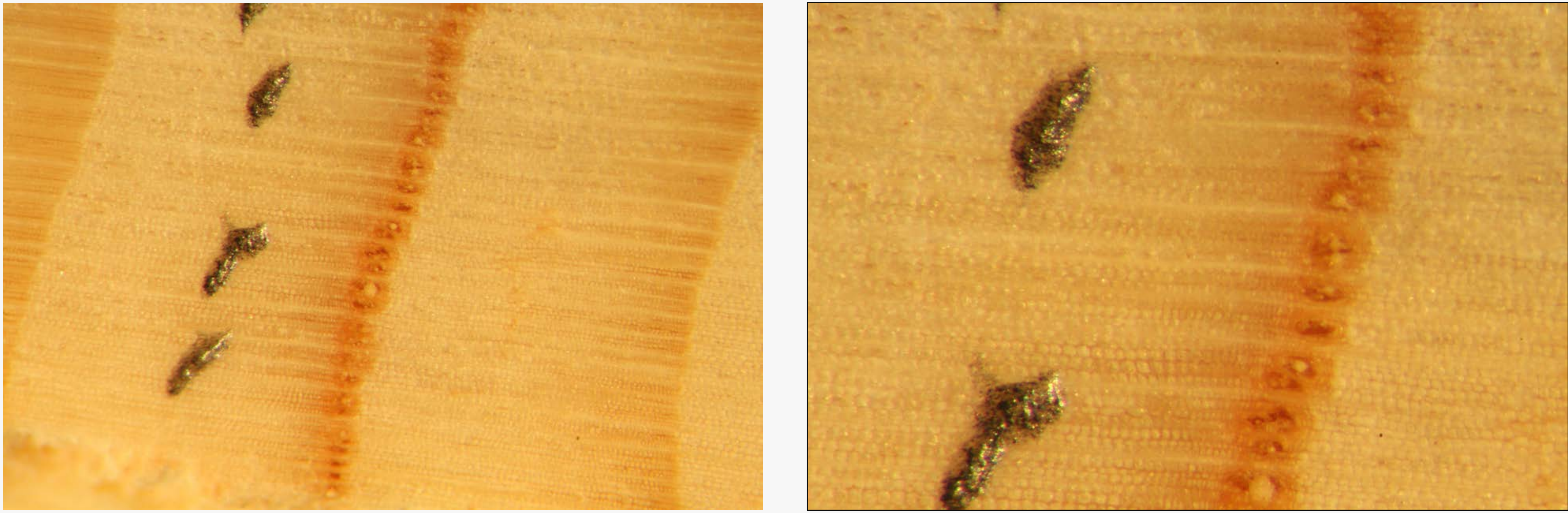
Traumatic Resin Ducts

Traumatic Resin Ducts (TRDs) in conifers mark the transport of resin to heal injuries.



DeRose, R. J., Bekker, M. F., & Long, J. N. (2017). Traumatic resin ducts as indicators of bark beetle outbreaks. *Canadian Journal of Forest Research*, *47*(9), 1168-1174.

[redacted]



TRDs in Mountain Hemlock, Mount Rainier NP

Reaction Wood

Reaction Wood can be used to date when a tree was tilted.

Compression Wood – in conifers, on the underside of branches and trunks, “pushes” the tree back upright

Tension Wood – in hardwoods, on the upper side of branches and trunks, “pulls” the tree back upright

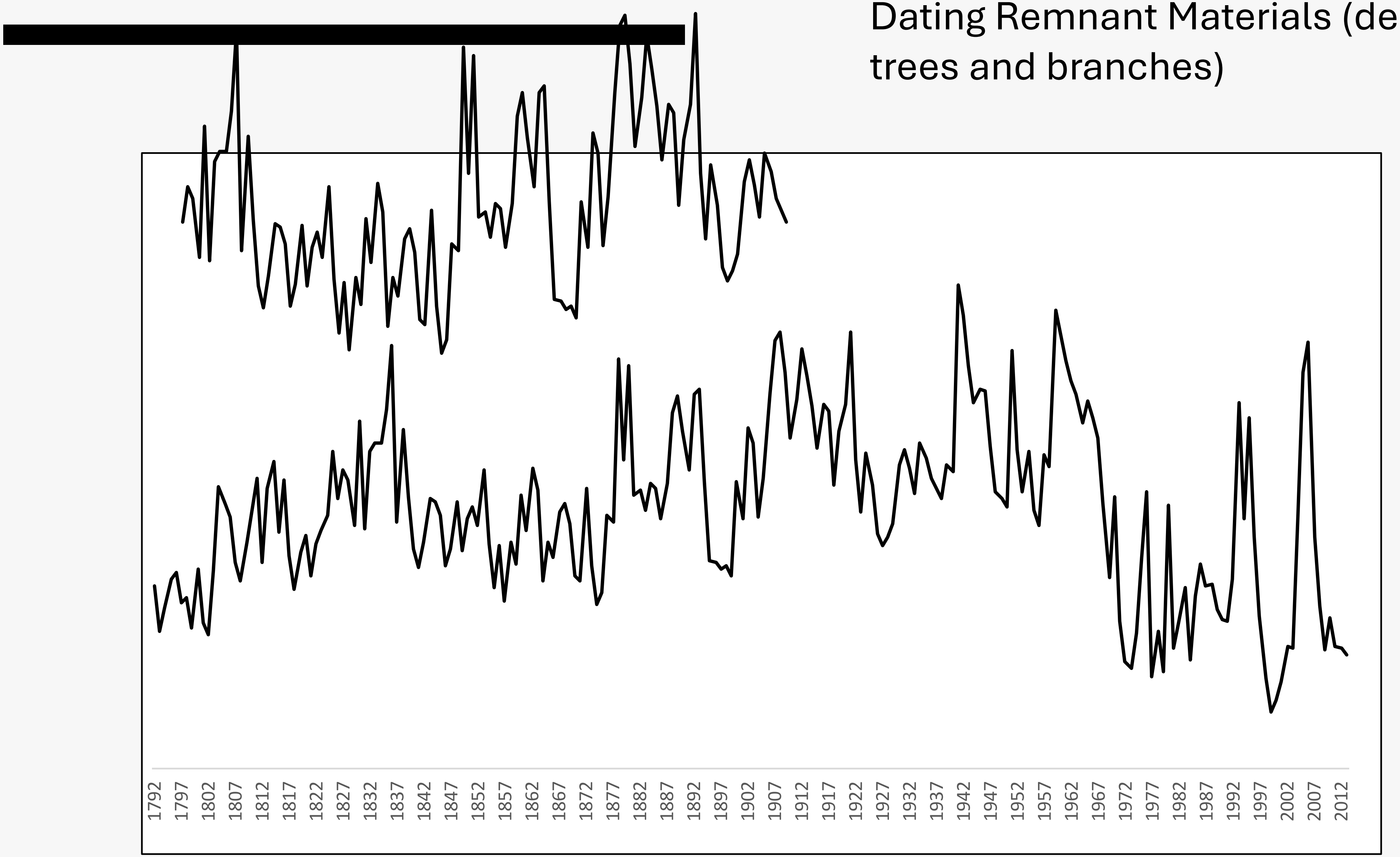
Kozlowski, T. T., & Pallardy, S. G. (1997). *Growth control in woody plants*. Elsevier.

Mortality, Canopy Loss, and Dead Branches

The principle of crossdating describes growth pattern matching between trees experiencing the same climate and environmental conditions.

A distinct pattern is necessary to date remnant/dead materials.

Dating Remnant Materials (dead trees and branches)



Thank you!

Any Questions?

Contact Information

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