Standardization

- One person's signal is another's noise
- Linear aggregate model
- Standardization
- Replication
- A reminder about dating

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One person's signal is another's noise.

- Signal – is the effect you are interested in;
- Noise – is all other variation.
- So – for a climatologist, the part of tree-ring variability that is caused by climate fluctuations is signal;
- For an ecologist – this is noise, because it may hide the effects of an ecological change.
- A tree-ring record may contain several signals – how to separate them?

A linear aggregate model

- The tree-ring series is a linear aggregate of several series – their mean, for example.
- Let's consider what controls this series:

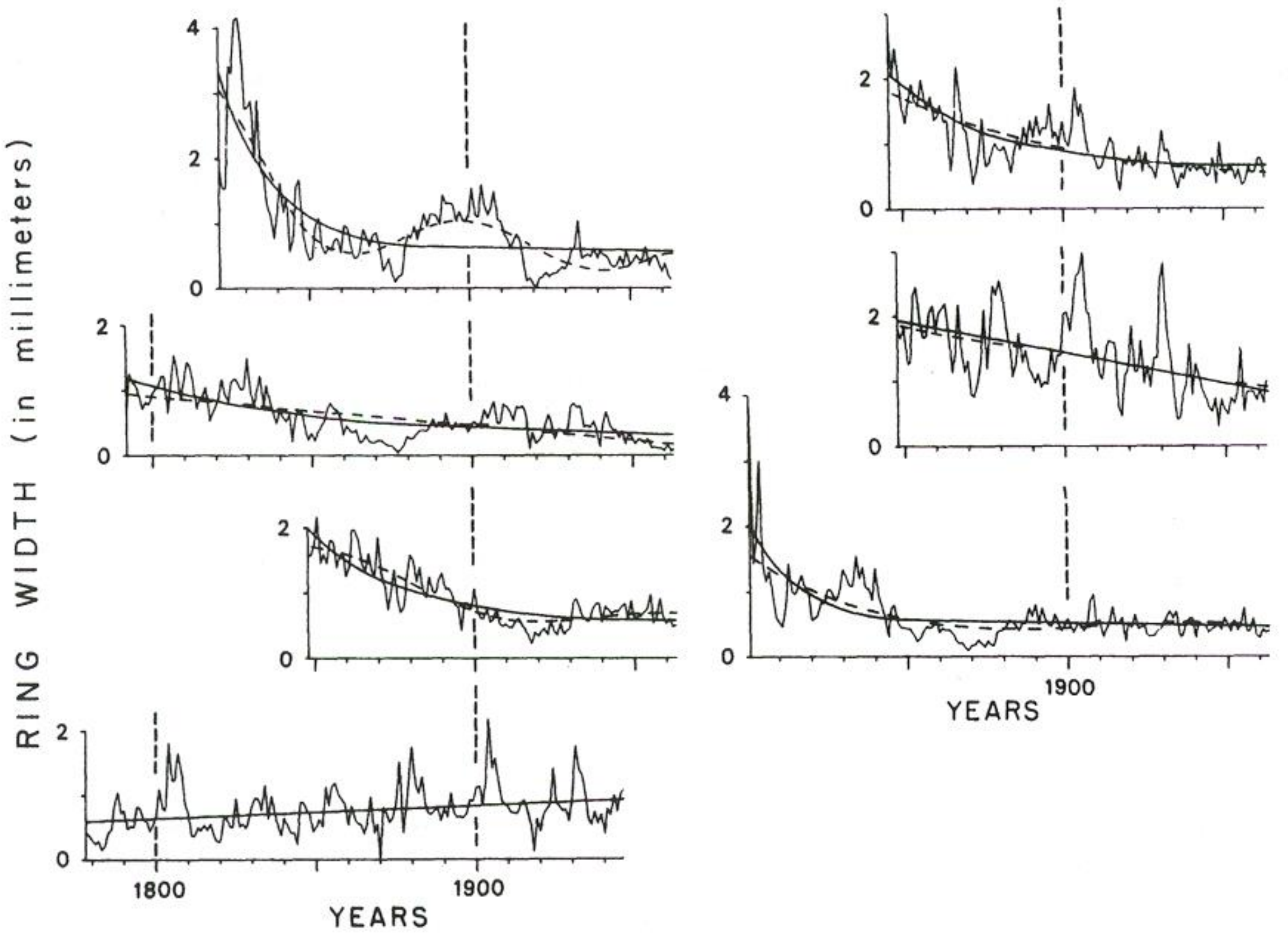
$$R_t = A_t + C_t + \delta D1_t + \delta D2_t + E_t \quad ,$$

where:

R_t	=	the observed ring-width series;
A_t	=	the age-size-related trend in ring width;
C_t	=	the climatically related environmental signal;
$D1_t$	=	the disturbance pulse caused by a local endogenous disturbance;
$D2_t$	=	the disturbance pulse caused by a standwide exogenous disturbance; and
E_t	=	the largely unexplained year-to-year variability not related to the other signals.

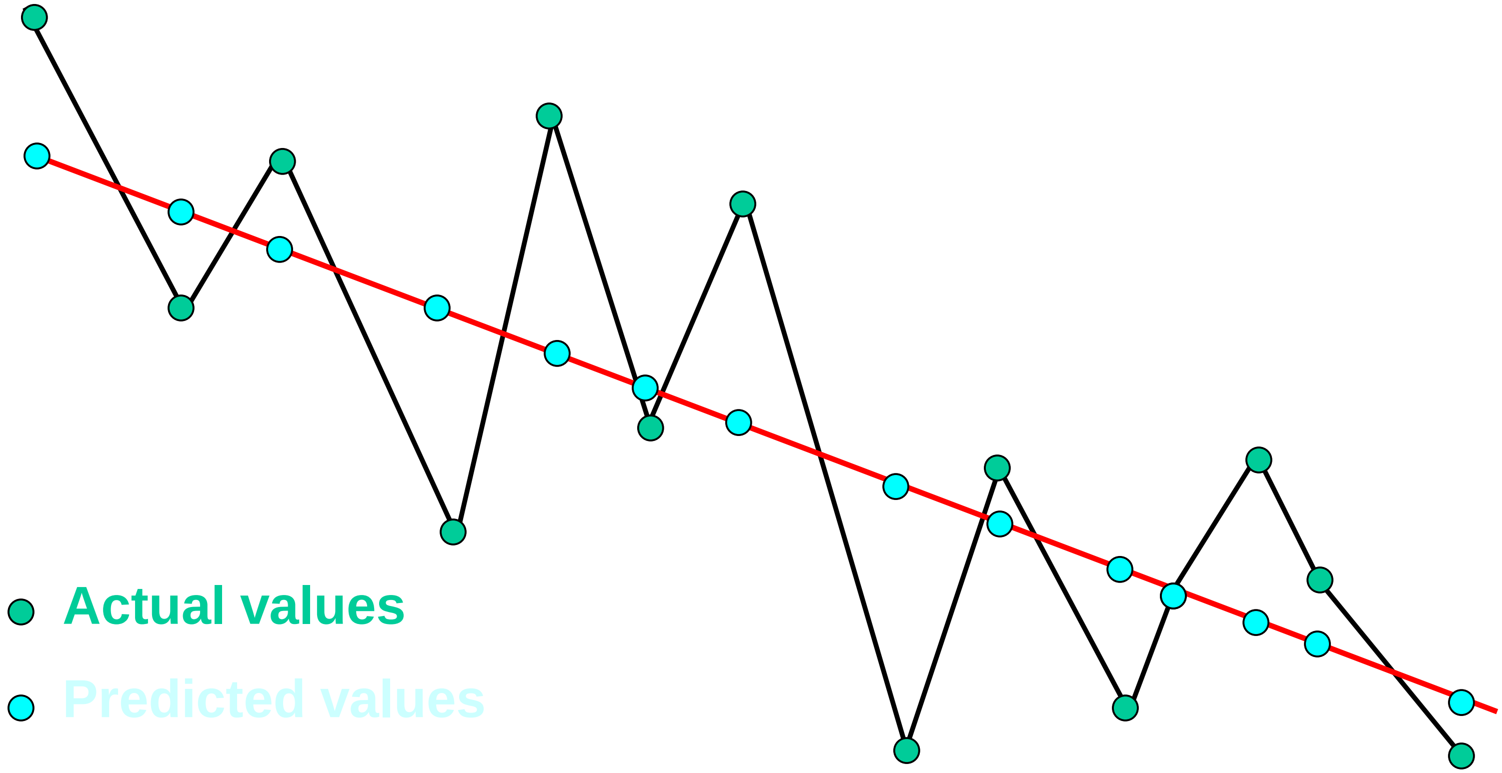
A_t, C_t and E_t are 'on' all the time. $D1_t$ and $D2_t$ may be on ($\delta = 1$) or off ($\delta = 0$).

- **Standardization**

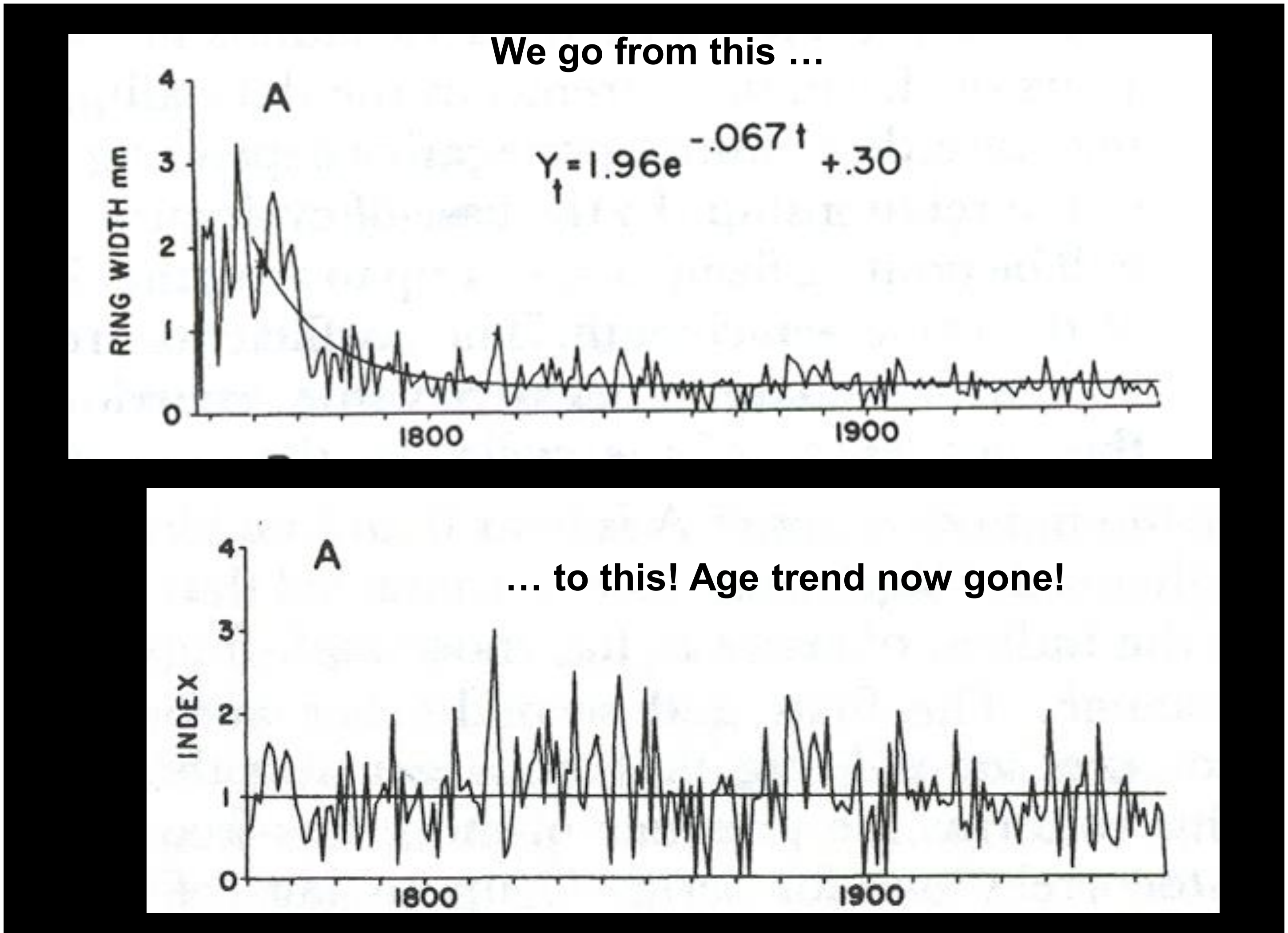


Notice different trends in growth rates among these different trees.

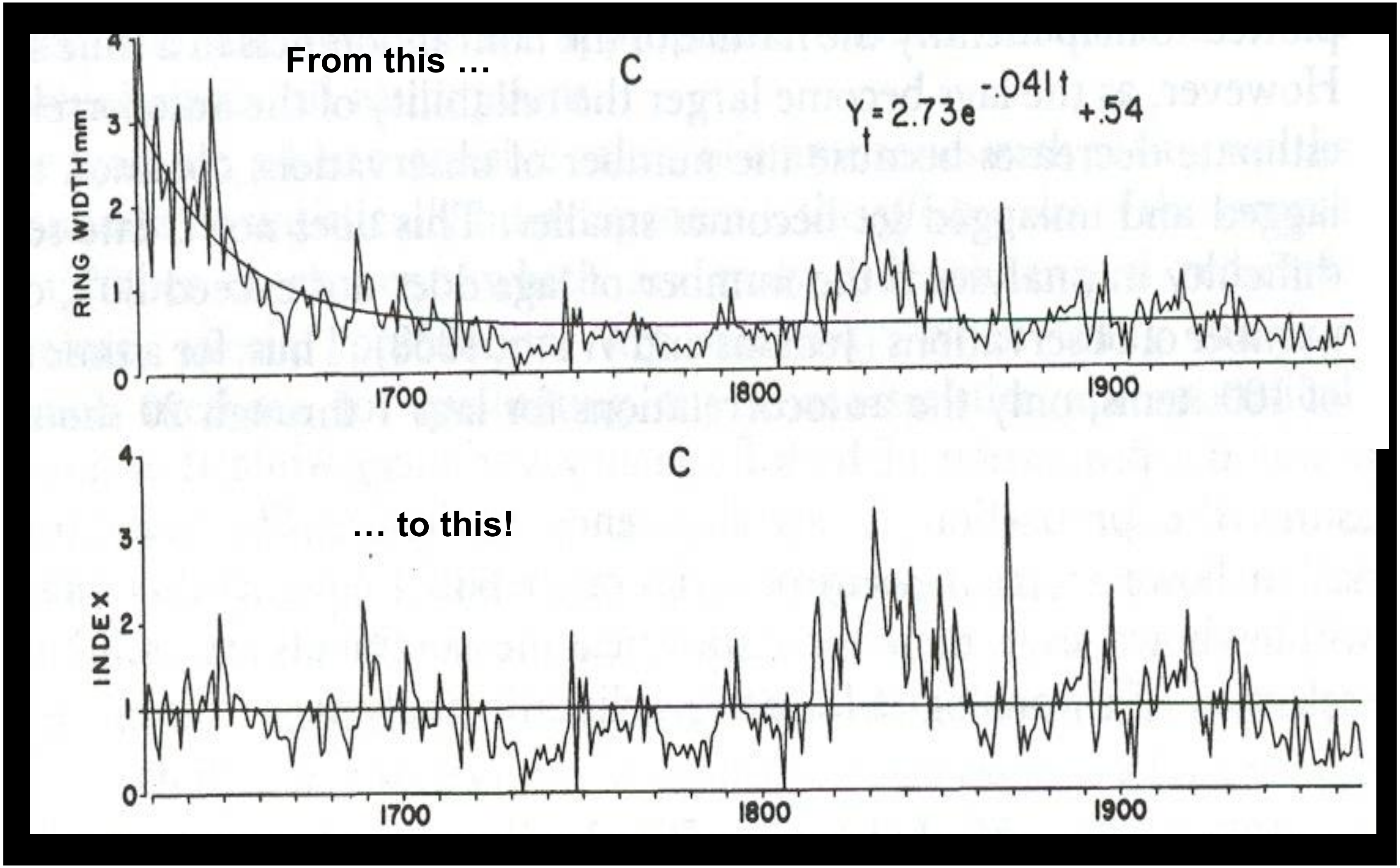
- **Standardization**

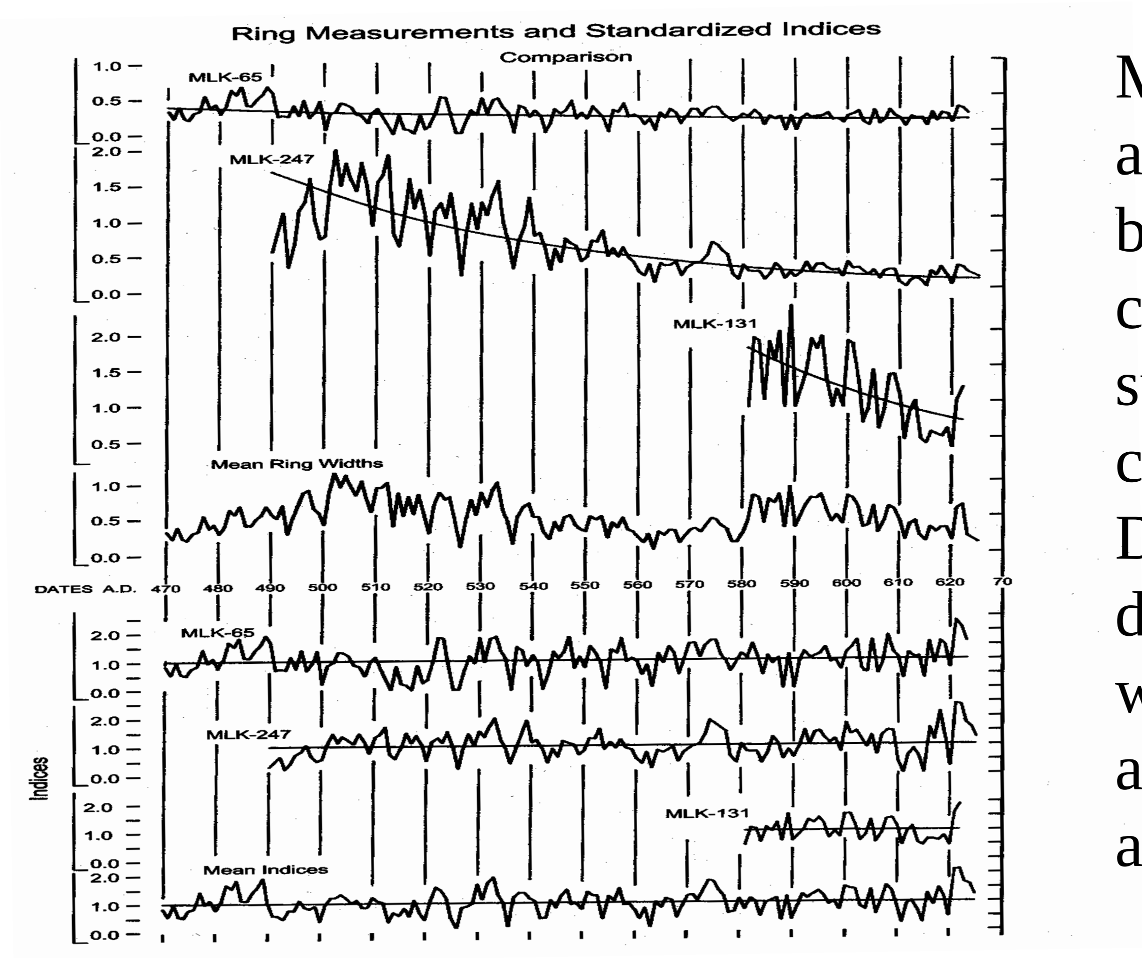


- **Standardization**



- **Standardization**

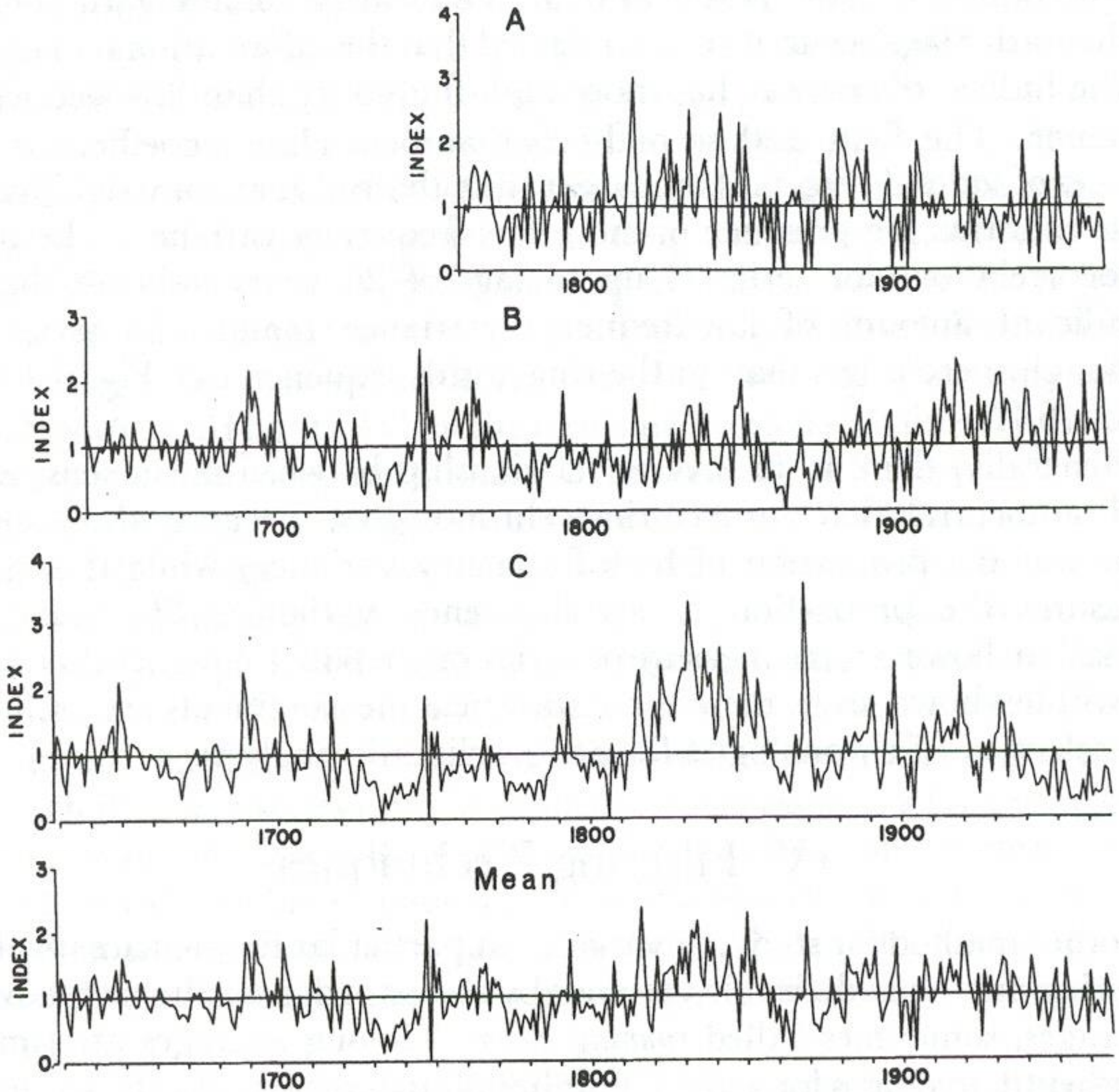




Make indices by dividing actual measurements by some growth curve (as here) or subtracting the growth curve from them. Division gives dimensionless indices with a mean of one, and deals with different absolute growth rates.

Fritts, 1976

- **Standardization**



Index Series 1

+

Index Series 2

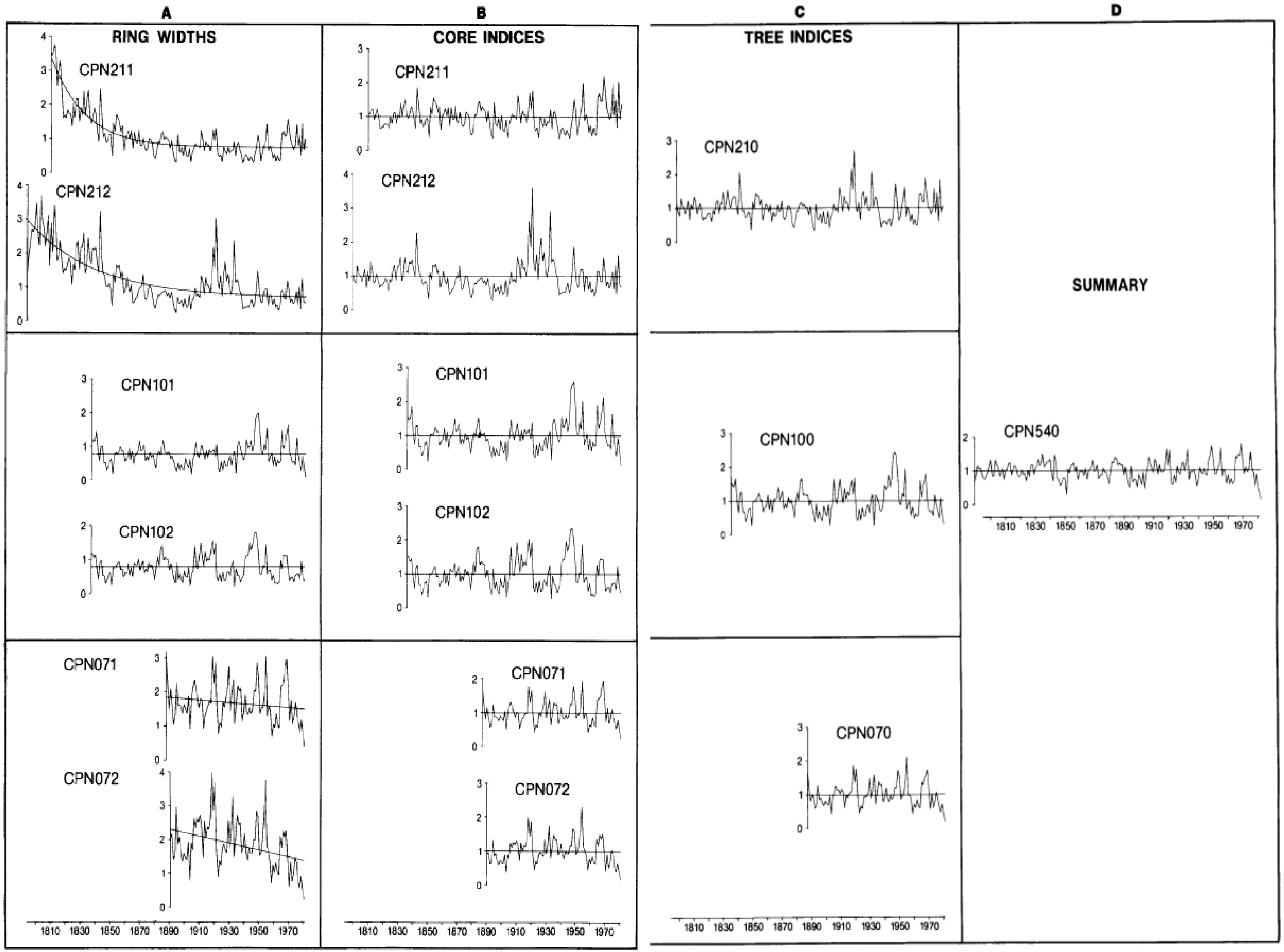
+

Index Series 3

Calculate Mean

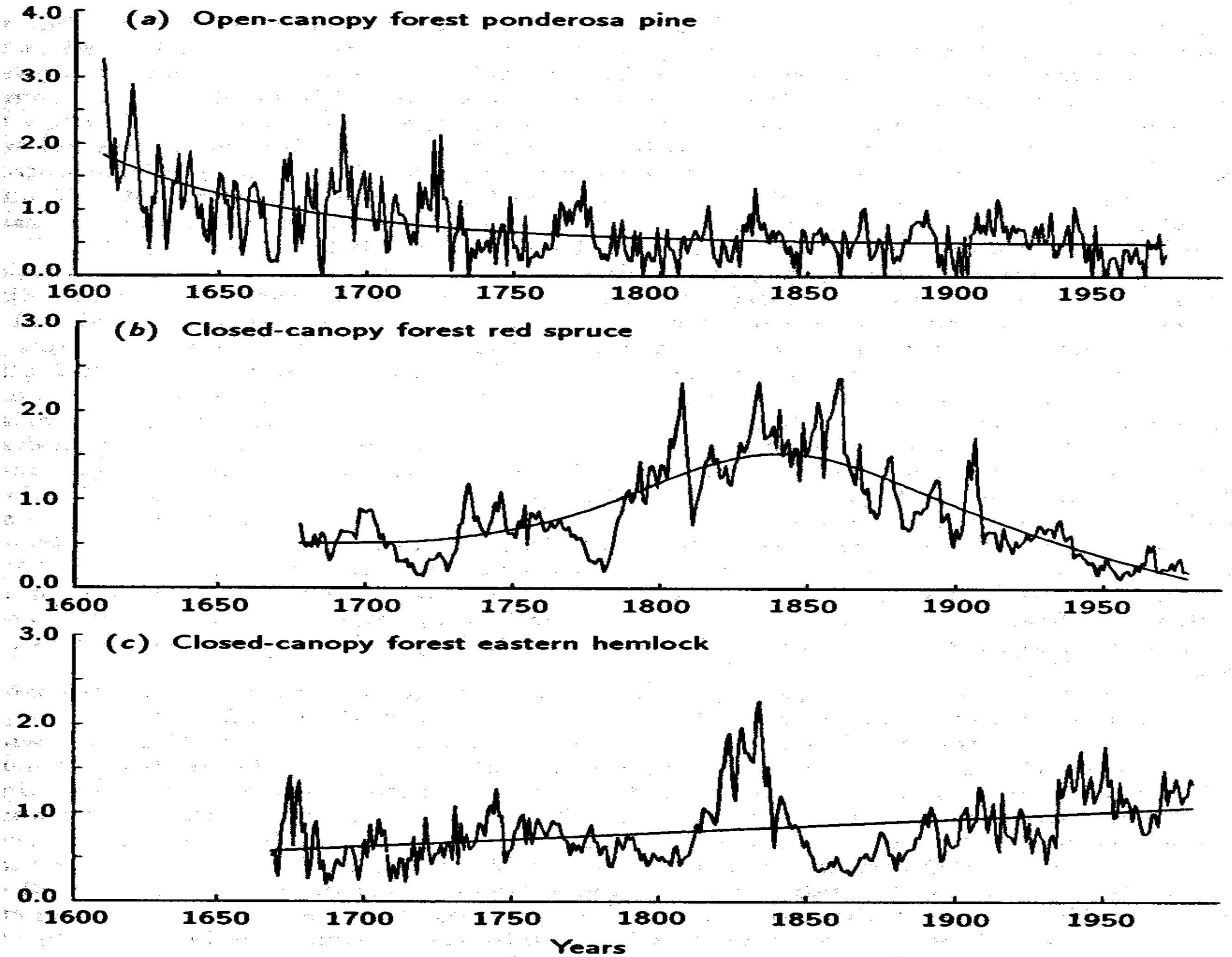
Master Chronology!

Standardizing ring-width series, and averaging the indices into a mean or “summary” chronology.



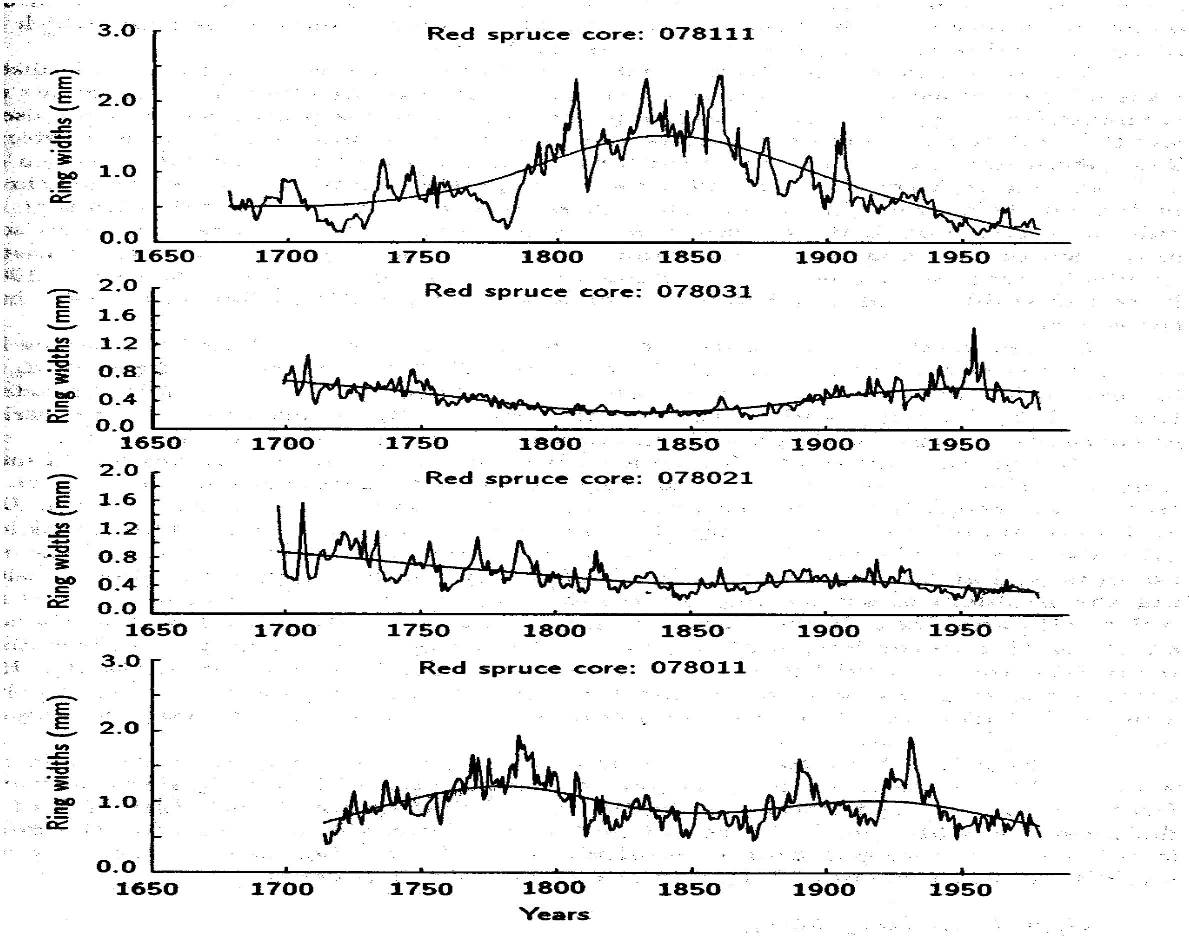
Some ring-width series

mm.



Cook, 1989

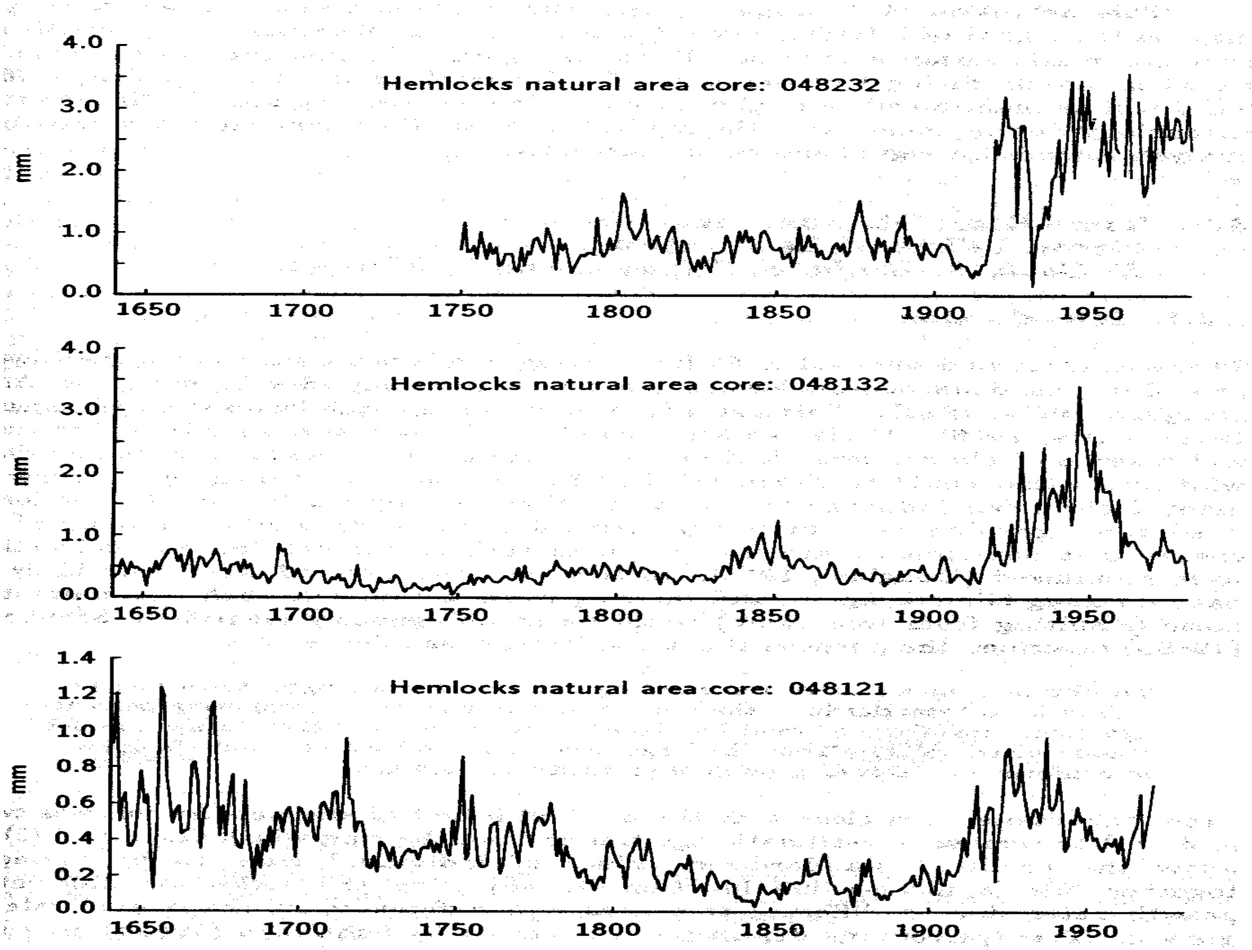
Some ring-width series



Cook, 1989

Four red spruce ring-width series from the same stand, but different trends in different trees related to competition and disturbance.

Some ring-width series

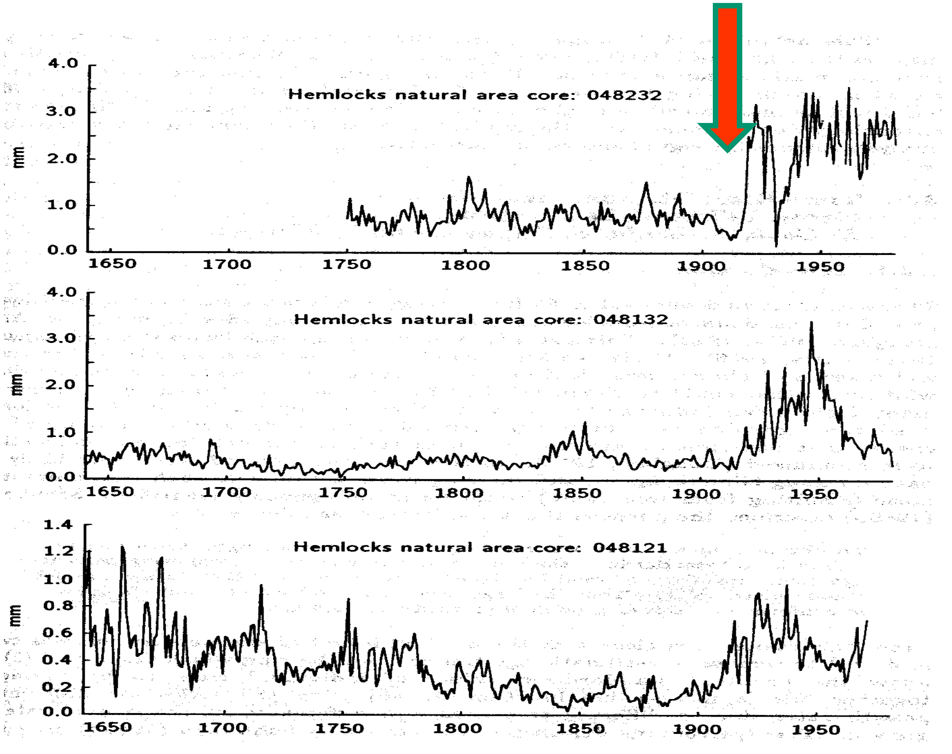


Ring-width records from 3 eastern hemlock from a stand logged round AD 1910.

Cook, 1989

Linear aggregate model – what do the terms look like?

- $D2_t$ – exogenous disturbance originating outside the forest, e.g. hurricane damage, ice storm, late frost, or logging; typically stand-wide effects.



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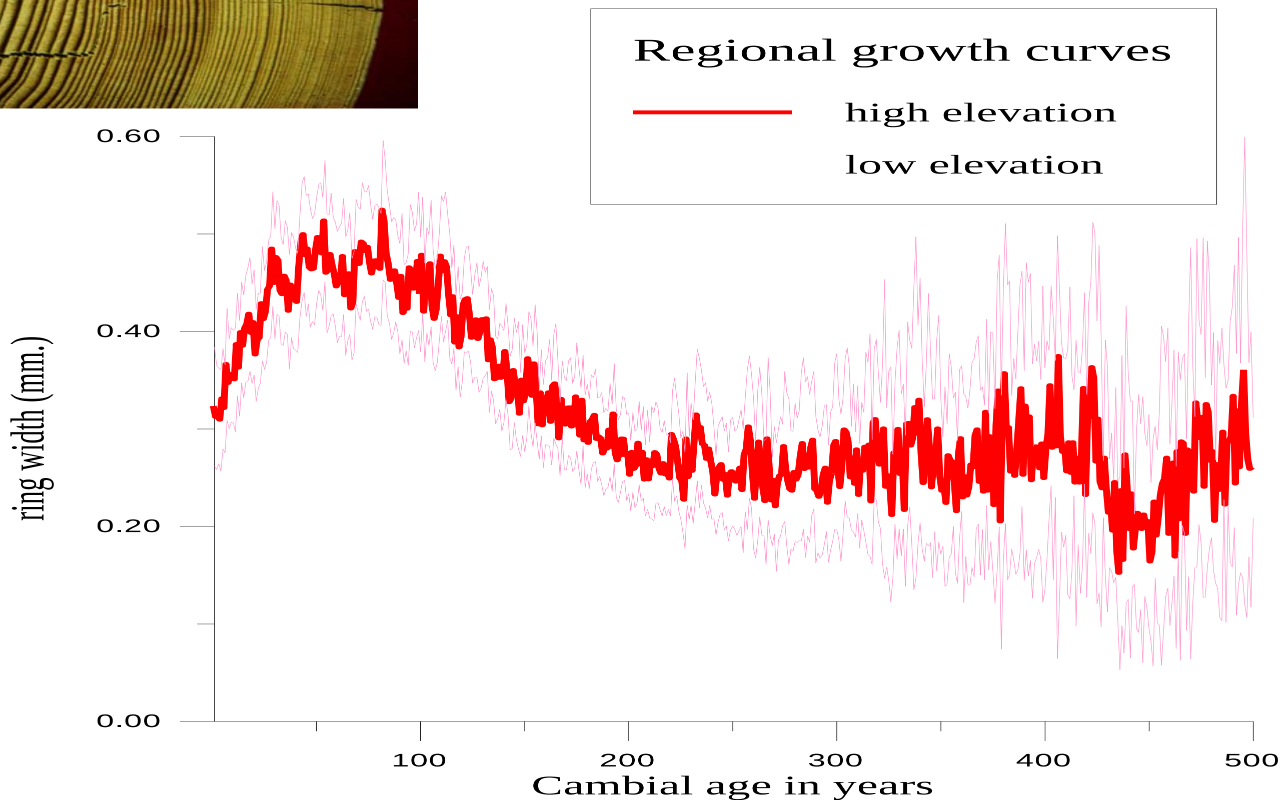
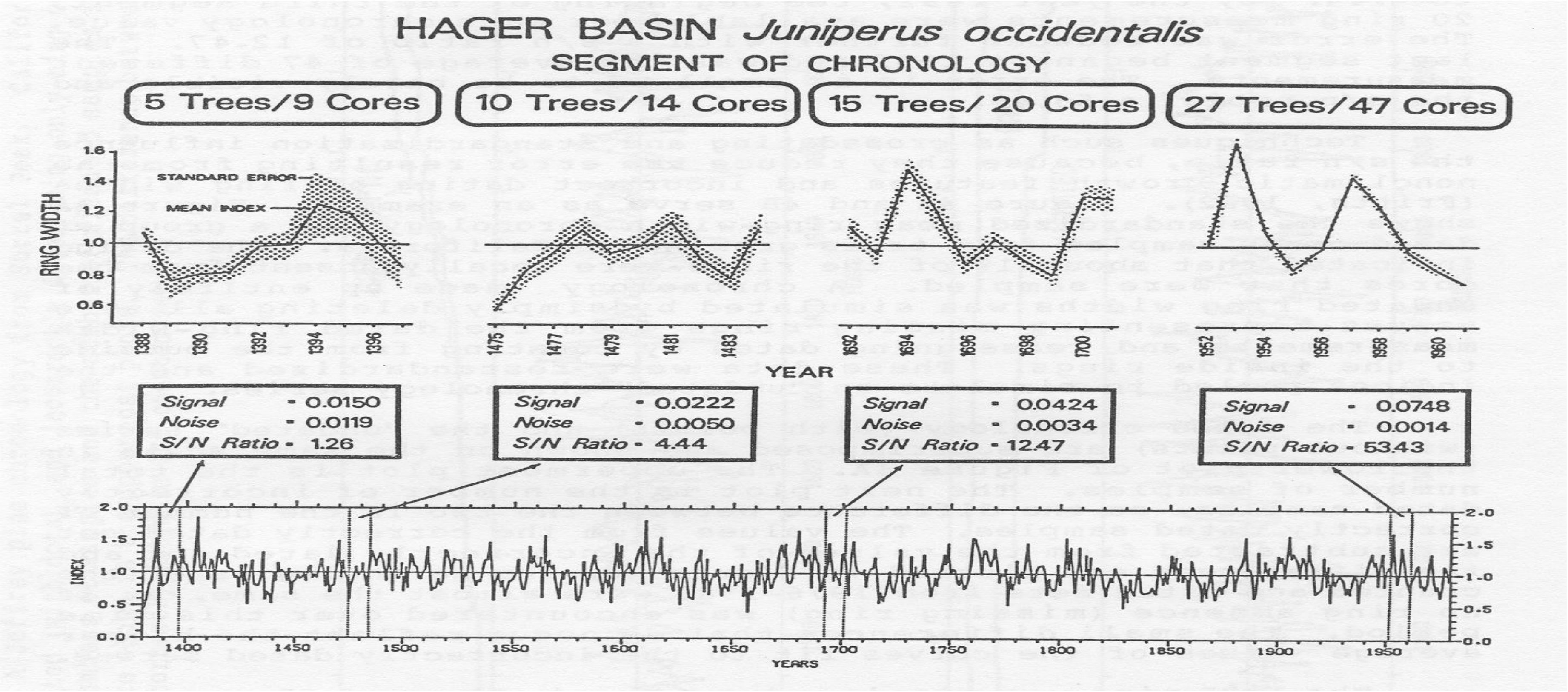
- A_t - age-size related trend in ring width

A single Douglas-fir tree in N. Arizona.

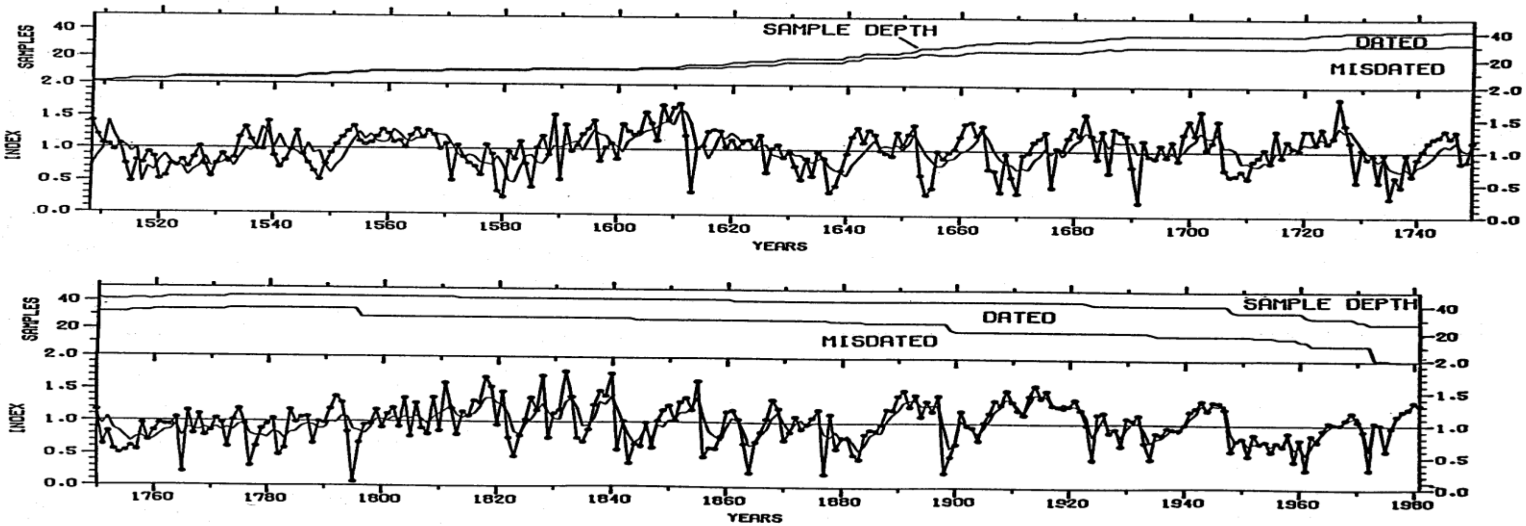
125 larch trees from Northeastern Siberia



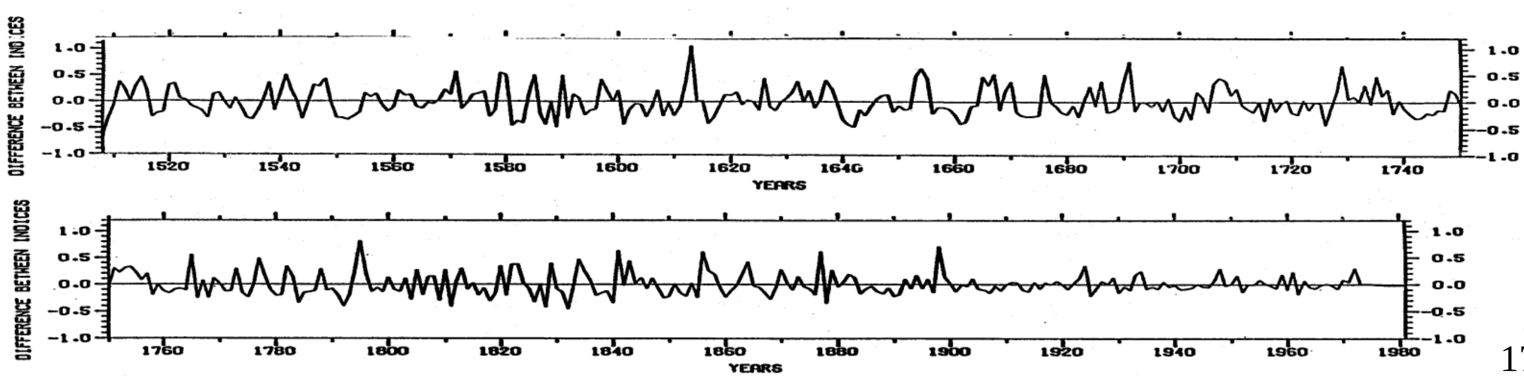
Signal to Noise Ratio



A reminder about dating



A jeffrey pine chronology from Sorrel Peak, California, dated (with dots) and only ring counted – below – the difference between the two.



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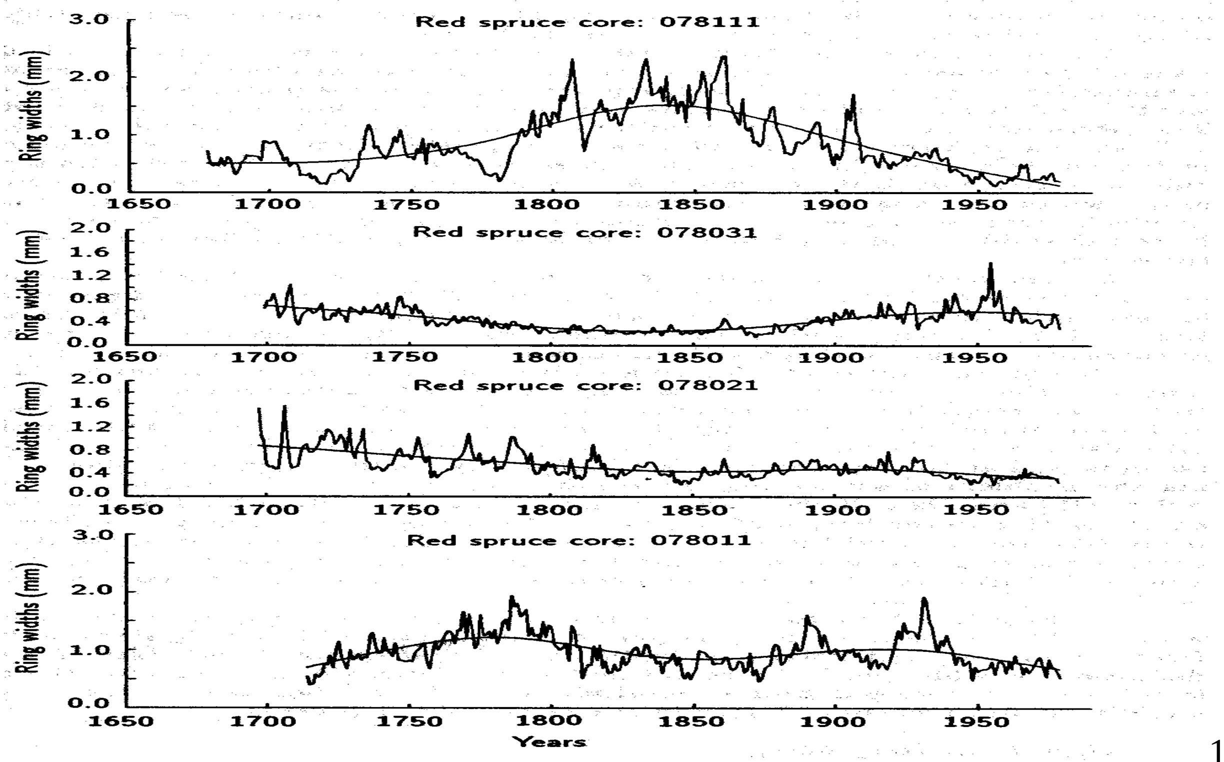
Linear aggregate model – what do the terms look like?

- $D1_t$ – disturbance pulse caused by local endogenous disturbance, for example competition, changing tree stature, etc.; typically within-stand effects



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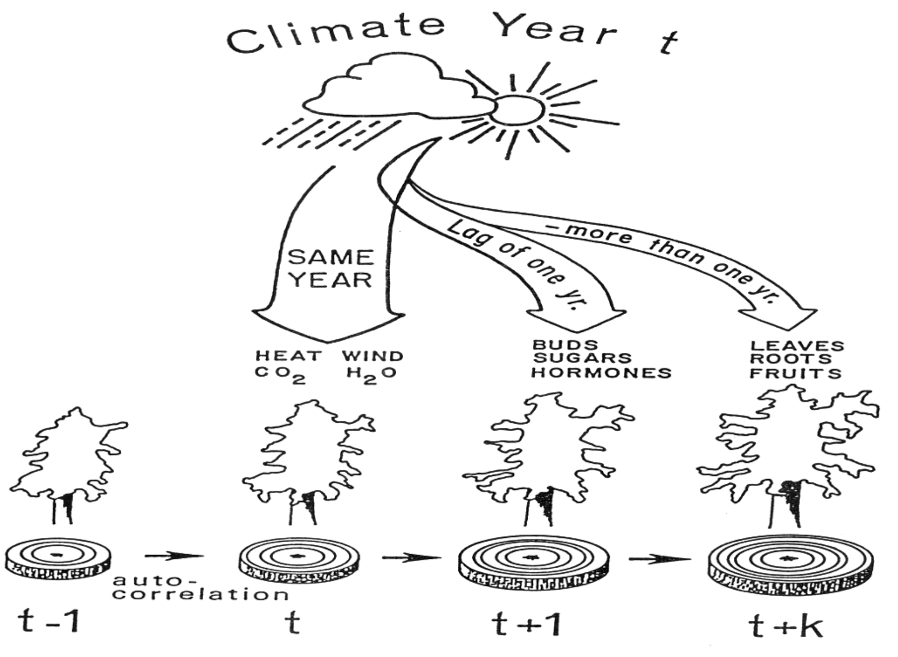
Linear aggregate model – what do the terms look like?

- Ct – climatically-related growth variations common to a stand of trees in year ‘t’ – not exactly same as climate signal because of persis



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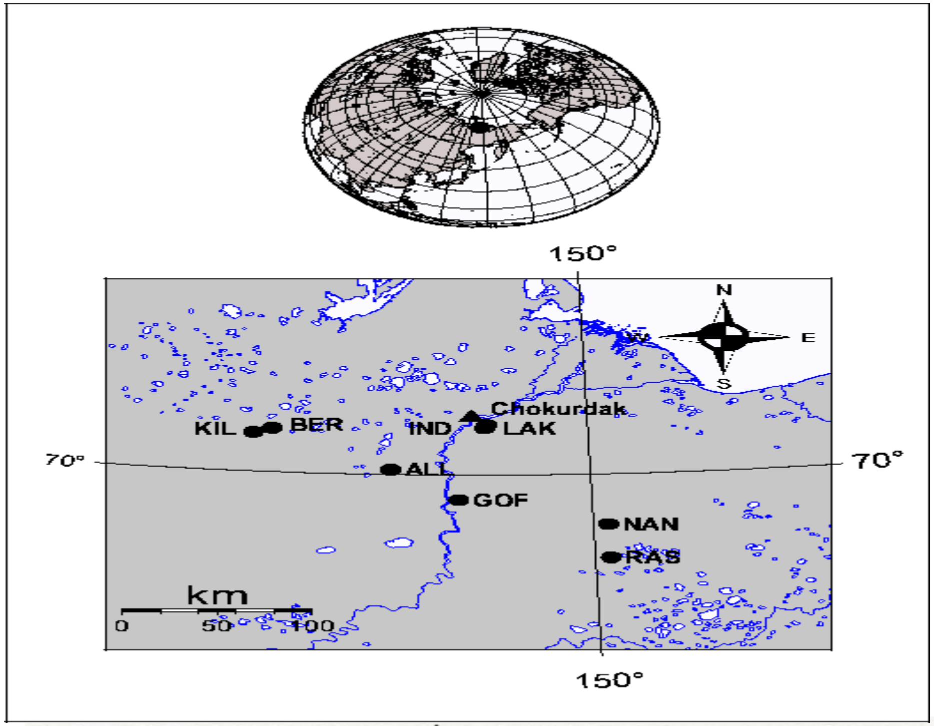

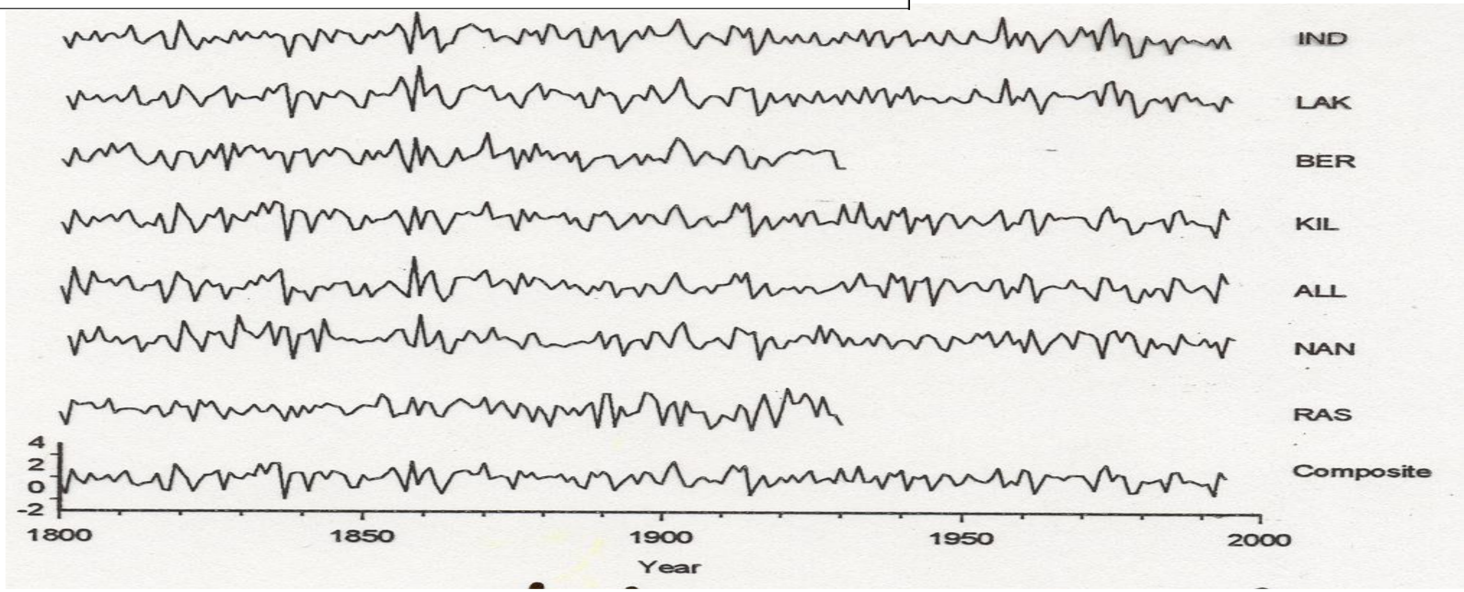

Larch trees at 70 degrees North – strong cross-dating within and between sites equals strong climate signal C_t

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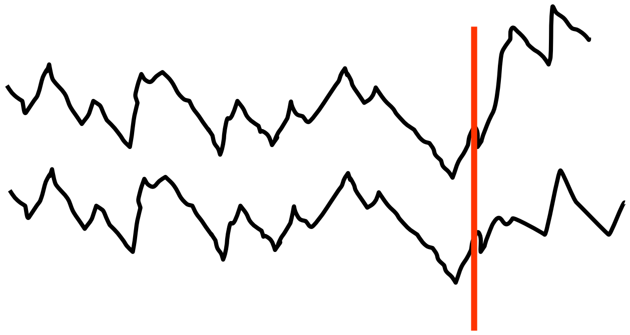
How to extract ecological signal

- First, remove the climate signal: either identify it statistically, remove it and see what is left:
  - Temporal partitioning: pollution example
  - Spatial partitioning: insect defoliation example



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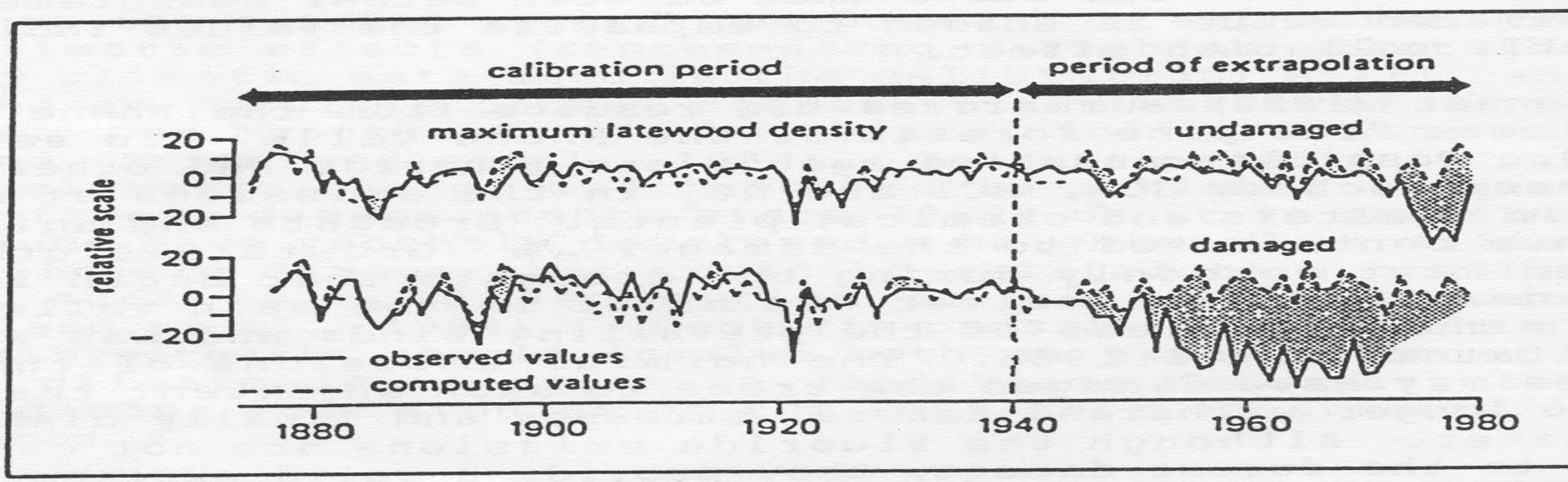
Kienast et al. 1985 used a partioning in time approach to study air pollution effects on tree ring growth in Switzerland. A ring-width chronology was calibrated with climate data prior to a period of observed growth decline, then the climate-growth model was used to project expected growth during the affected period.



How to extract ecological signal

- Or, compare growth in species or a stand you expect to be ecologically affected with one you do not:

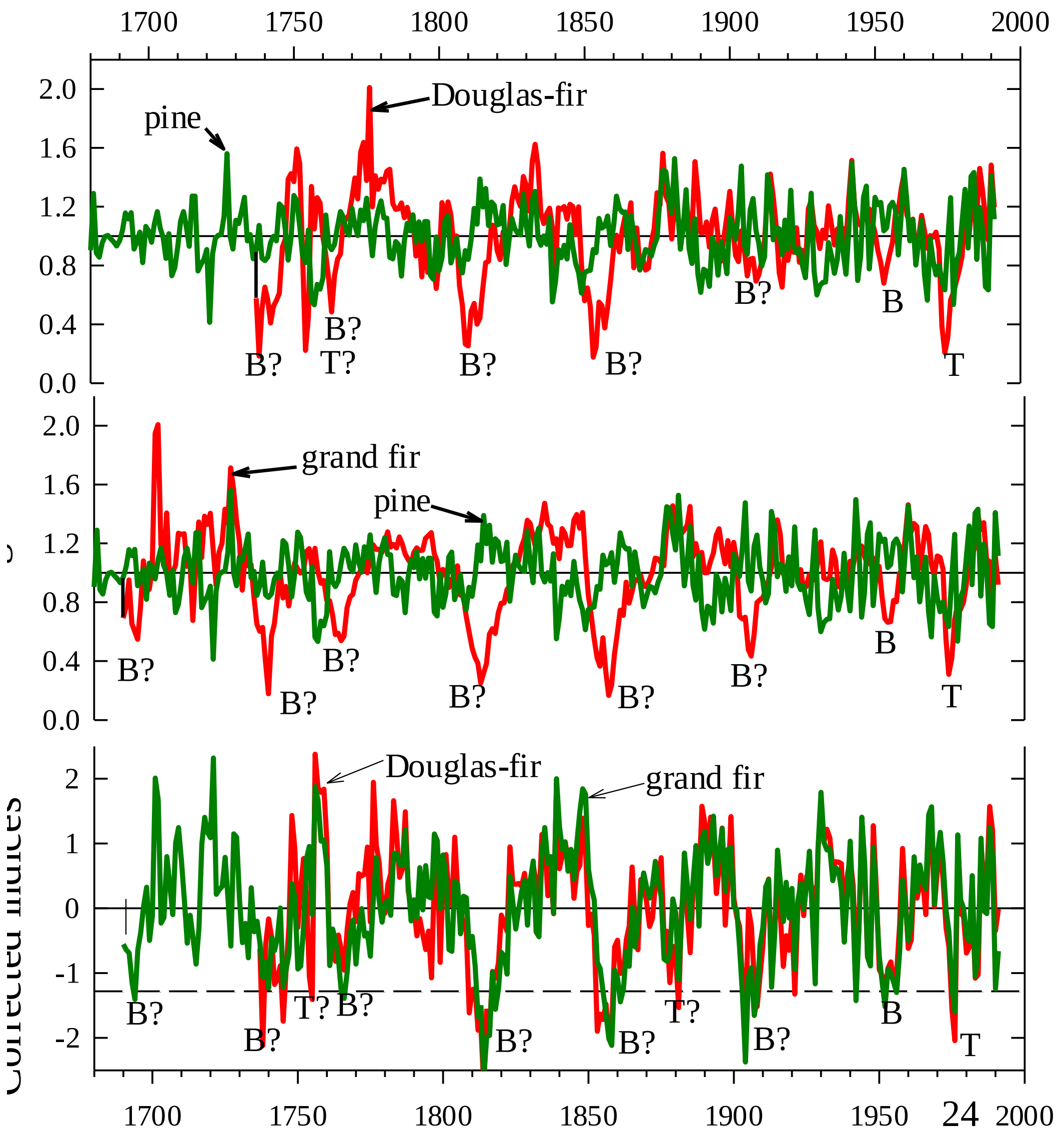
Spatial, and/or species partitioning: e.g., Douglas-fir & Grand fir – host chronologies, versus ponderosa pine -- non-host chronologies, with similar climate responses; Swetnam and Lynch 1990.

Comparisons of host and non-host tree-rings series enables us to separate climate effects from defoliation effects.

Douglas-fir versus ponderosa pine:

Grand fir versus ponderosa pine:

Host minus Non-Host series:



Swetnam, T.W., B. E. Wickman, H. G. Paul, and C. H. Baisan. 1995. Research Paper PNW-RP-484. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 27 p.

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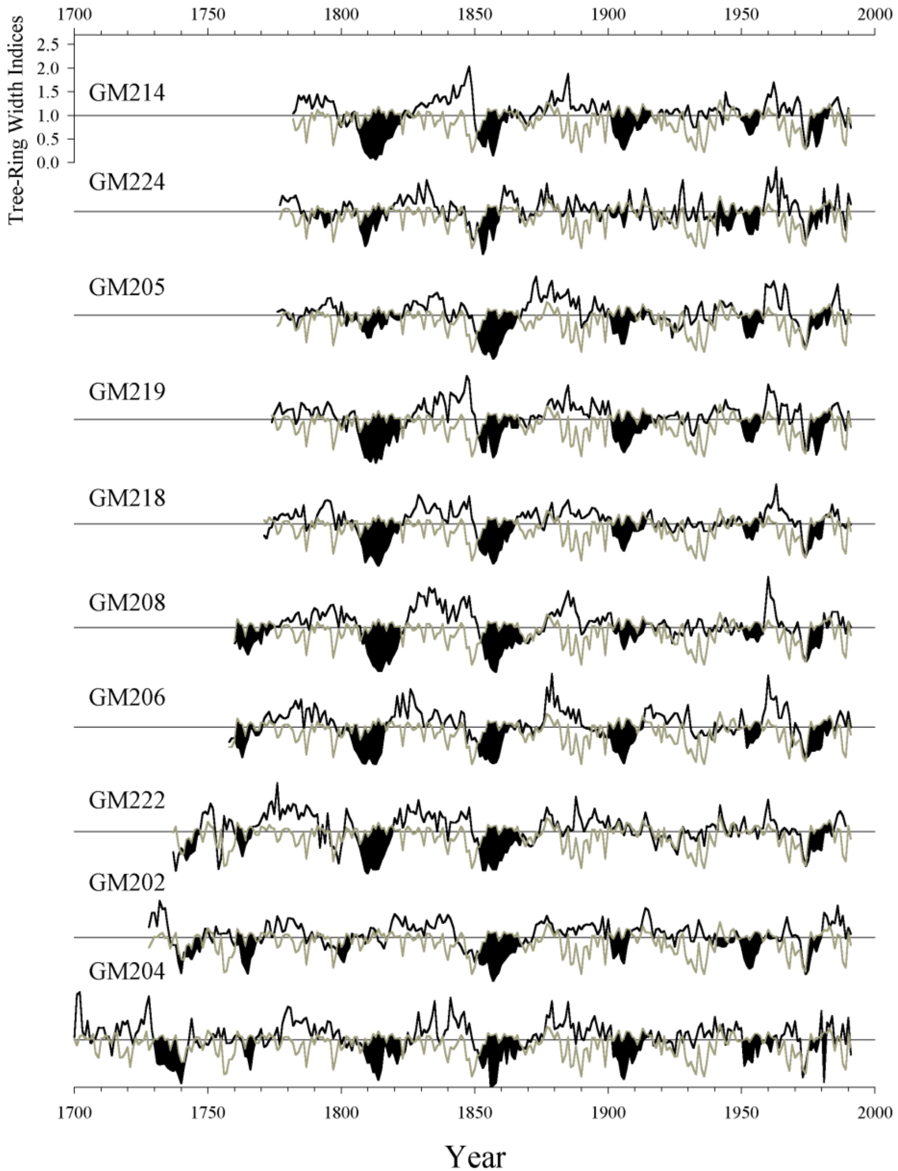


Host vs. non-host ring-width comparisons can be quite effective in identifying outbreaks, and helping to assure that climatic episodes) e.g., droughts) are not confounded.

Swetnam, T.W., B. E. Wickman, H. G. Paul, and C. H. Baisan. 1995. Research Paper PNW-RP-484. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 27 p.

How to extract ecological signal

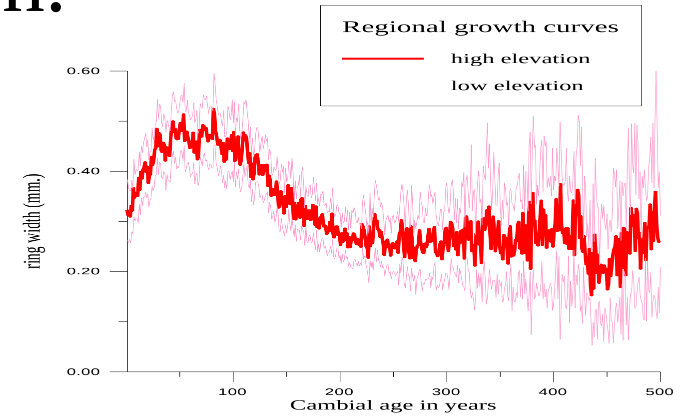
- This latter is an example of developing a sampling structure to deal with an ecological question – could also stratify samples by age, status within the stand, soil type, etc.
- Pollution studies have also used a partitioning in space approach, i.e., sampling trees downwind and nearby a pollution source, and sampling “control” trees upwind and/or distant from the pollution source.

How to extract climate signal

- Need to exclude ecological signals.
- First – exclude, as far as possible, samples and trees that show evidence of disturbances such as those described here, i.e., via sampling strategies
- screen samples and measurements for growth releases and suppressions, reaction wood, etc.. This should get rid of much of $D1_t$ and $D2_t$.

How to extract climate signal

- Second, remove age/size trend. In the ideal case, where all the disturbance signals have been excluded by sample selection, can use a regional growth curve, if the pith date of each sample is known.

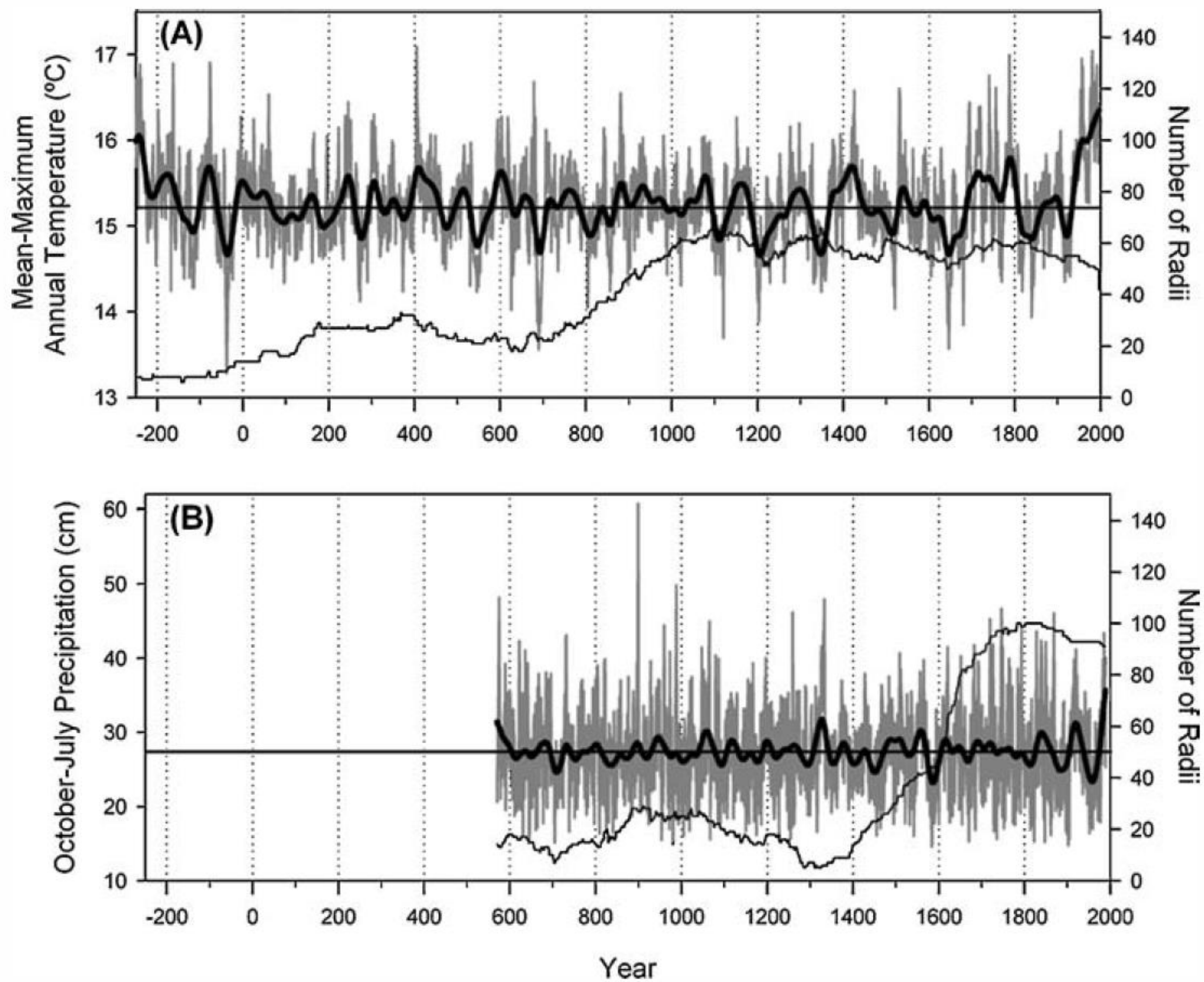


How to extract climate signal

- In many cases this will not be possible, and so some empirical approach will be needed.
- In many cases, especially in closed-canopy, mesic forests, there will also be much disturbance signal.
- It’s necessary to remove these, but this will involve loss of climate information varying on the same time scales.

How to extract climate signal

- Third, working on the assumption that many of the $D1_t$ and E_t effects are tree specific, and probably randomly distributed, whereas the climate signal will be common to all trees, strengthen climate signal by replication, and by deriving a mean value (or measure of central tendency) for each year in the chronology. This should average out the disturbance and error effects.



Salzer & Kipfmueller 2005. Climatic Change 70:465-487

Figure 4. Time-series plots of the southern Colorado Plateau tree-ring based climate reconstructions. (A) Reconstructed mean-maximum annual temperature from 250 BC to 1997. (B) Reconstructed October–July precipitation from AD 570–1994. The gray lines are the annual estimates. The heavy smooth lines are the reconstructions smoothed with a 50-year spline. The thin black lines represent the sample depths of the tree-ring chronologies (number of radii) through time.

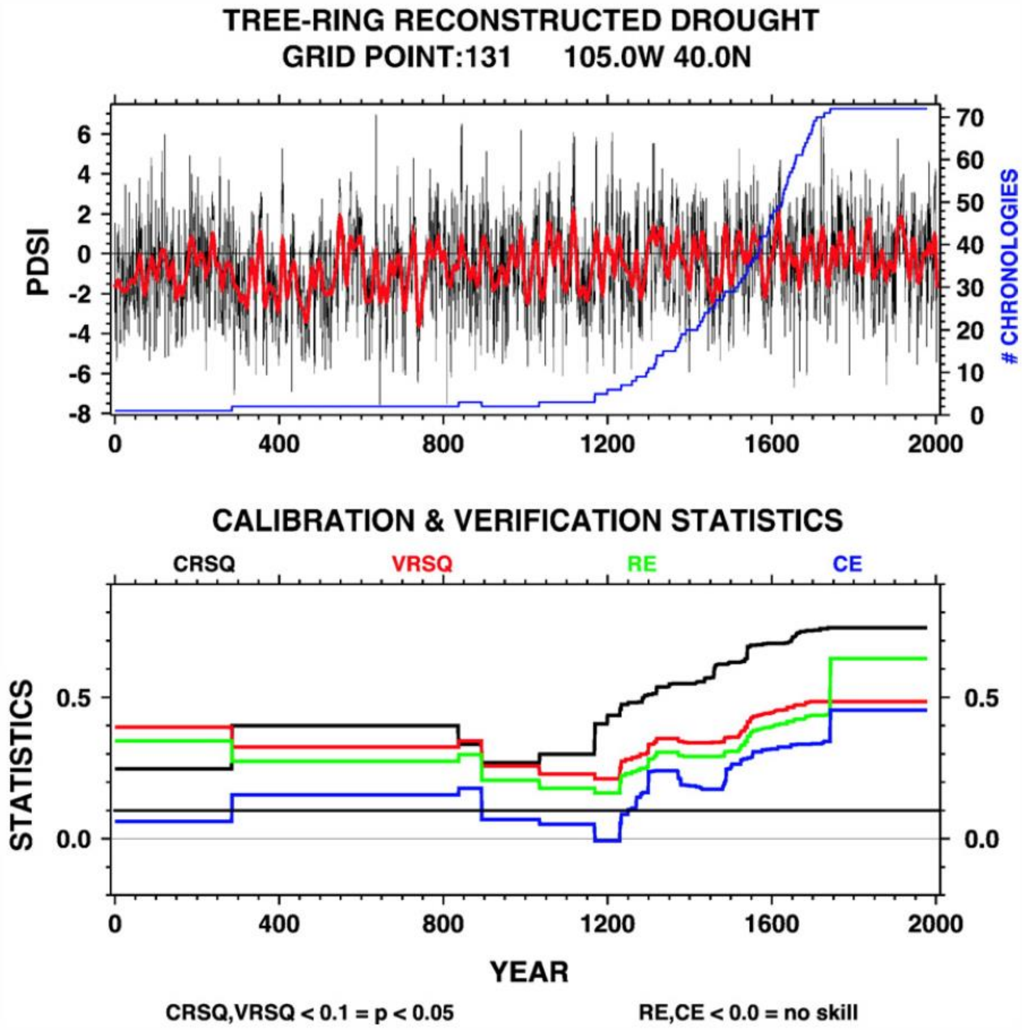


Fig. 5. An example of an extended PDSI reconstruction (upper plot in gray and red) from the North America Drought Atlas, created by using PPR in a nested manner to generate all possible length reconstructions from a suite of tree-ring chronologies with uneven starting years. The blue curve in the upper plot shows the change in the number of chronologies available back in time. As a consequence, each extension back in time has its own calibration (CRSQ, same as R^2 in the text) and verification (VRSQ, RE, and CE; VRSQ=RSQ in the text) statistics, which causes them to vary over time in the lower plot.

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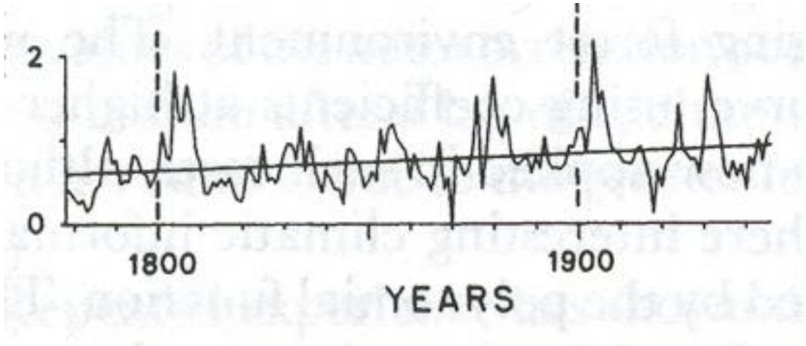
A reminder about dating

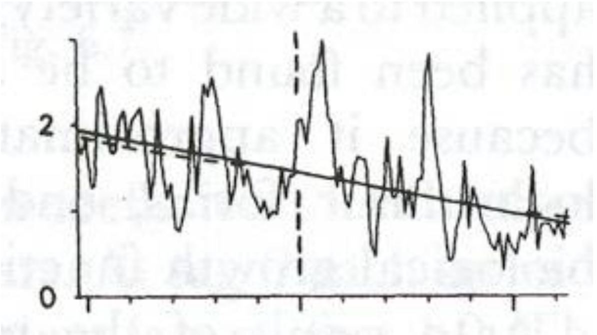
- This has been just an outline of some of the approaches used – there are many more some rather sophisticated.
- Remember, no amount of manipulation will help if the material is not well dated. Recall Holmes experiment with missing rings and effect on signal and variance of chronology.

- **Standardization**
  - **Straight lines can be either horizontal (zero slope), upward trending (positive slope),**

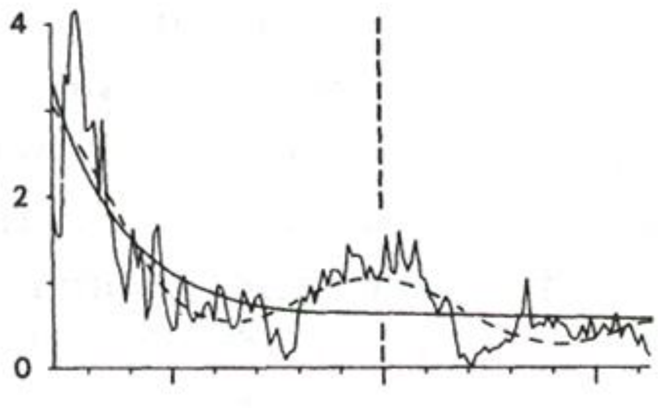


y = ax + b

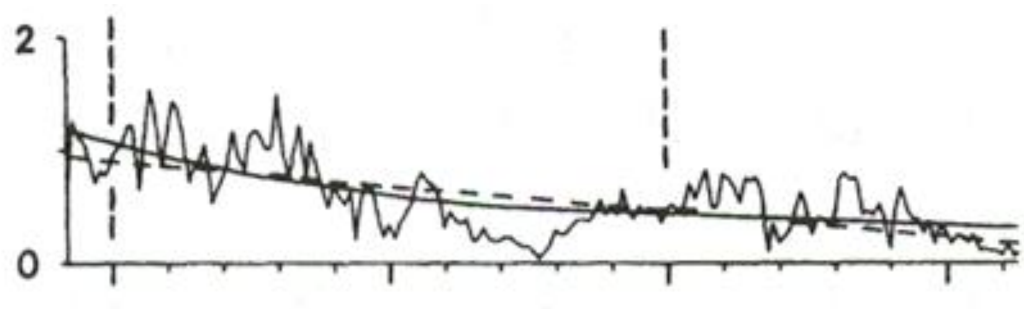
or downward trending (negative slope)



- **Standardization**
  - **Curves are mostly negative exponential…**

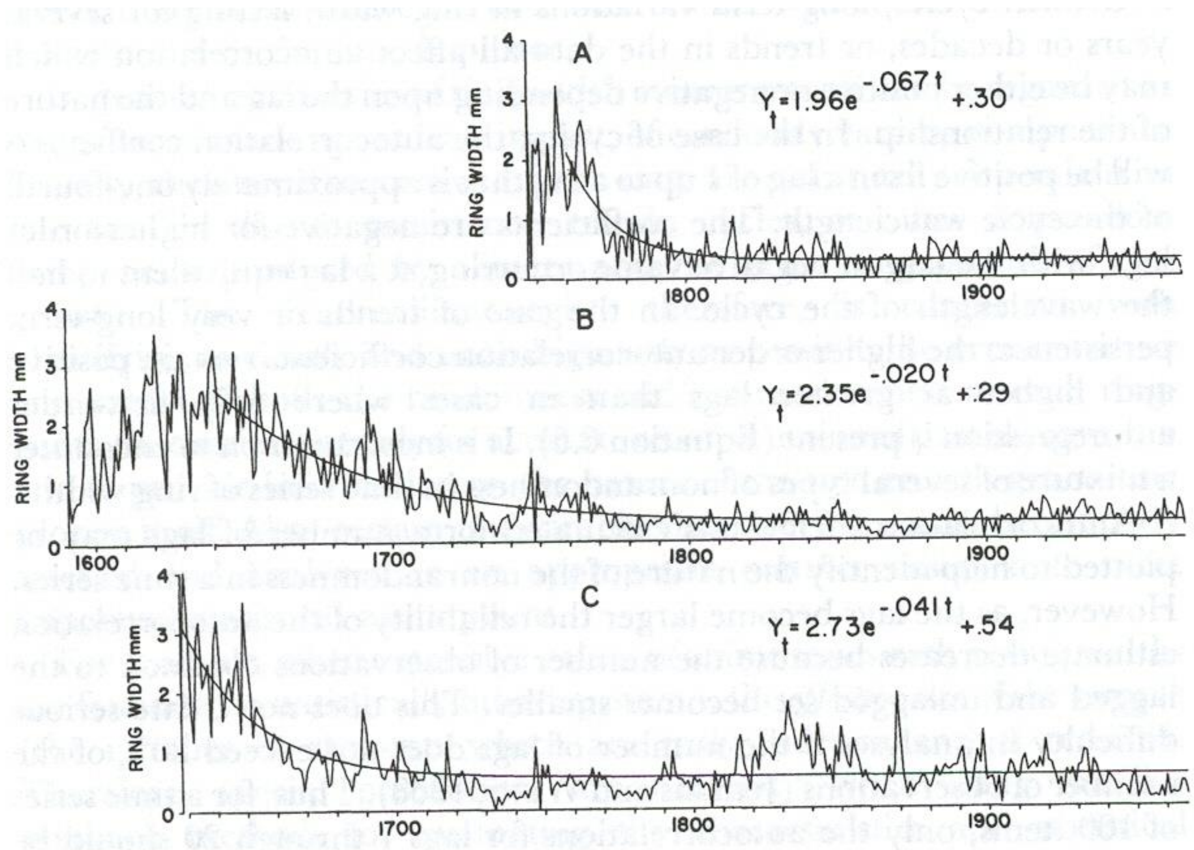


$$y = ae^{-b}$$



- **Standardization**

  - **…. but negative exponentials must be modified to account for the mean.**



$$y = ae^{-b} + k$$