Statistics Café, Summer term 2018

Analyzing time series of tree growth - Concepts, peculiarities and methods

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Structure

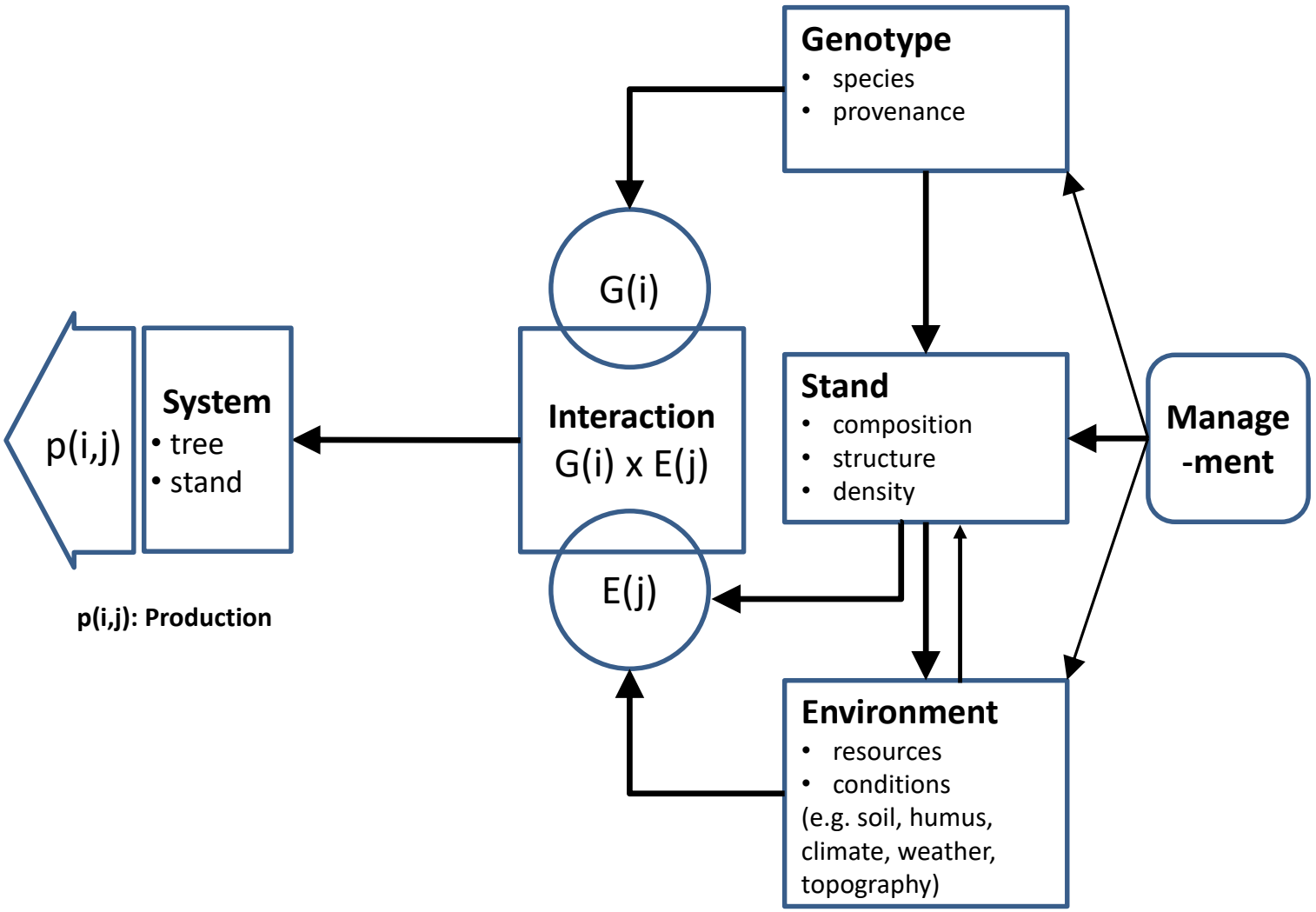
- **Concepts**
  - Tree growth and tree growth parameters
  - Tree-rings and growth zones
  - Cross-dating
  - Principles of dendrochronology/-ecology
- **Peculiarities**
  - Growth trends
  - Multiple states
  - Sensitive/transient response, autocorrelation
- **Methods**
  - Detrending
  - Chronology building
  - Response function

Tree growth and tree growth parameters

- **Tree growth**
  - primary growth/secondary growth
  - leaf/needle, branch, stem, bark, root growth

(Douglas fir, Mooswald, date of cutting: 27.04.2006)

System analysis: Production process



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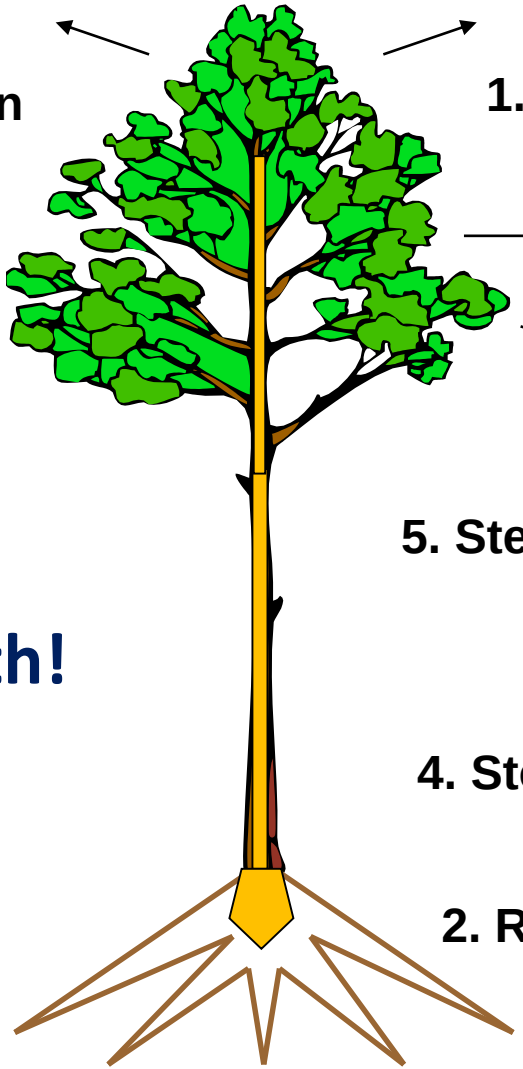
System analysis: Biomass partitioning in trees



3. Seed production

1. Leaf growth /bud formation

6. Defense

5. Stem/branch growth

Sink strength!

4. Storage

2. Root growth

(acc. to Waring 1986)

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Tree growth and tree growth parameters

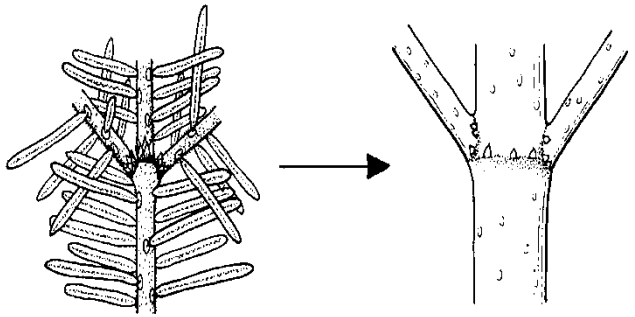
- **Tree growth**
  - primary growth/secondary growth
  - leaf/needle, branch, stem, bark, root growth
- **Tree growth parameters**
  - diameter growth/diameter increment, e.g., $d_{age\ 100}$, ir, TRW
  - basal area growth/basal area increment, e.g., ig, iG
  - height growth/height increment, e.g., $h_{age\ 100}$, ih
  - volume growth/volume increment, e.g., $v_{age\ 100}$, iv, iV
  - biomass growth/biomass increment
- **Analysis of tree growth:**
  - **Retrospective methods**
    - Stem analysis
    - Increment cores
  - **In situ methods**
    - Repeated measurements, e.g., long-term forest research plots, inventory
    - Continuous measurements, e.g., point dendrometer, permanent circumference band

Stem analysis

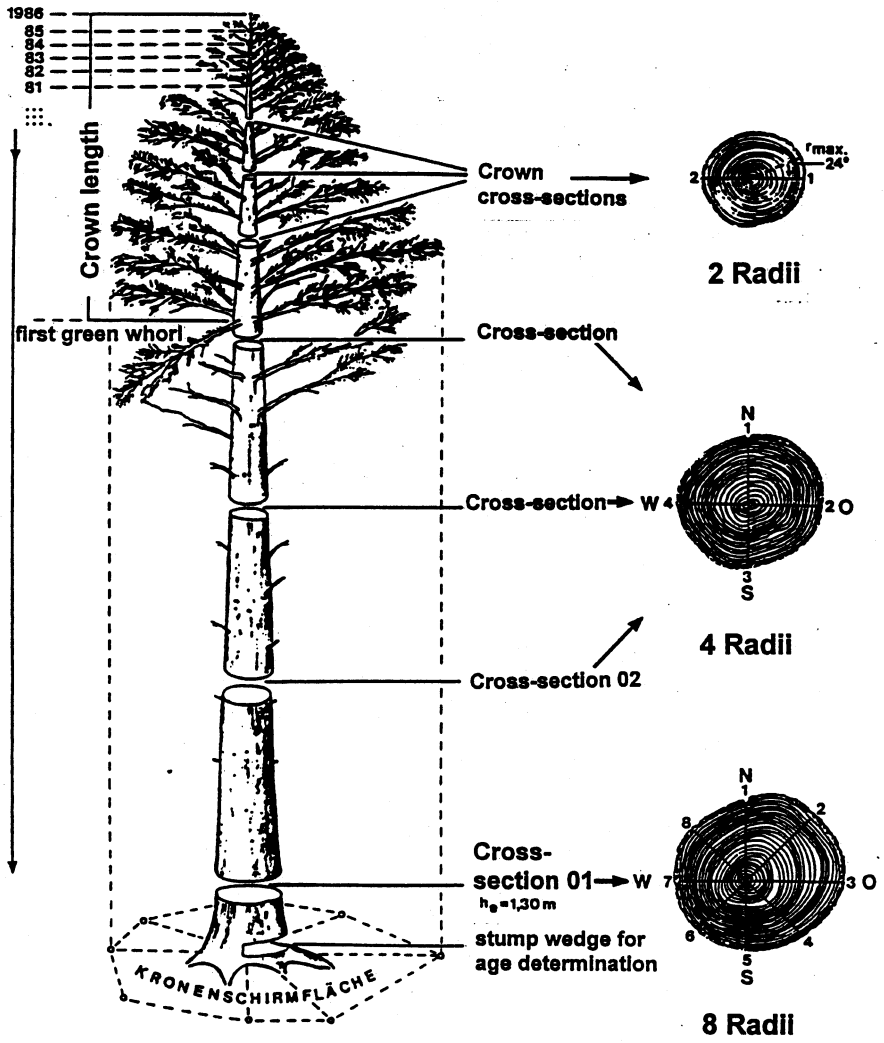
Height analysis

Analysis of stem cross-sections

Traces of bud scales

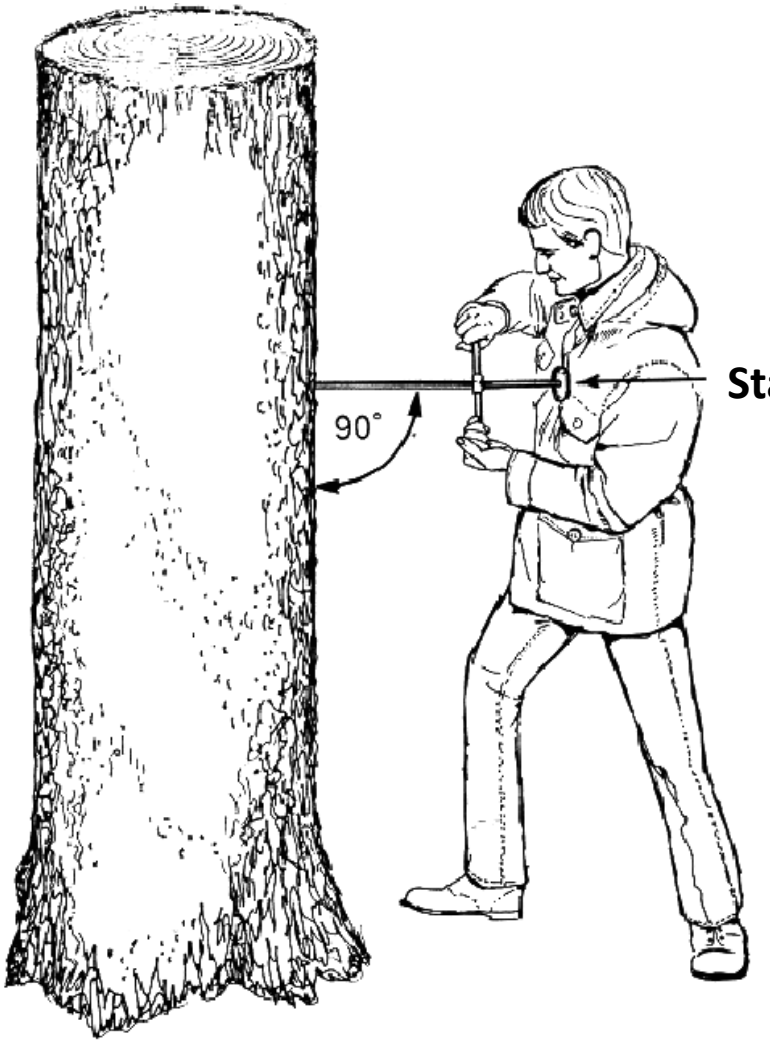


(Roloff 2001)



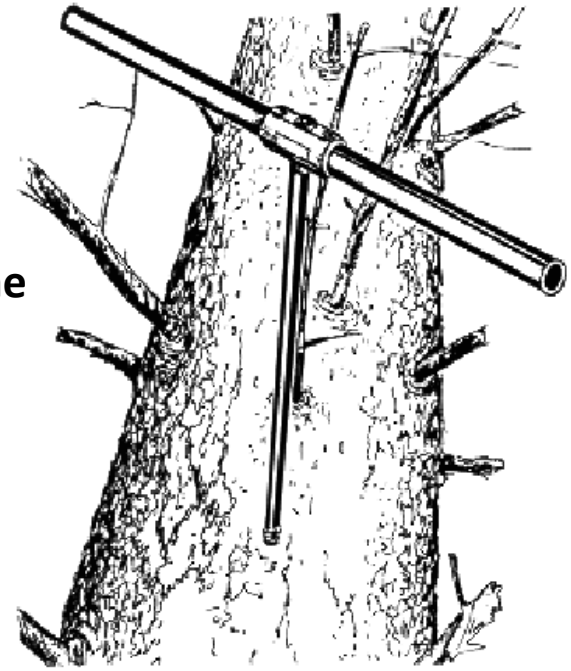
(Gerecke 1988)

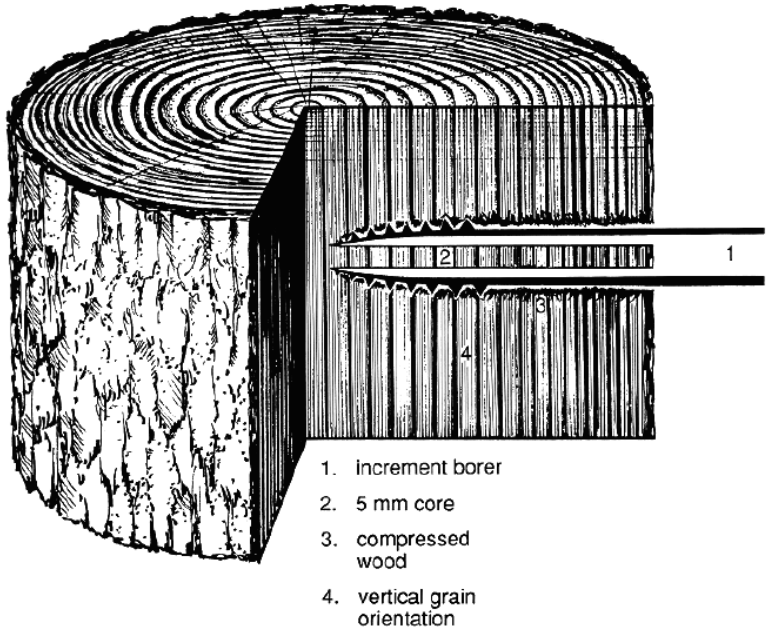
Application of increment borer



Starter-aid

Hitting the centre

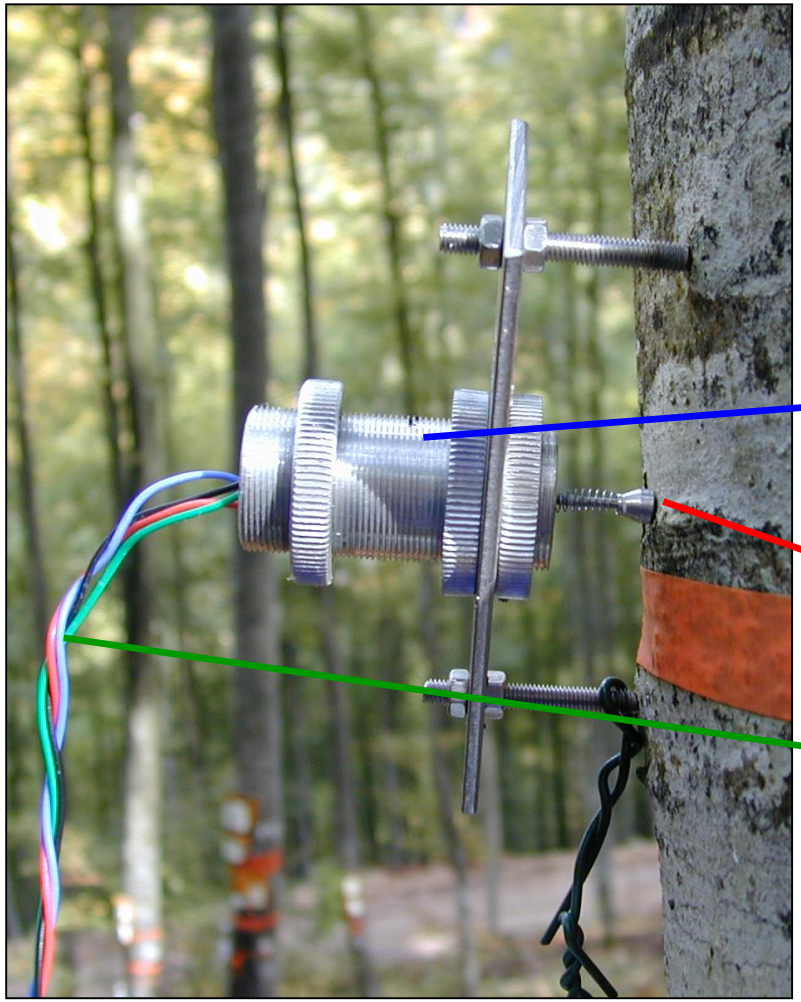




(Jozsa 1988)

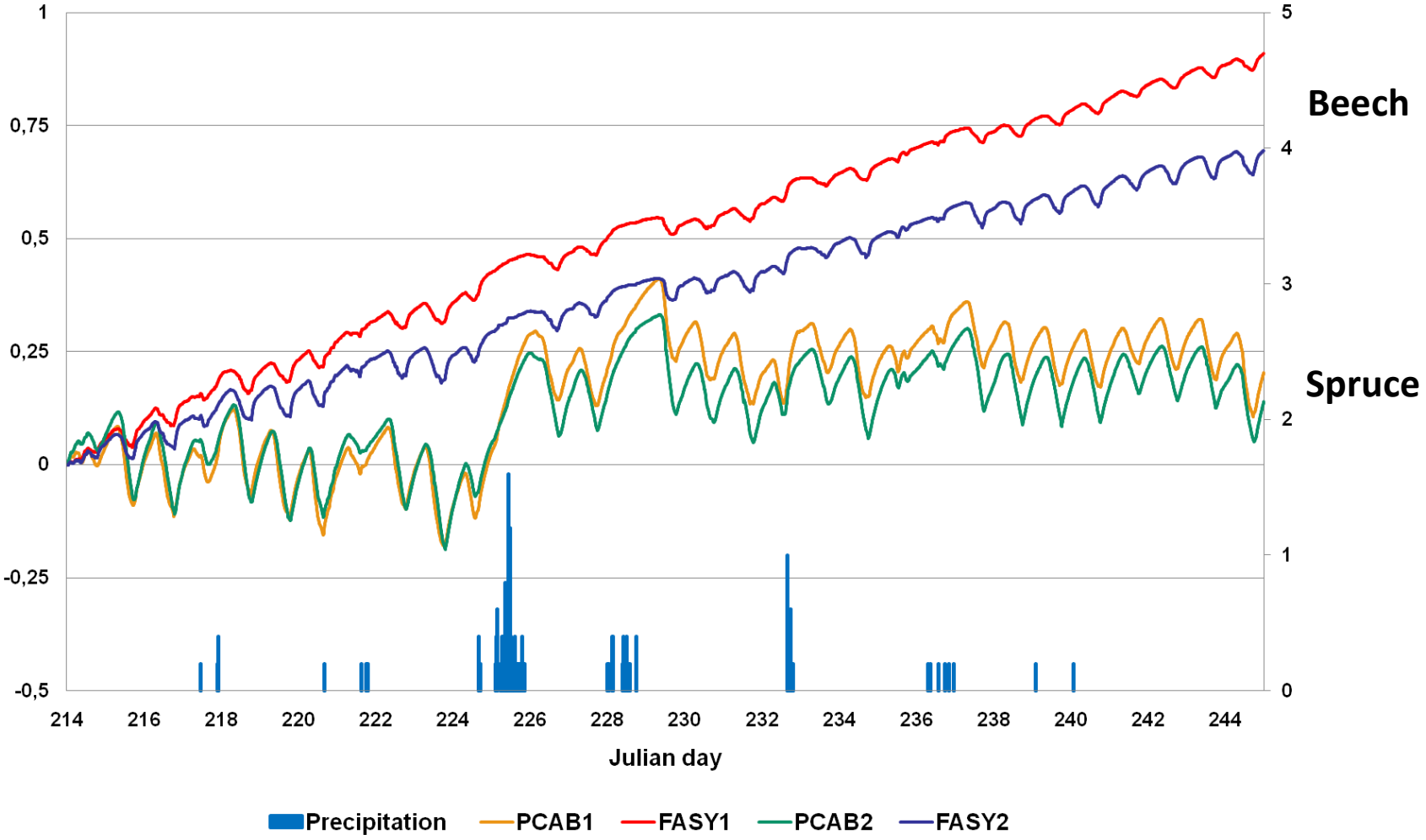
Dendrometer measurements

Point dendrometer



(Hauser 2002)

Dendrometer measurements



Structure

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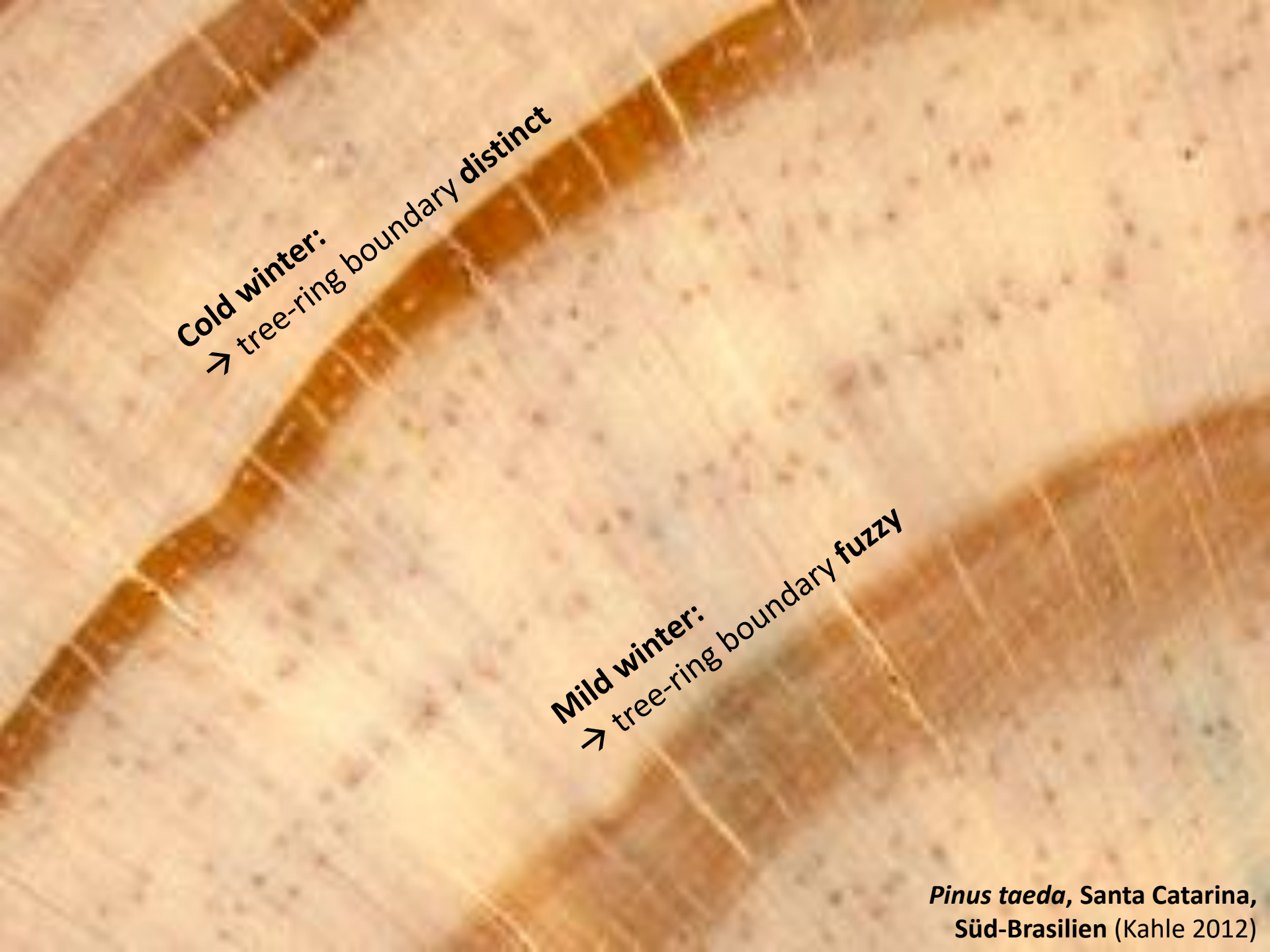
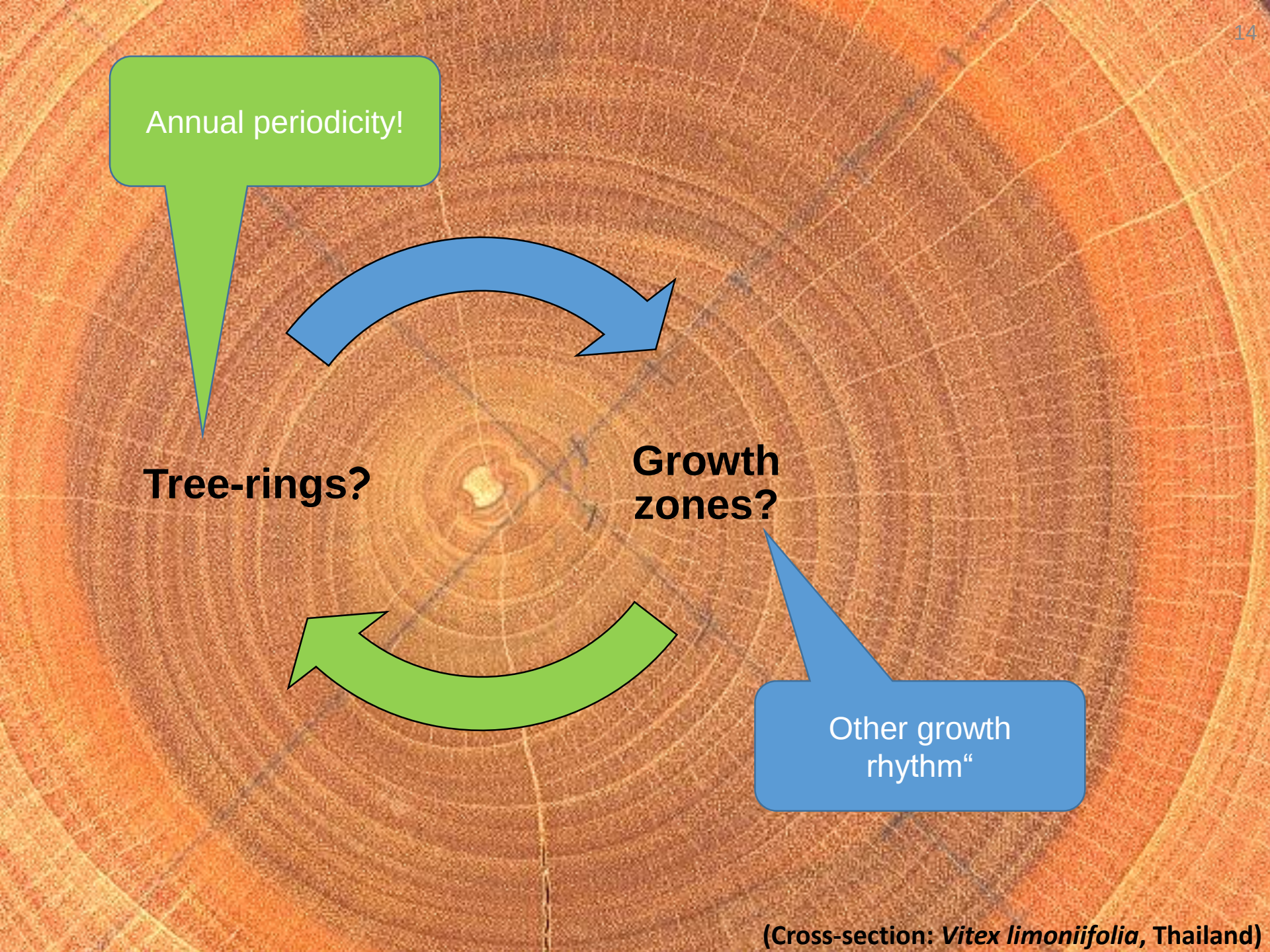
  - Tree growth and tree growth parameters
  - Tree-rings and growth zones
  - Cross-dating



***Pinus taeda*, Santa Catarina, Süd-Brasilien** (Kahle 2012)



(Cross-section: *Vitex limoniifolia*, Thailand)

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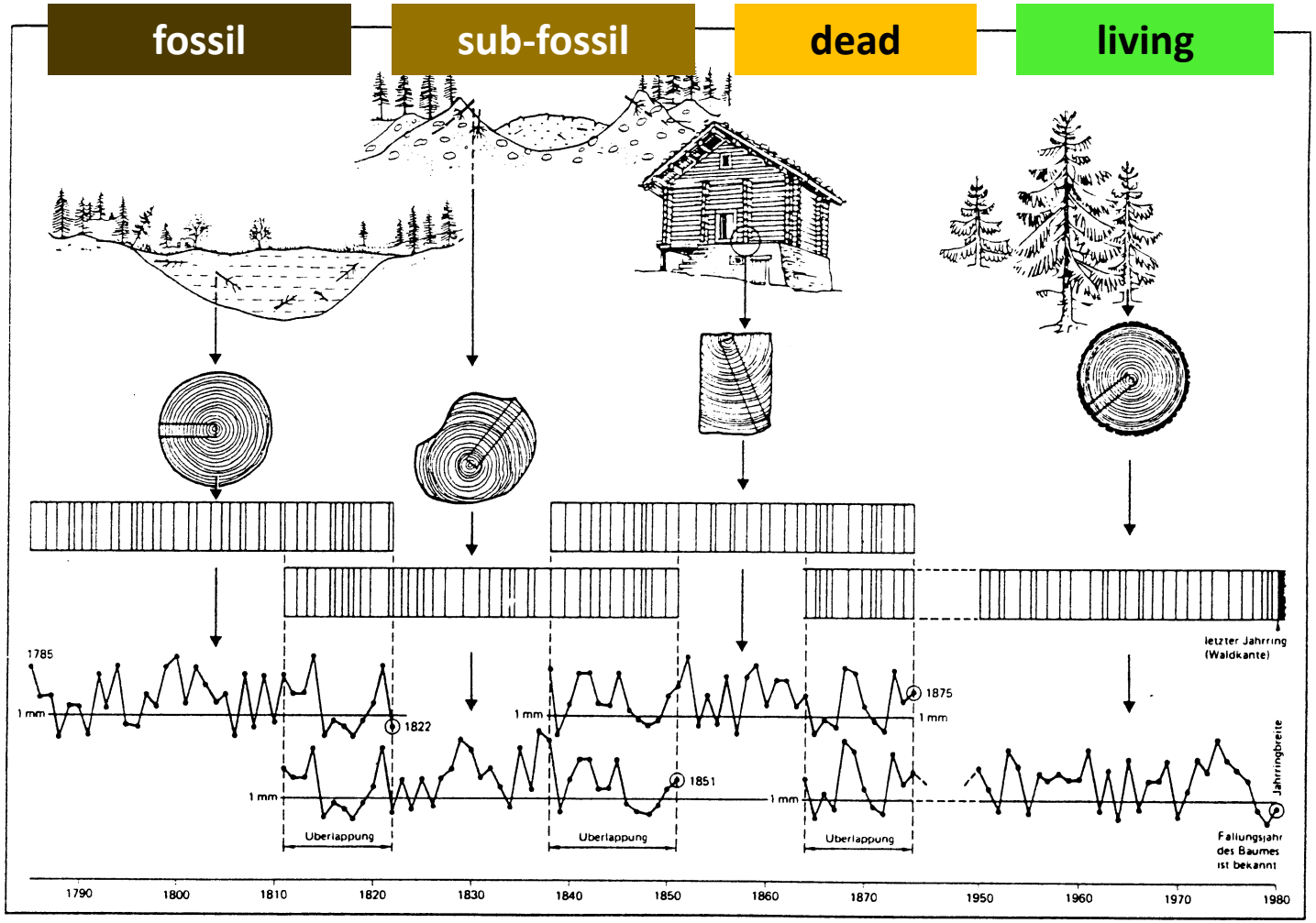
Cross-dating and chronology building



(Schweingruber 1989)

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Missing rings?

A tree ring which in a sample is absent due to **failure of cambial activity.**

Missing rings can be located by **cross-dating**.

The term "missing ring“ is used for tree rings which are **absent on the whole sample**.

When a tree ring is discontinuous (partial, incomplete), it is a **wedging ring**.

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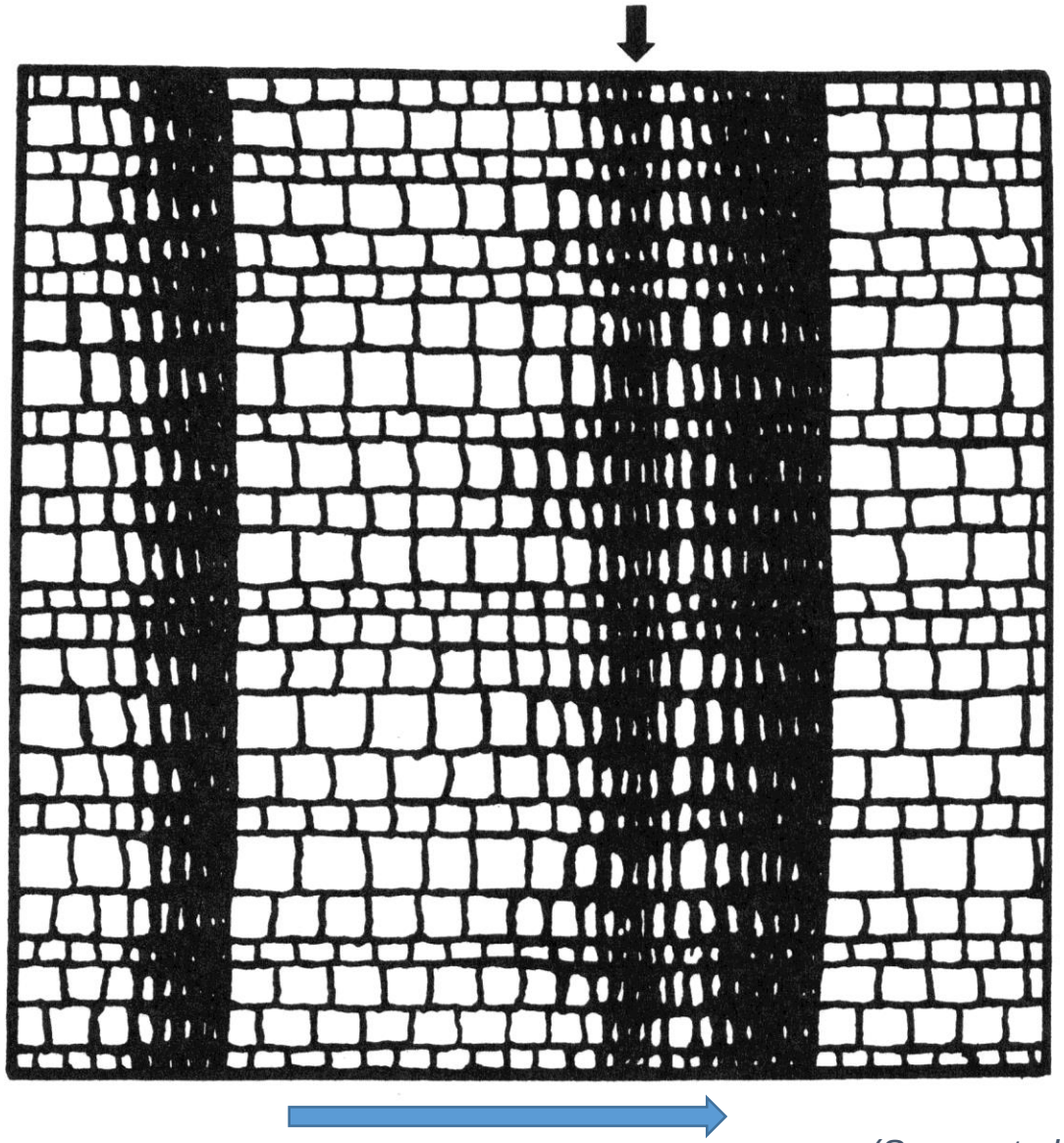
False rings?

Cells leading into the false ring will **gradually decrease** in size and then **gradually increase back** to earlywood cells.



(Speer *et al.* 2004)

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Principles of dendrochronology/-ecology

1. The principle of aggregate tree growth
2. The uniformitarian principle
3. The principle of ecological amplitude, and
4. The principle of site selection

http://web.utk.edu/~grissino/

Principles of dendrochronology/-ecology

The principle of aggregate tree growth

"Any individual tree growth series can be decomposed into an aggregate of environmental factors that affected the patterns of tree growth over time".

(e.g. web.utk.edu/~grissino/)

$$R_t = A_t + C_t + \delta D1_t + \delta D2_t + E_t \quad (1)$$

(acc. to Cook 1990)

- R_t = growth response variable, *e.g.* radial increment, in year *t*
- A_t = age trend component in year *t*
- C_t = climate factor in year *t*
- $D1_t$ = tree individual disturbance in year *t*
- $D2_t$ = stand wide disturbance in year *t*
- δ = binary indicator (δ = 1: presence, δ = 0: absence)
- E_t = error term (white noise process) in year *t*

Principles of dendrochronology/-ecology

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(acc. to Cook 1990)

Dendroclimatology: „maximize the climate signal by minimizing the other factors through chronology building, *i.e.* (1) detrending/standardization, and (2) aggregation".

Trend component:

$$G_t = f(A_t, \delta D1_t, \delta D2_t) \quad (2)$$

$D1_t$ = stand-wide disturbance in year t

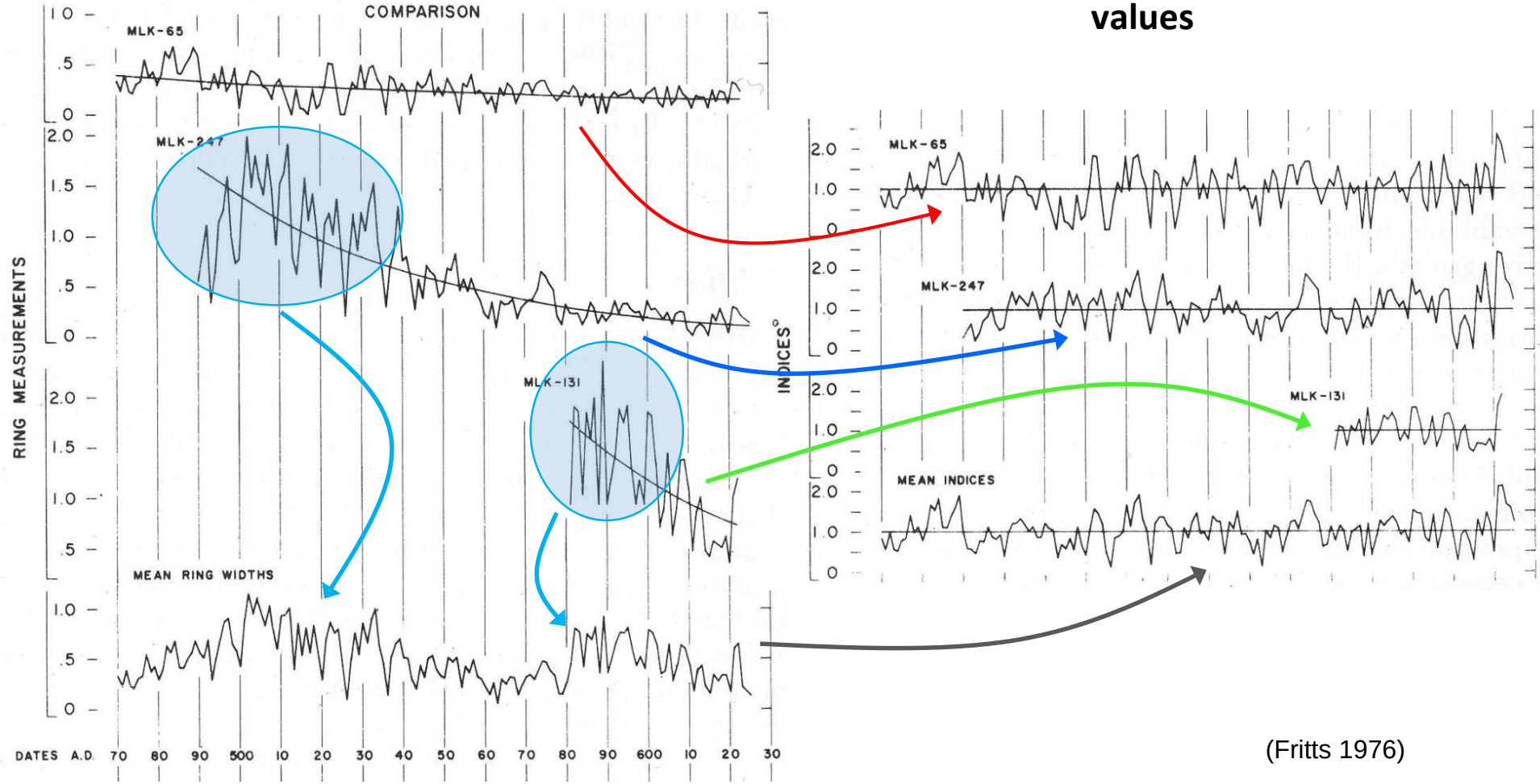
δ = binary indicator (δ = 1: presence, δ = 0: absence)

E_t = error term (white noise process) in year t

Standardization - Detrending

Raw (measurement-) values

Detrended (standardized) Index values



(Fritts 1976)

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Standardization - Detrending

Models for nonstationary series (series with a trending mean):

Trend stationarity:

The mean trend is deterministic, i.e., once the trend is estimated and removed from the data, the residual series is a stationary stochastic process

Difference stationarity:

The mean trend is stochastic, i.e. once the series is differenced D times, the series yields a stationary stochastic process

Concept rarely applied in dendroecology!

The principle of aggregate tree growth - Critics

$$R_t = A_t + C_t + \delta D1_t + \delta D2_t + E_t \quad (1)$$ (acc. to Cook 1990)

"Age trend" component (A_t) in year t:

The endogenous trend component comprises effects of **chronological AND of physiological age** (i.e. dimension related trend). **Alternative:** e.g., multi-step detrending

"Climate factor" (C_t) in year t:

The climate factor is an amalgamation of effects of **weather** (operating at high frequencies) **AND climate** (operating at low frequencies). Effects can be **delayed and long-lasting** (lag and carry-over effects). **Alternative:** e.g., distributed-lag model

Disturbances:

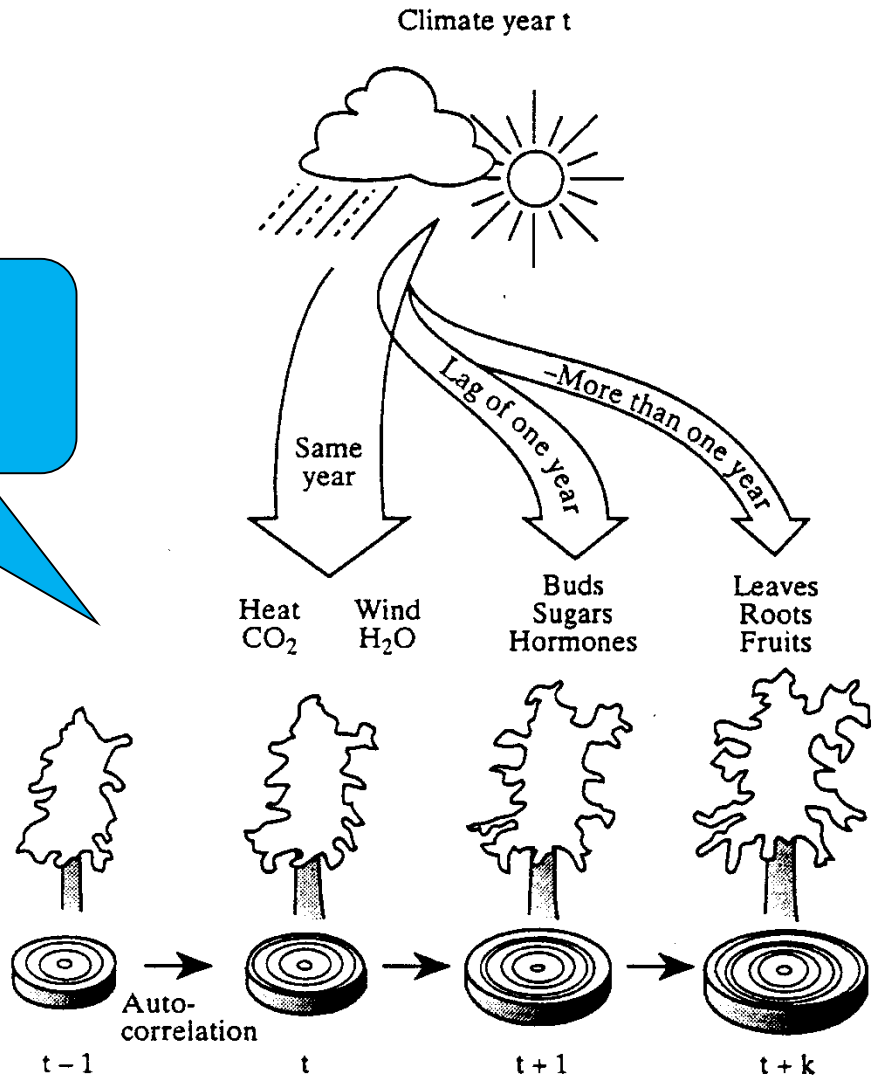
Disturbances can have **long-lasting effects**. Weather factors, e.g. late frost, can also cause disturbance. **Alternative:** e.g., threshold autoregression model

Additive aggregation:

The assumption of **additive linkage without interaction** of components is biologically not meaningful. **Alternative:** multiplicative aggregation

Time lagged effects: memory/autocorrelation

- endogenous factors
  AND
- exogenous factors



(Fritts 1976)

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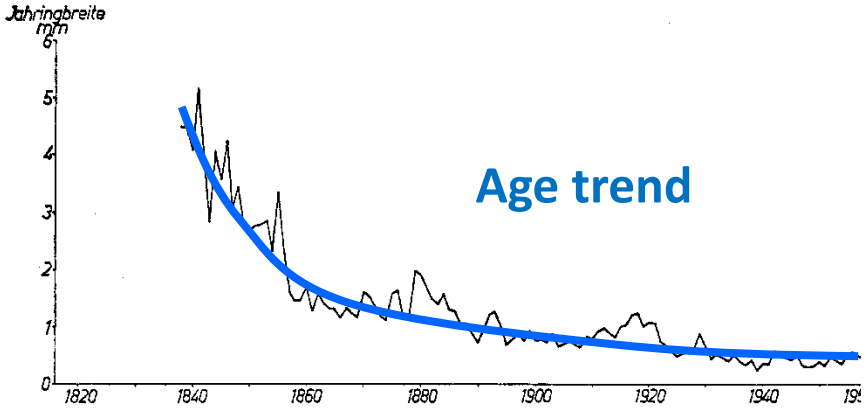
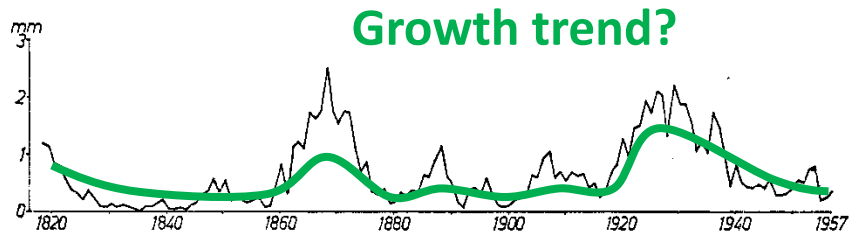
(Douglas fir, Mooswald, date of cutting: 27.04.2006)

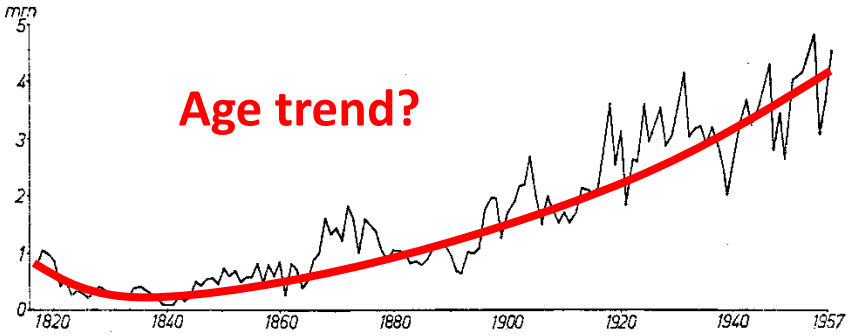
Radial increment of forest trees in the Black Forest

Age class forest (Fir)



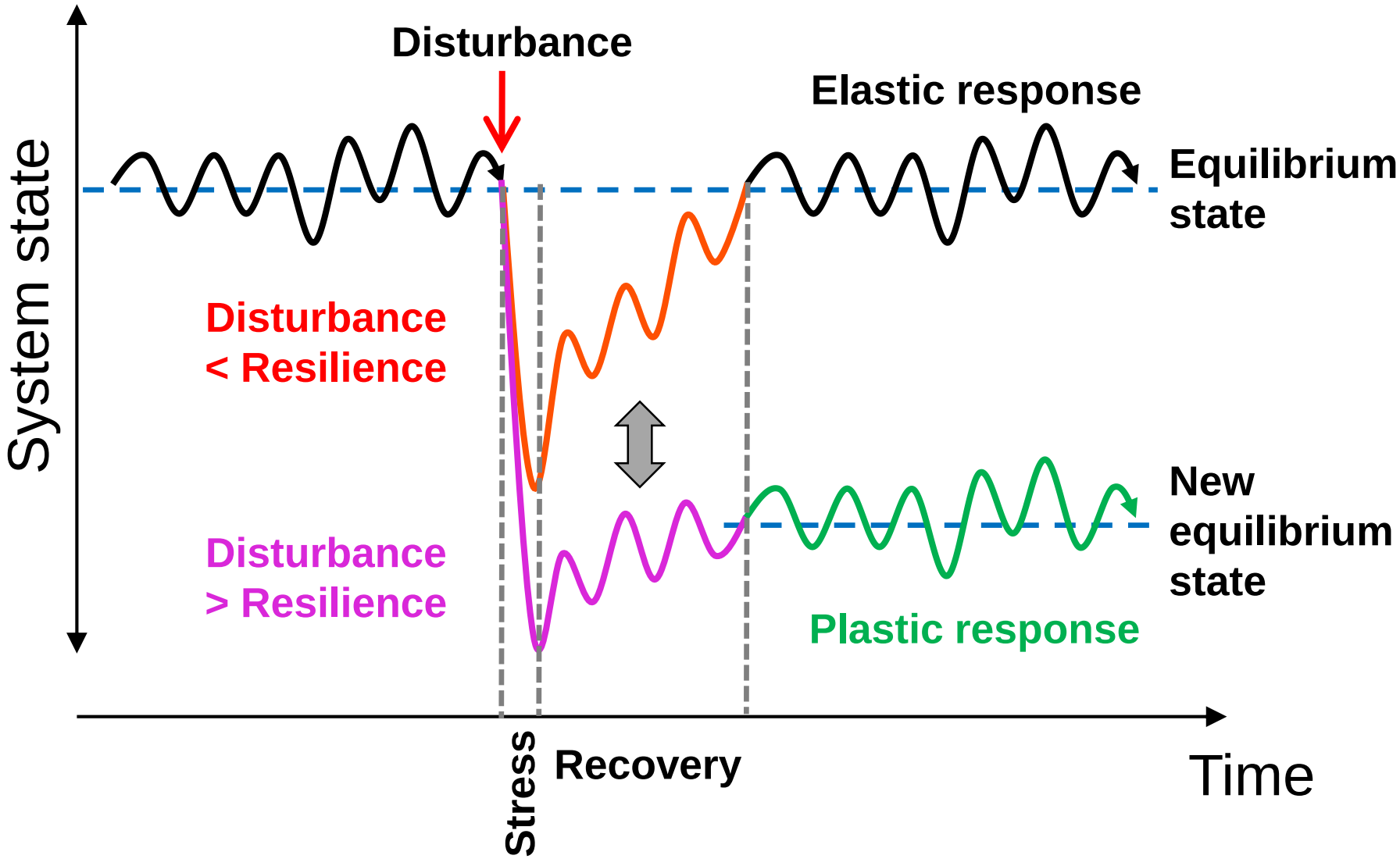
Plenterwald (Fir)





(acc. to Mitscherlich, 1978)

Disturbances and resilience of forest ecosystems



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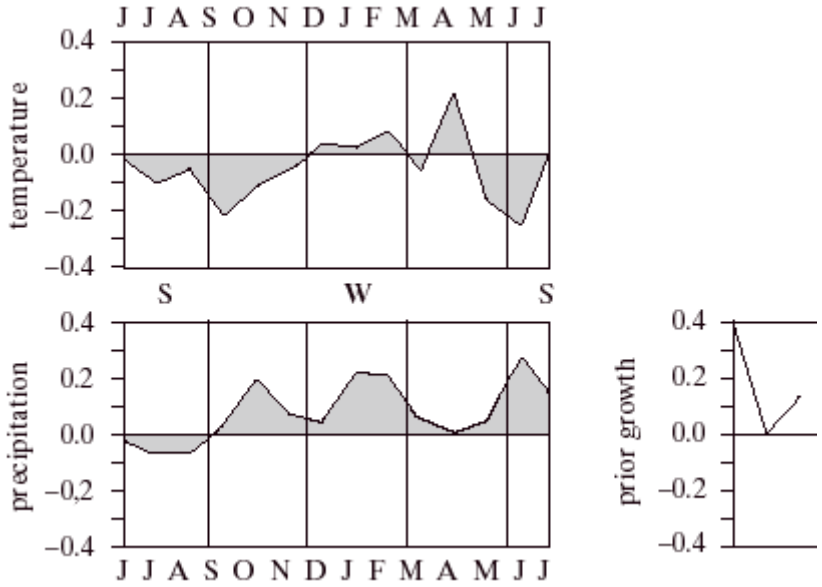
- **Methods**
  - Detrending
  - Chronology building
  - Response function

(adapted after Puettmann et al. 2015)

Response function analysis

- **multiple regression technique** using the **principal components (PCs) of monthly climatic data** to estimate **indexed values of ring-width** growth.
- the regression coefficients are then multiplied by the PCs of climate to obtain a new set of regression coefficients related to the original monthly climatic data variables.



Results from response function analyses (A) for temperature and precipitation (previous June to current July) and autocorrelation analyses (B) for a 3-year period (semi-arid sites in the American Southwest). (Fritts 1976)

(http://www.wsl.ch/dendro/products/dendro_glossary)

Weblinks

Ultimate Tree-Ring Web Pages
http://web.utk.edu/~grissino/

Multilingual Glossary of Dendrochronology
http://www.wsl.ch/dendro/products/dendro_glossary

Dendrochronology Program Library
http://www.ltrr.arizona.edu/pub/dpl/

Dendrochronology Program Library in R
https://cran.r-project.org/web/packages/dplR/index.html

Climate explorer
https://climexp.knmi.nl/start.cgi

International Tree-Ring Data Bank
http://www.ncdc.noaa.gov/paleo/treering.html

Gesellschaft für Jahrringforschung / Association for Tree-Ring Research
http://www.tree-ring.org/