Neotoma Paleoecology Database

European Pollen Database

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Depth-age models

What are they for and how to make them?
Some examples using the EPD

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https://petr.kunes.net/ | https://gilromera.com/

Our palaeoecological interpretations can only be as good as our chronological (un)certainties.

Neotoma Paleoecology Database

European Pollen Database

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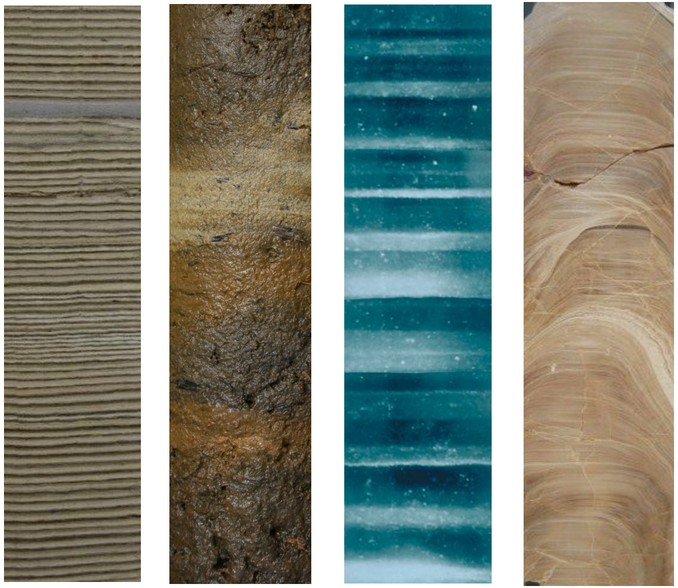

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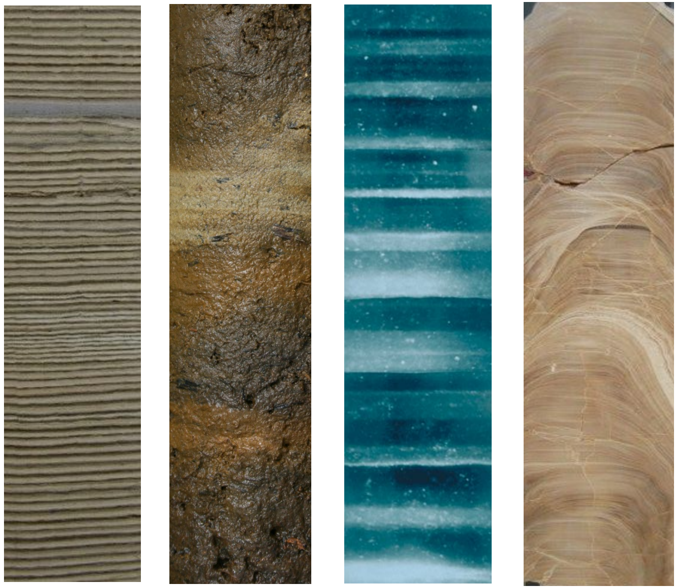
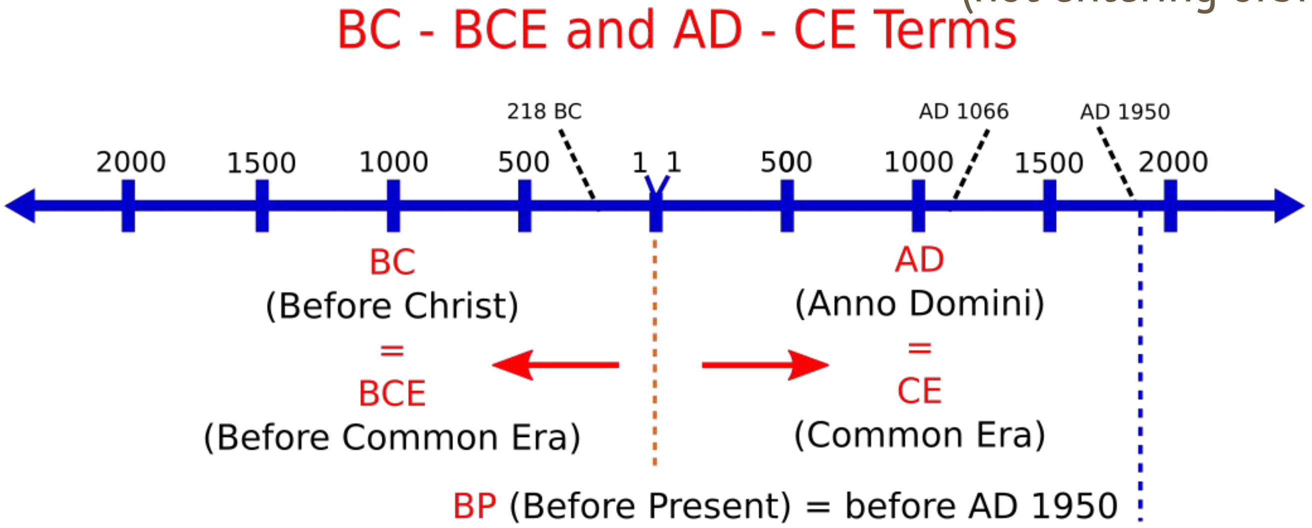


Our palaeoecological interpretations can only be as good as our chronological uncertainties.

What is our timeline?

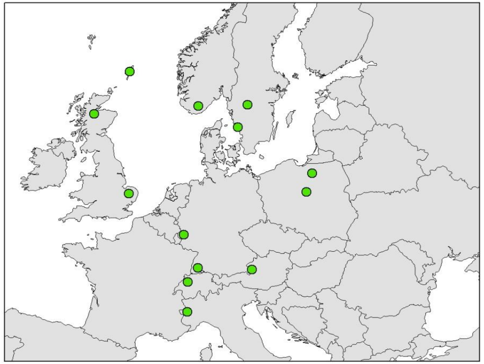
(not entering orbital descriptions)



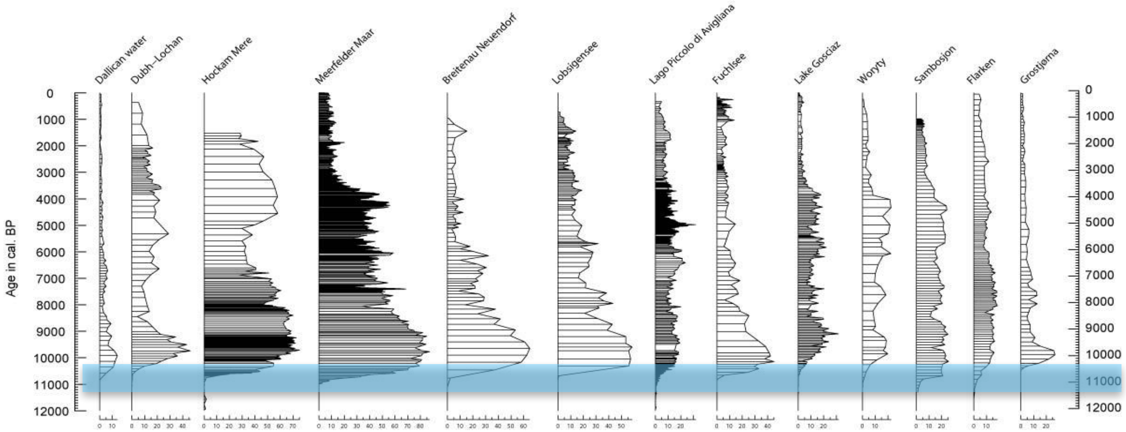
- BC/AD: Before Christ - Anno Domini
- BCE-CE: Before Common Era - Common Era
- BP: Before Present, 1950 CE

No-zero value

Dating techniques - absolute vs relative



Corylus



Dating techniques - absolute vs relative

Quaternary Science Reviews 117 (2015) 1–41

Contents lists available at ScienceDirect

Quaternary Science Reviews

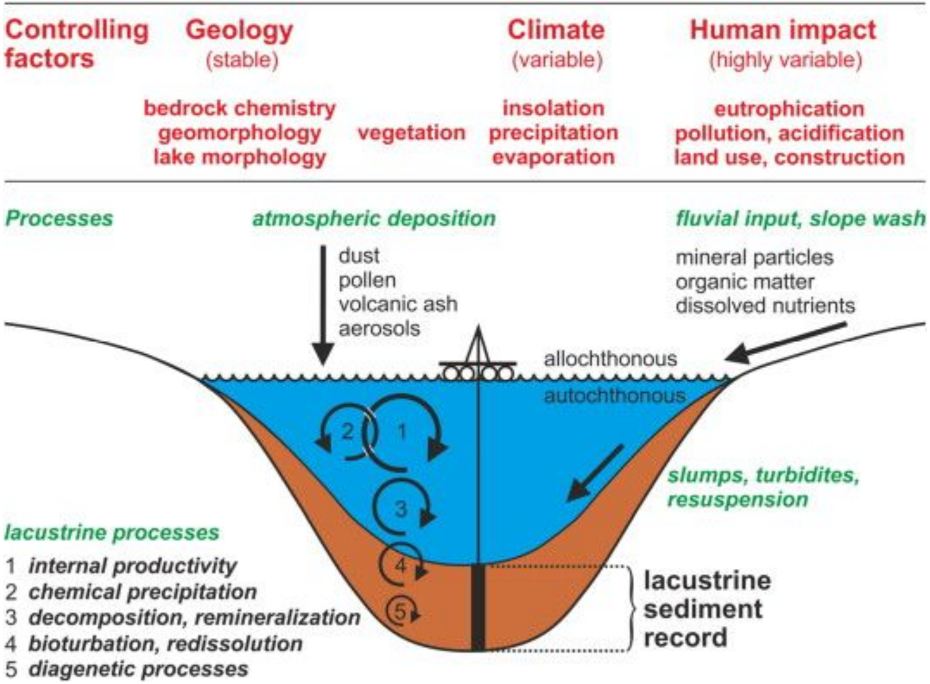
journal homepage: www.elsevier.com/locate/quascirev

Invited review

Varves in lake sediments – a review

Bernd Zolitschka [a, *], Pierre Francus [b, c], Antti E.K. Ojala [d], Arndt Schimmelmann [e]

Dating techniques - absolute vs relative

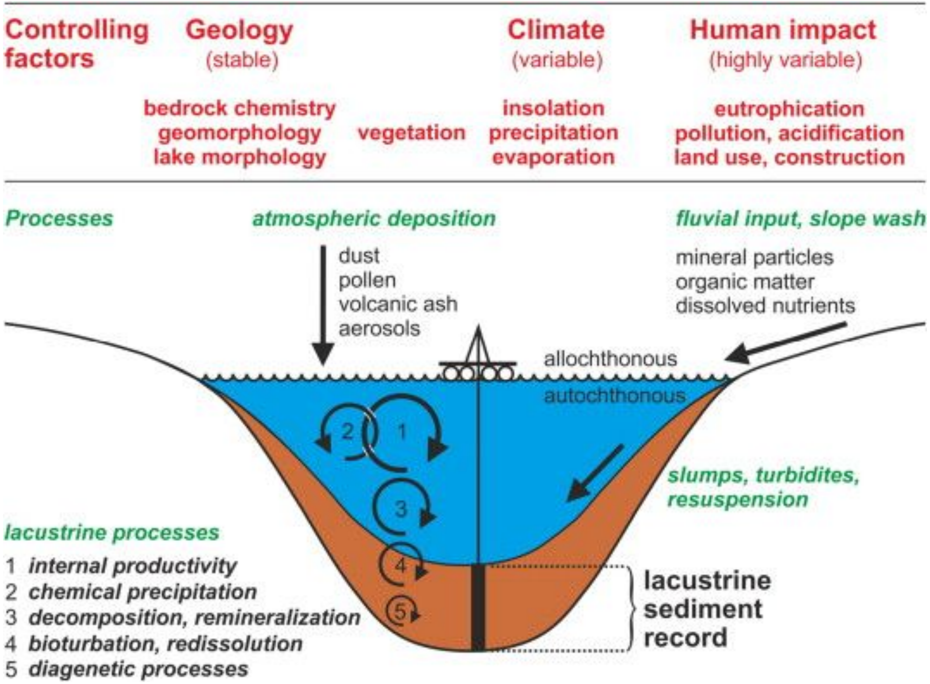


[Zolitschka, B., et al 2015. Varves in lake sediments – a review. Quaternary Science Reviews 117, 1–41.]()

Dating techniques - absolute vs relative

Radiometric dating

- ^{14}C
- U/Th
- ^{210}Pb
- ^{36}Cl
- ^{40}Ar
- Luminescence (not technically a radiometric one)



[Zolitschka, B., et al 2015. Varves in lake sediments – a review. Quaternary Science Reviews 117, 1–41.]

Dating techniques - absolute vs relative

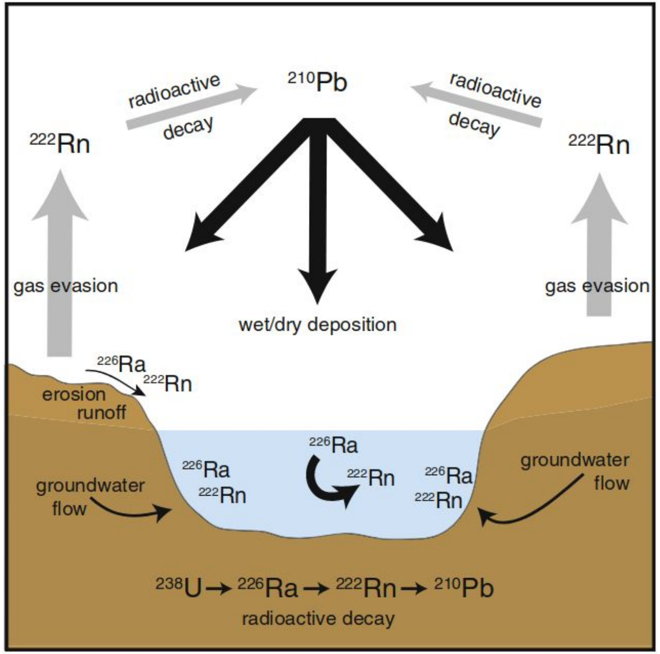
Radiometric dating

- **^{210}Pb**

Pb-210 is a naturally occurring radionuclide of the 238U radioactive decay chain and has a half-life of 22.23 years.

- Does not experience seasonal variations, and atmospheric concentration is constant → No need to transform into calendar years, so no calibration.

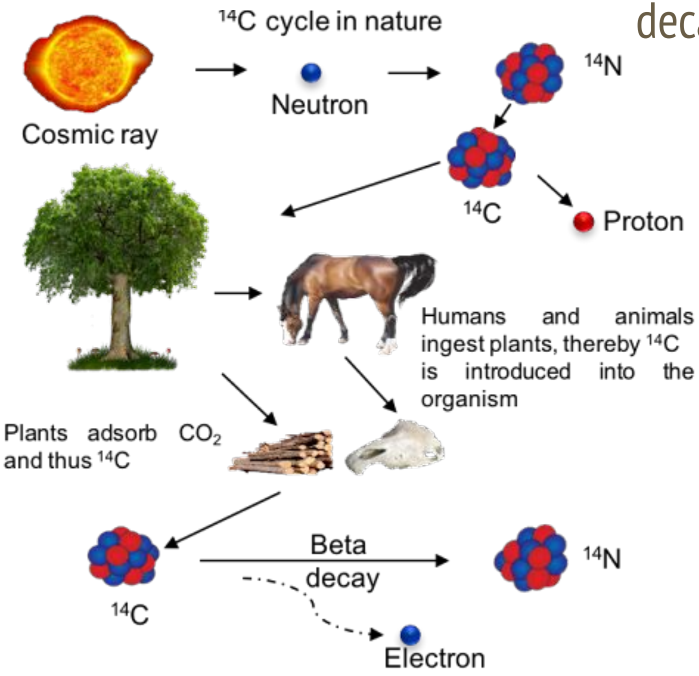
- Needs different depositional models.



Dating techniques - absolute vs relative

Radiometric dating ^{14}C

All living organisms fix ^{14}C, a carbon isotope which half-life time decay is known.



When an animal or plant dies, it will not take in any more carbon, and the 14C present will begin to decay. We can thus measure how long it's been since the animal or plant died by comparing the presence of 14C with the known half-life.

http://dfna.nipne.ro/RadioCarbon/dating.php

Calibrating, why and how?

Radiometric dating ^{14}C

14C dating provides “radiocarbon measurements”, i.e. a date that we cannot accurately place in a calendar:

Changing atmospheric concentration of ^{14}C over time

- fluctuations in the Earth's geomagnetic moment,
- fossil fuel burning,
- and nuclear testing.

^{14}C

Radiometric dating ^{14}C

Calibrating, why and how?

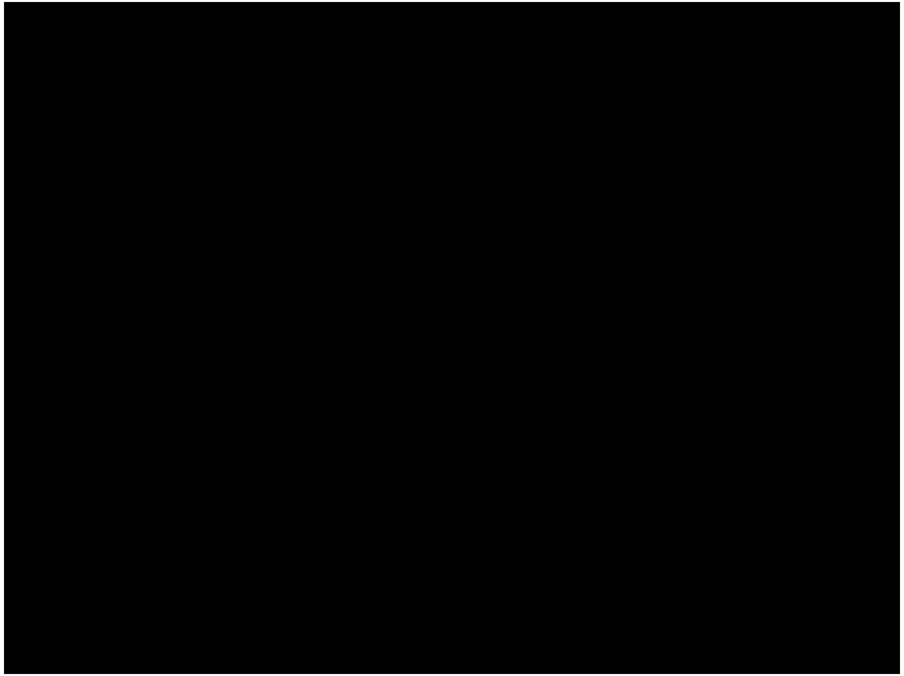
Calibration algorithm = curve

"Bristlecone pines" rings *Pinus longaeva* D.K.Bailey

Paula Reimer

Calibrating, why and how?

Calibration algorithm = curve

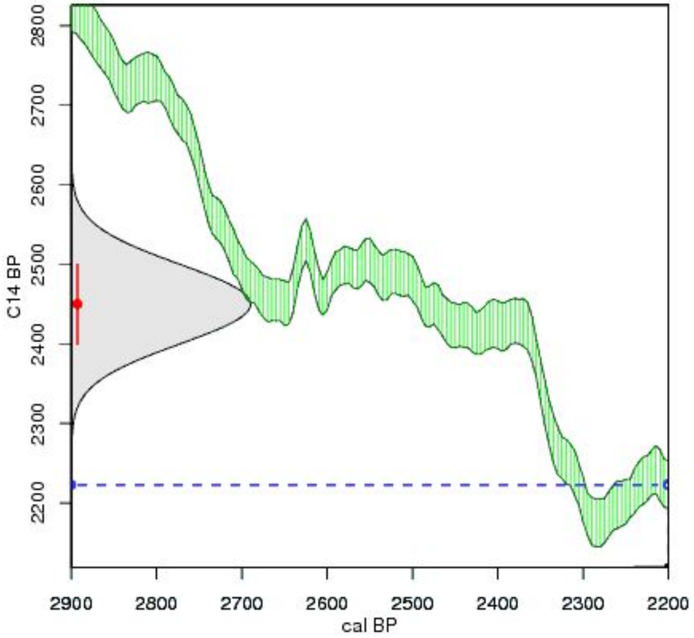


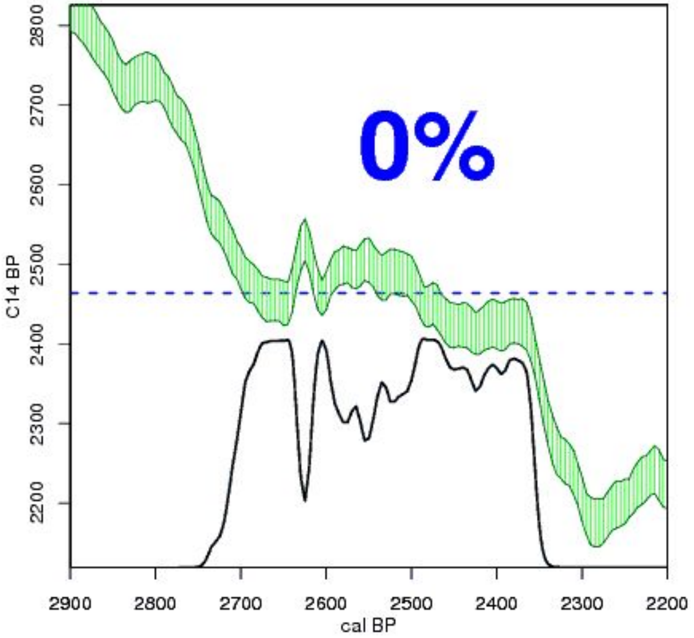
Maarten Blaauw

https://maarten14c.github.io/

Calibrating, why and how?

Calibration of a single date





Let's calibrate!

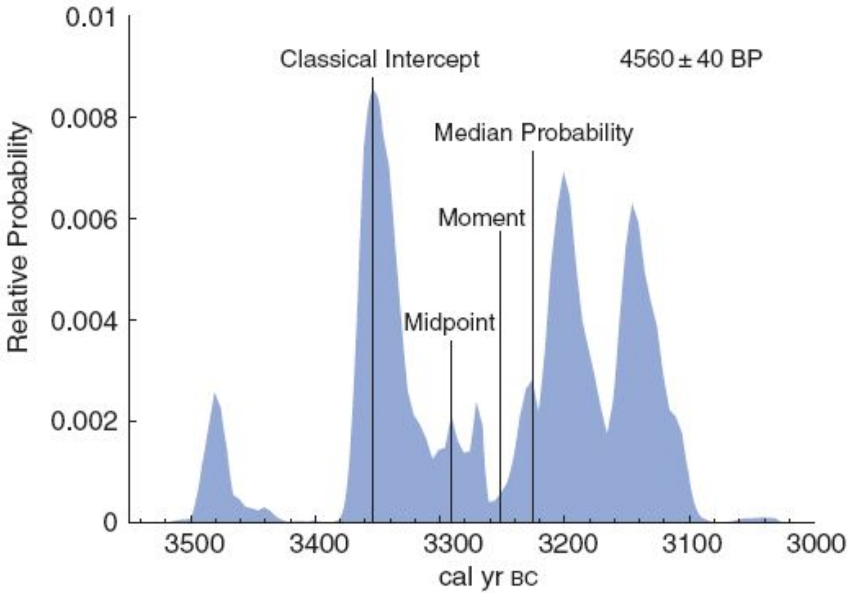
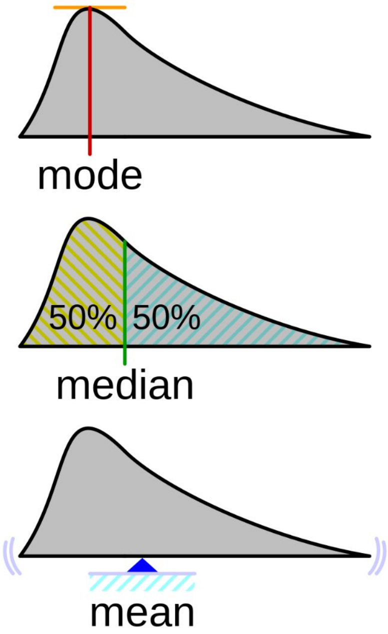


Figure 4 Age estimators for the probability distribution of the radiocarbon age 4560 ± 40 BP calculated with the IntCal04 calibration curve, including the classical intercept of the radiocarbon age with the calibration curve, the midpoint of the 95% cal age ranges, the median probability, and the moment or weighted average of the probability distribution.



Let’s calibrate!

Open your script and the handout and let’s calibrate!

Coming back to our aim: depth and age

Maarten Blaauw

All models will make assumptions that you'll carry with you in your interpretations.

Coming back to our aim: depth and age

ELSEVIER

Quaternary Science Reviews 23 (2004) 1–5

Rapid Communication

All age–depth models are wrong: but how badly?

R.J. Telford[a,*], E. Heegaard[a,b], H.J.B. Birks[a,b,c]

[a] Bjerknes Centre for Climate Research, University of Bergen, Allégaten 55, N-5007 Bergen, Norway
[b] Botanical Institut
[c] Environmental Change Research (

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The Holocene
1–10
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DOI: 10.1177/0959683616675939
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All age–depth models are wrong, but are getting better

Mathias Trachsel[1,2] and Richard J Telford[1,3]

All models will make assumptions that you'll carry with you in your interpretations.

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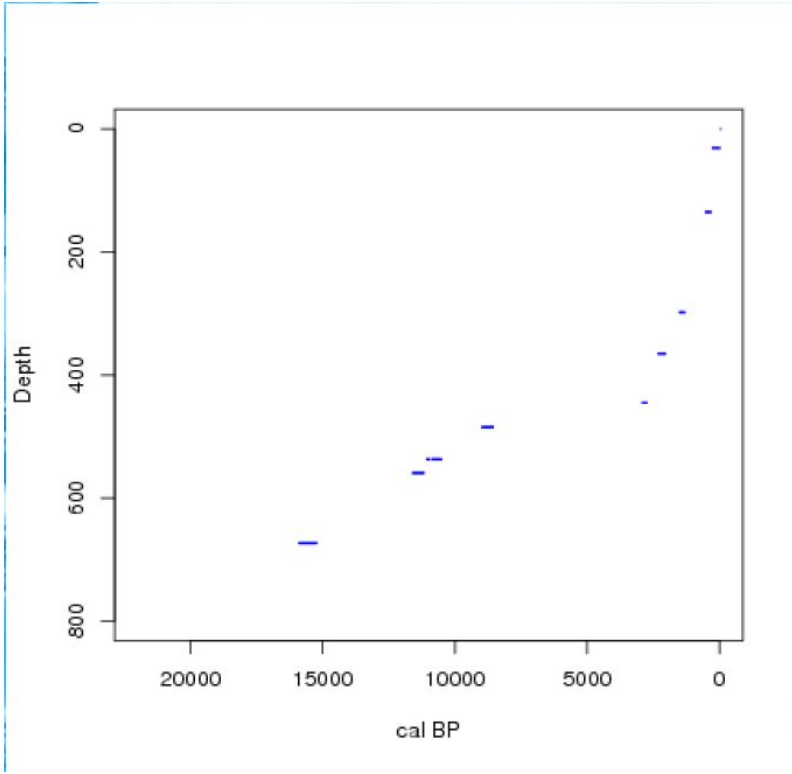
Depth and age: classical modeling, CLAM

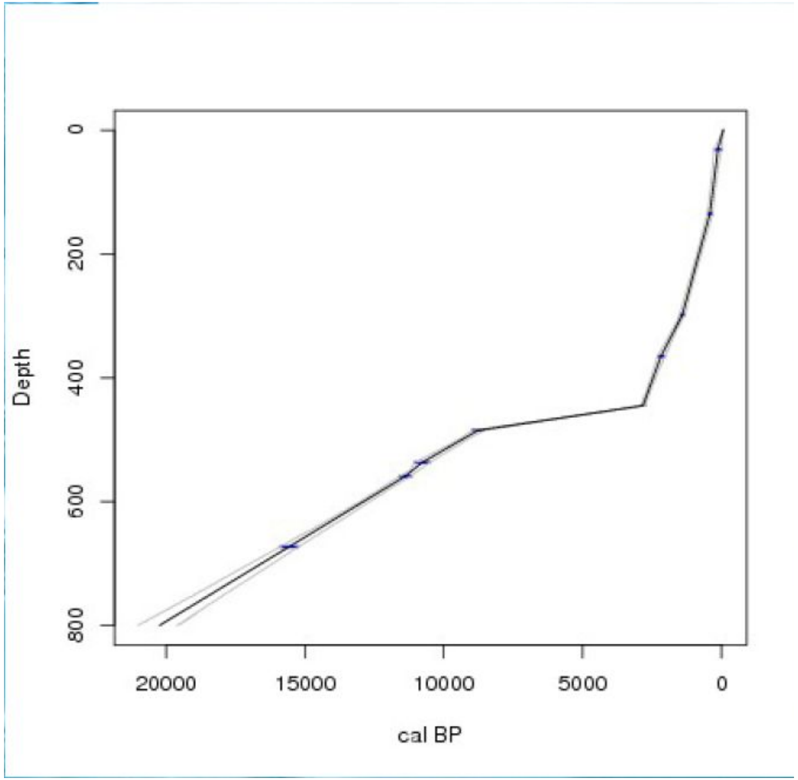
800cm

nine 14C dates

! core longer than last tie point



Depth and age: classical modeling, CLAM



800cm | nine 14C dates

Linear interpolation

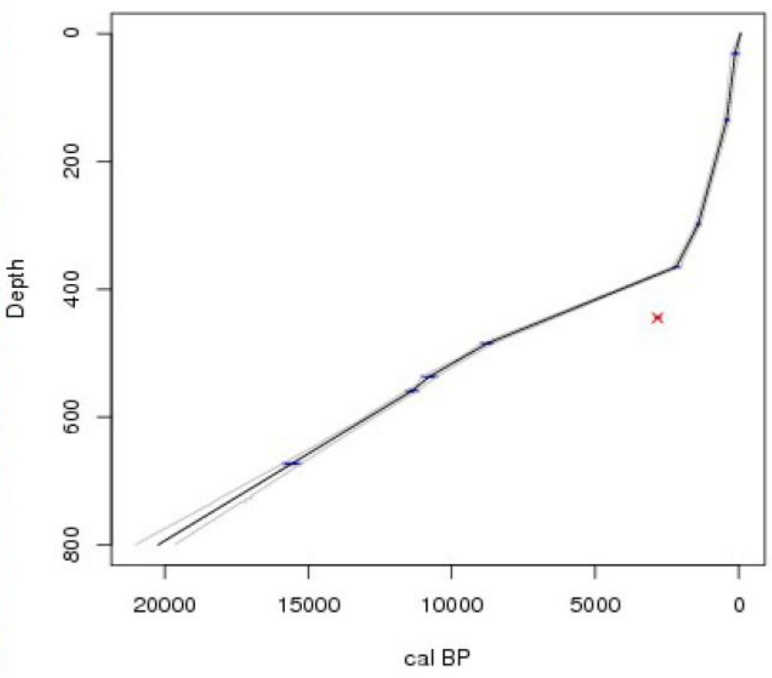
- Extrapolation
- Reliable dates?

Depth and age: classical modeling, CLAM

800cm | nine 14C dates

Linear interpolation

- Outlier?
- Else?



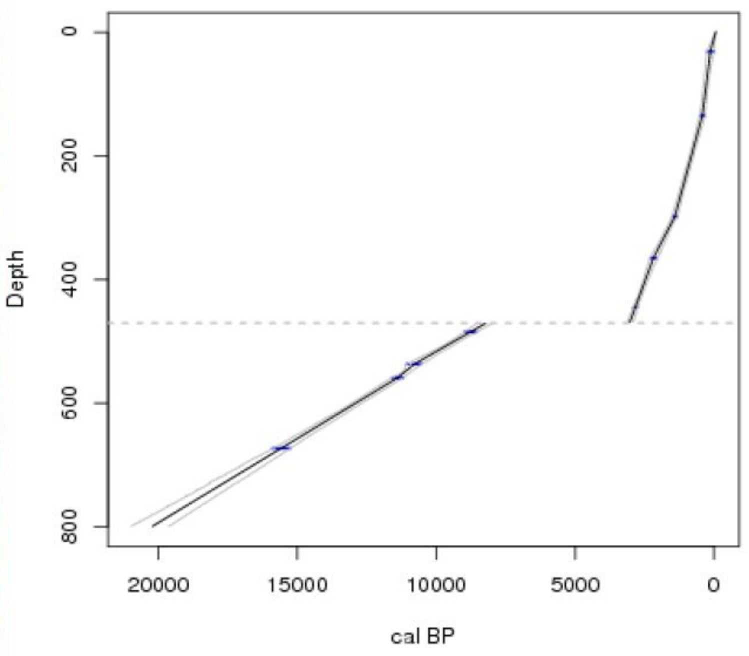
Depth and age: classical modeling, CLAM

800cm | nine 14C dates

Linear interpolation

- Hiatus?

Time “jump” with no sedimentation: erosion, cold spells, sediment lost/alterations.



Depth and age: classical modeling, CLAM

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Linear interpolation

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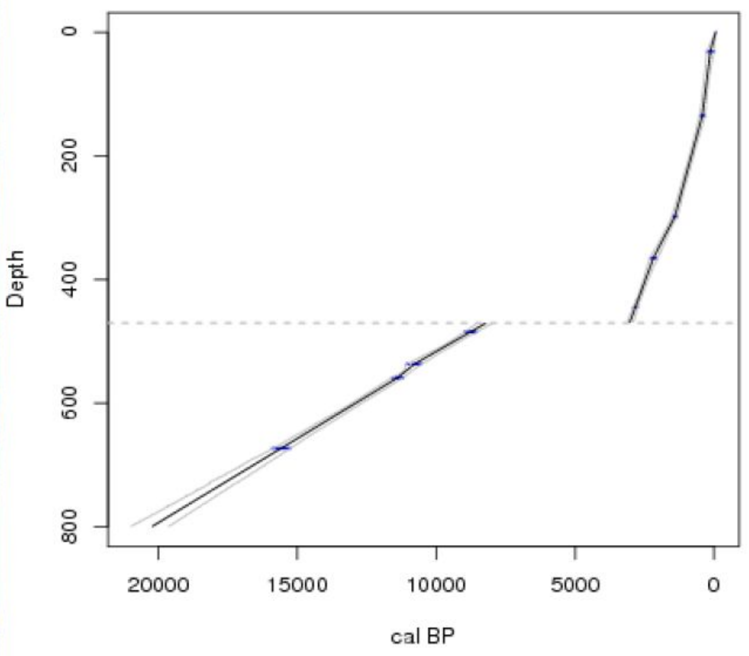
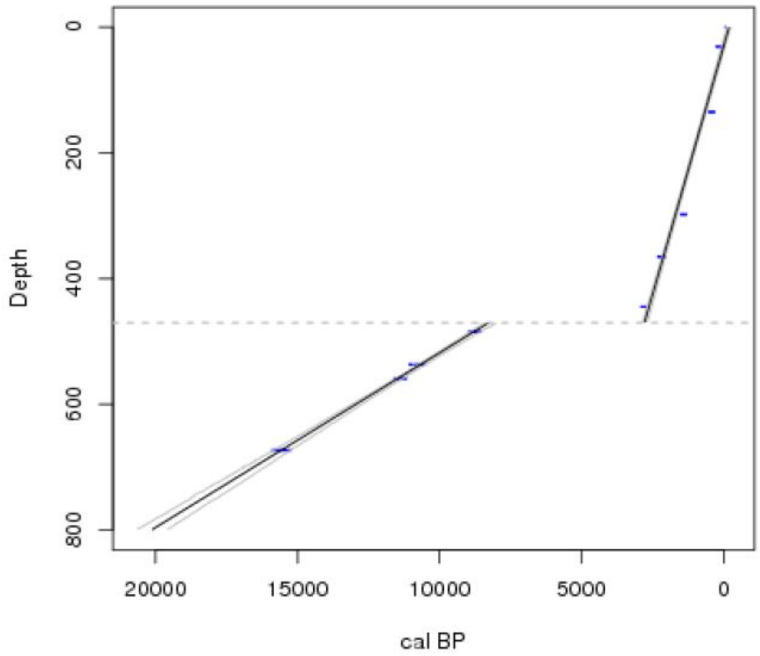


Depth and age: classical modeling, CLAM

800cm | nine 14C dates

Linear regression

Does not make optimal fitting but over-optimistic uncertainties.



Depth and age: classical modeling, CLAM

800cm | nine 14C dates

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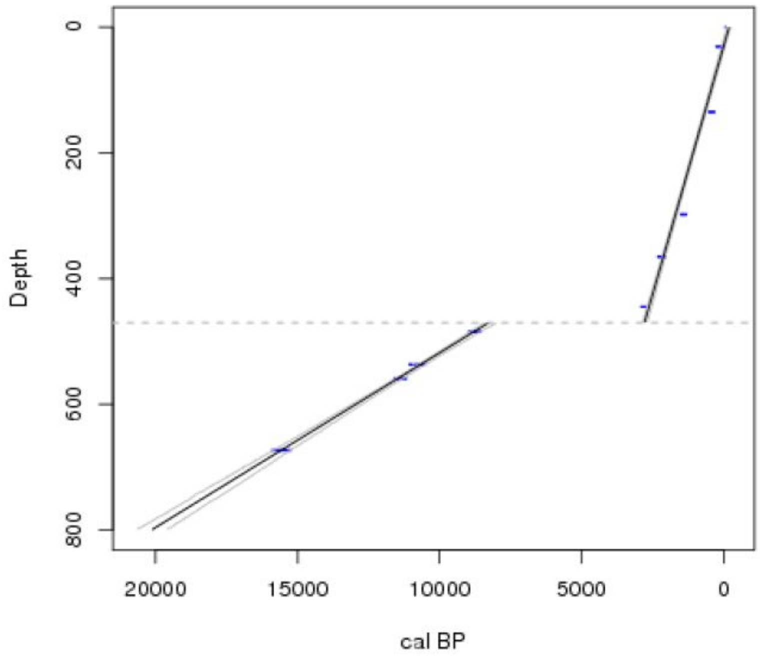
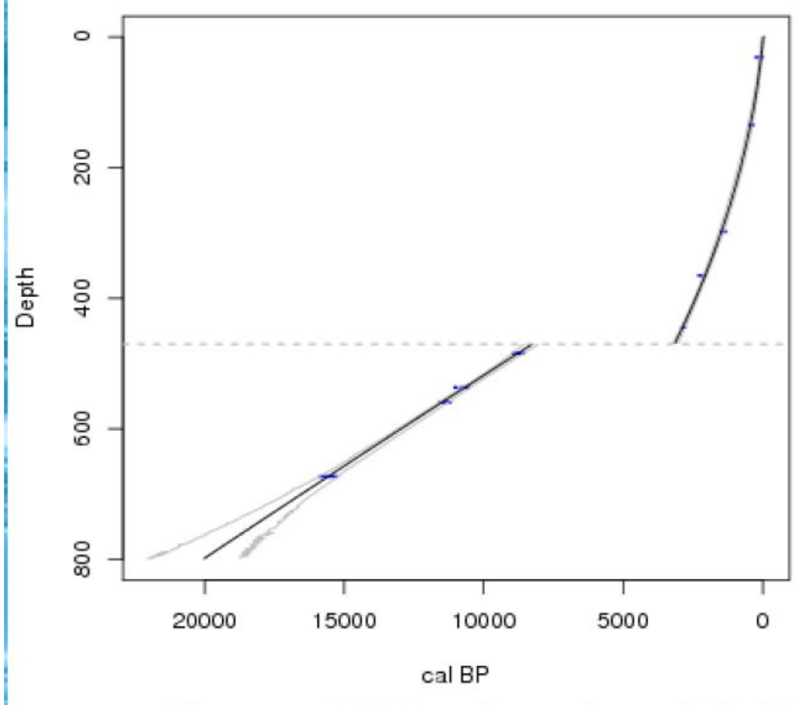


Depth and age: classical modeling, CLAM

800cm | nine 14C dates
Polynomial

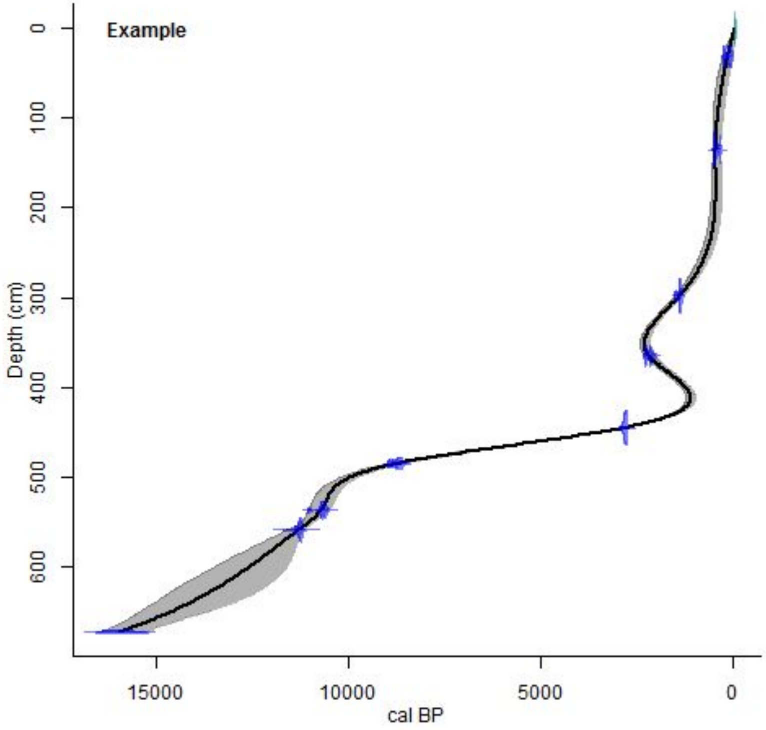
Interesting sedimentation for the last 5ka, but extrapolation also produces funny uncertainties.



Depth and age: classical modeling, CLAM

Splines

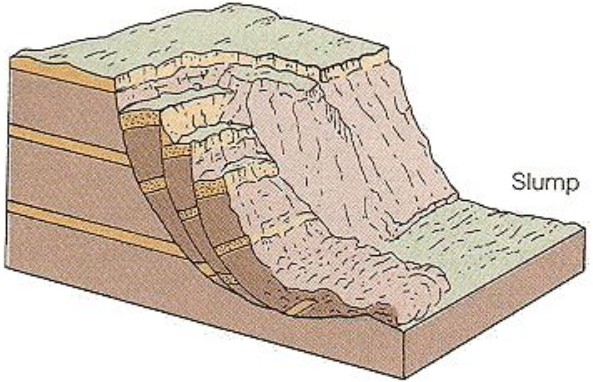
May produce aberrant sedimentation patterns (like going back in time)

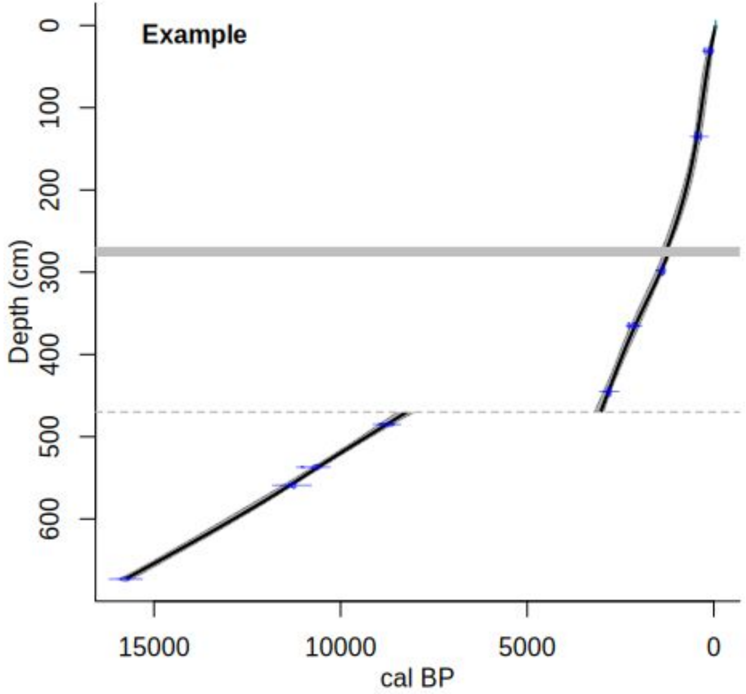


Depth and age: classical modeling, CLAM

Slumps

Instant events of sedimentation that can also be modeled.





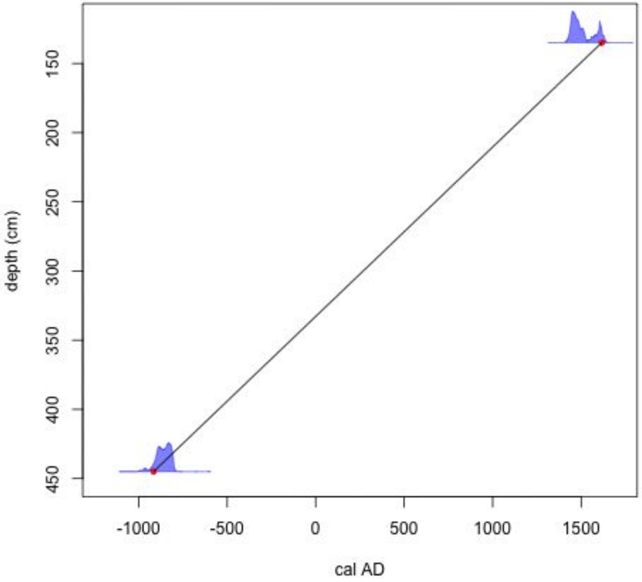
Depth and age: classical modeling, CLAM

Let’s try some depth-age modelling with CLAM!

How is uncertainty treated? CLAM

Linear interpolation vs flexible random process

The further away the more certain



How is uncertainty treated? CLAM

Linear interpolation vs flexible random process

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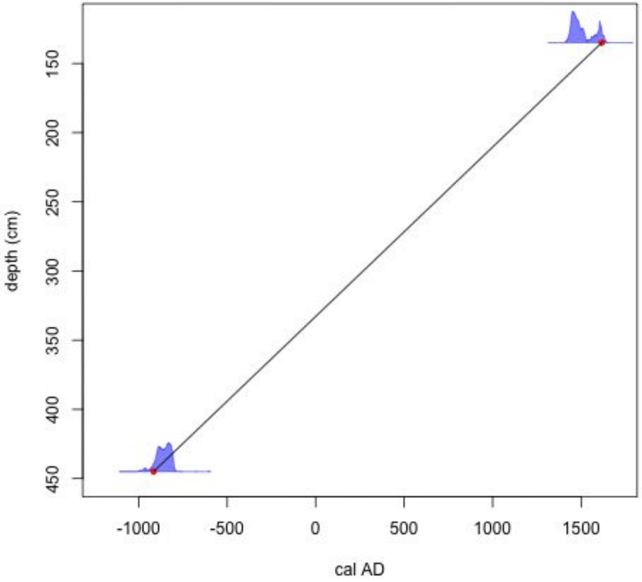
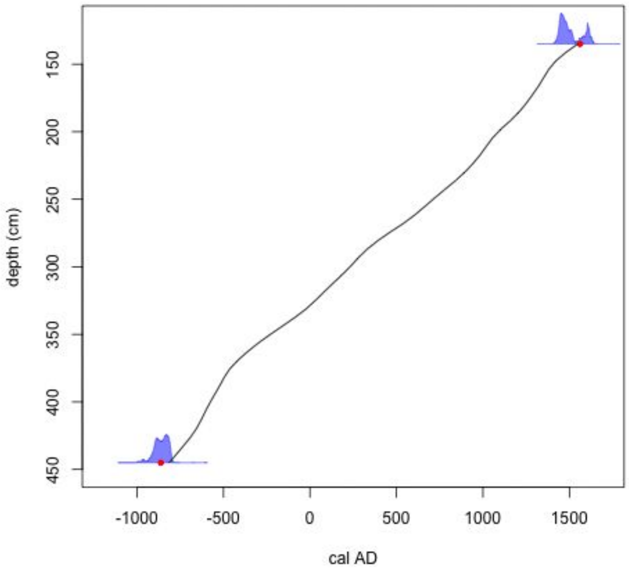


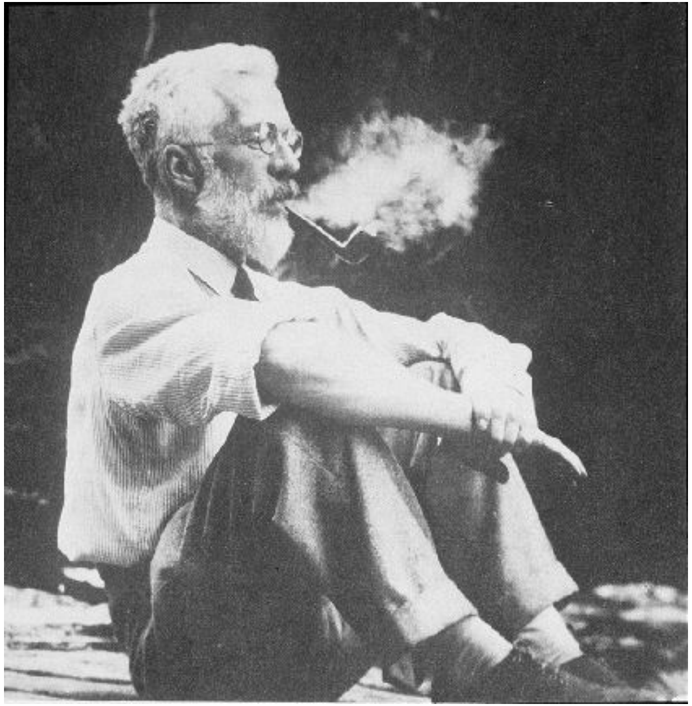
Monte Carlo iteration

The further away the less certain



How is uncertainty treated?
Bayesian inference

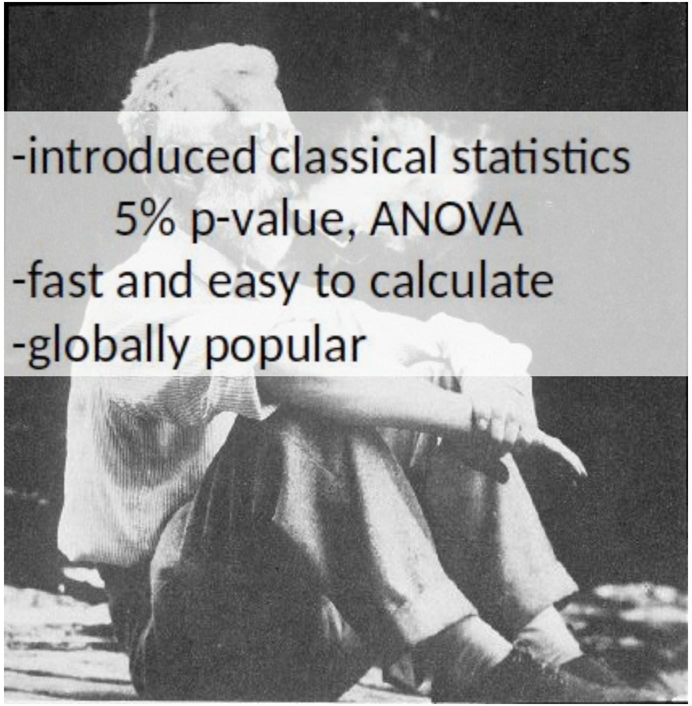
Sir Ronald Fisher (1890-1962)



Rev. Thomas Bayes (1701-1760)

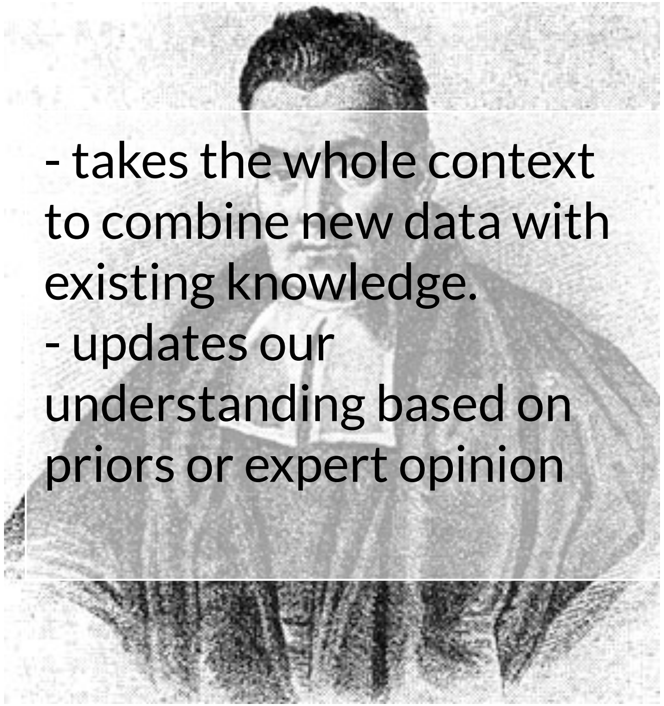
How is uncertainty treated? Bayesian inference

Sir Ronald Fisher (1890-1962)



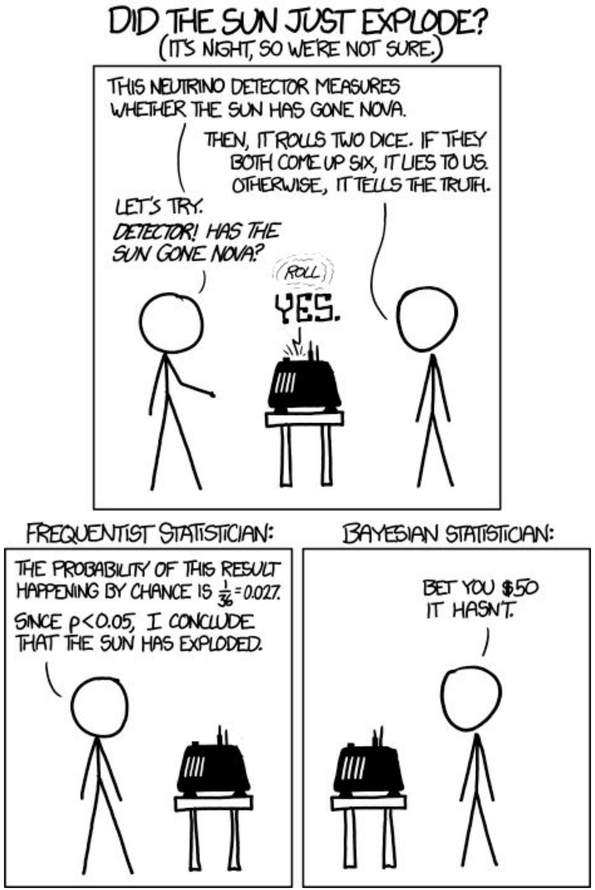
-introduced classical statistics
5% p-value, ANOVA
-fast and easy to calculate
-globally popular

Rev. Thomas Bayes (1701-1760)



- takes the whole context to combine new data with existing knowledge.
- updates our understanding based on priors or expert opinion

How is uncertainty treated? Bayesian inference



- Bayesian inference makes guesses based on information that is constantly updated.
- It is context-dependent.
- Can work asking about past events and future events.
- Examples:
    - Frequentist: coin, prob. of heads?
    - Bayesian: what's the probability that I have 30€ in my pocket?

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How is uncertainty treated? Bayesian inference

Update our understanding, by combining prior information with new data

$$p(\,A \mid B\,) \propto l(\,B \mid A) * p(A)$$

$$p(\,\text{prior} \mid \text{data}\,) \propto l(\,\text{data} \mid \text{prior}) * p(\text{prior})$$

How does this translate to building a depth age model?

How does this translate to building a depth age model?

- MCMC: Markov-chain Monte Carlo
  - Produce initial series of values that fit the data and obey the prior.
  - For next iteration, randomly change one value by a bit.
  - Accept if this enhances the fit, otherwise possibly accept.
  - Repeat millions of times (thin to reduce similarity between iterations)

- All iterations together approach the true distributions of the parameters

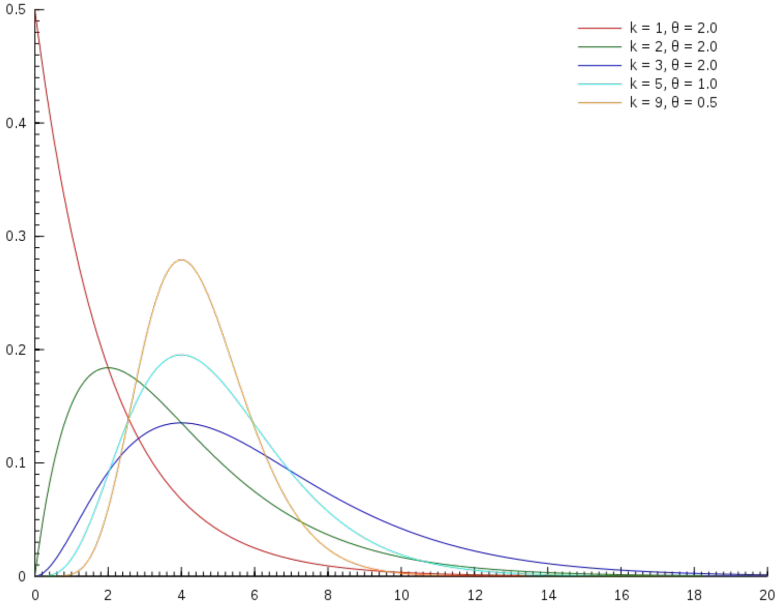
Bayesian age models
Bacon

How does this translate to building a depth age model?

https://vimeo.com/602543020

https://vimeo.com/602585449

https://vimeo.com/602585477



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How is uncertainty treated? Bayesian inference

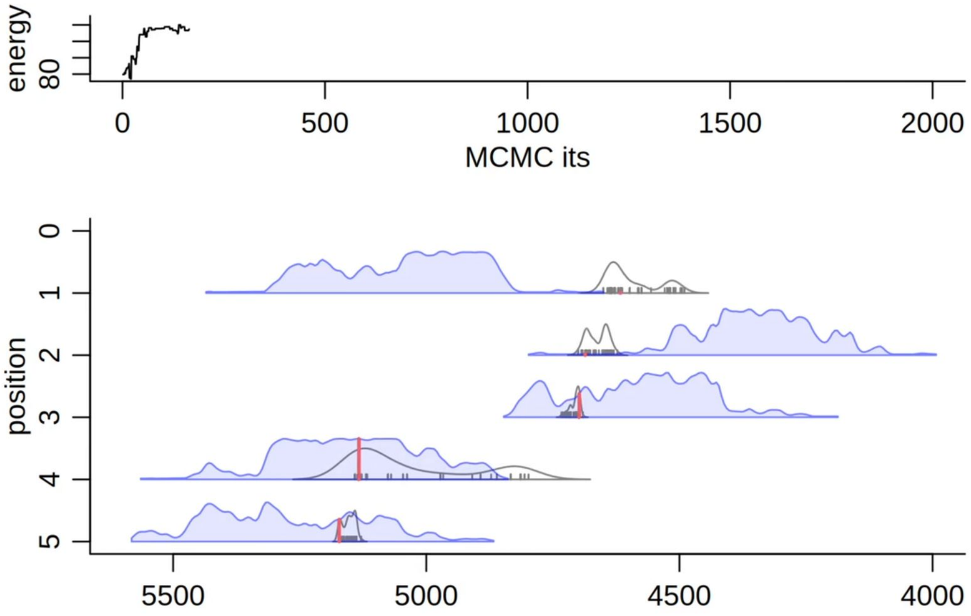
How does this translate to building a depth age model?

Example: five radiocarbon dated depths from a sequence

- We model them to be in chronological order
- Simulate 5 initial ‘ball-park’ values (years) in chronological order
- Calculate how well they fit the calibrated radiocarbon dates
- Now randomly change one of the values by a bit
- Check that the values remain in chronological order
- Accept if the fit has enhanced, possibly accept if not
- Repeat millions of times (thin, remove burn-in)

How is uncertainty treated?
Bayesian inference

How does this translate to building a depth age model?



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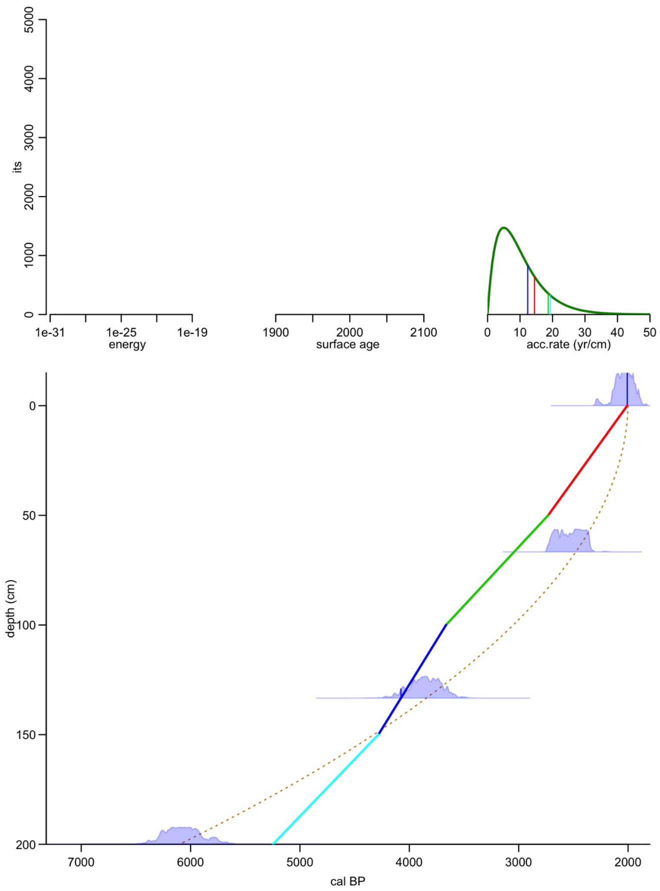
How is uncertainty treated? Bayesian inference

How does this translate to building a depth age model?

Piece-wise linear age-depth model

- Divide 200 cm core into 4 50cm-sections (section elbows not necessarily where dates are)
- Linear accumulation rate within each section (gamma prior distr)
- 4 14C dates
- For each iteration, calculate product of p(priors) * p(dates)

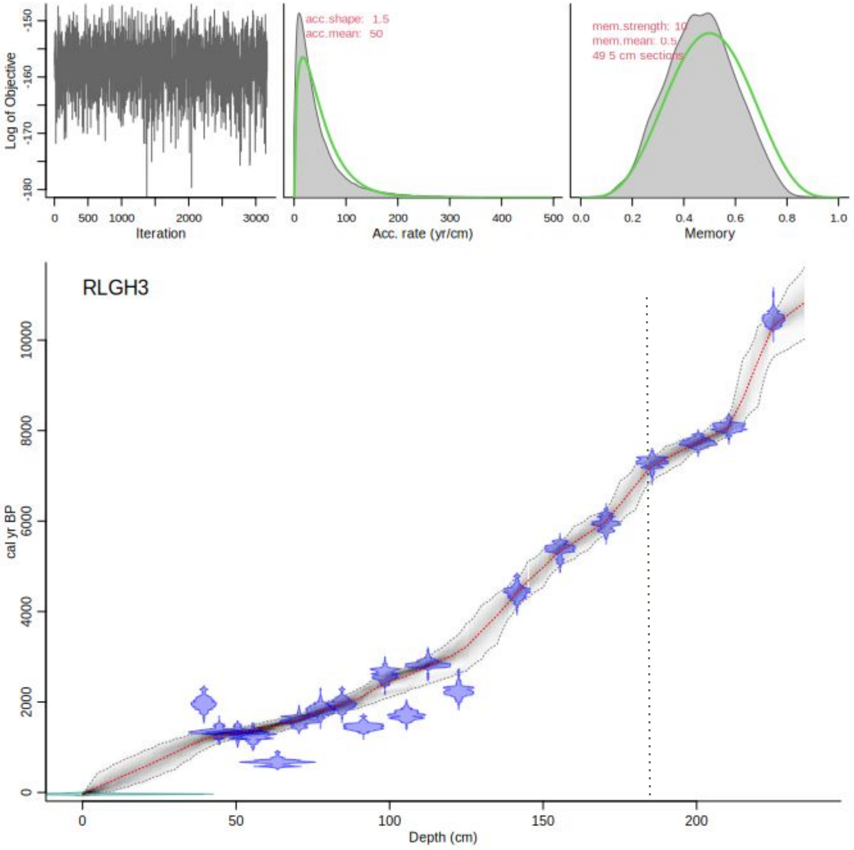
How is uncertainty treated? Bayesian inference



- Ballpark iteration: simulate accs. from gamma prior
- 4 likelihoods for accs (heights of prob. distr.)
- Also simulate top date (uniform)
- This defines the entire model
- Now calculate fit of model w dates
- 4 likelihoods for dates

https://vimeo.com/548372489

How is uncertainty treated? Bayesian inference



- Only accept iterations with correct order,
- Reduces error ranges,
- Removes outliers,
- Flexible modelling, can change the parameters in different sections.
- Easy to defend.

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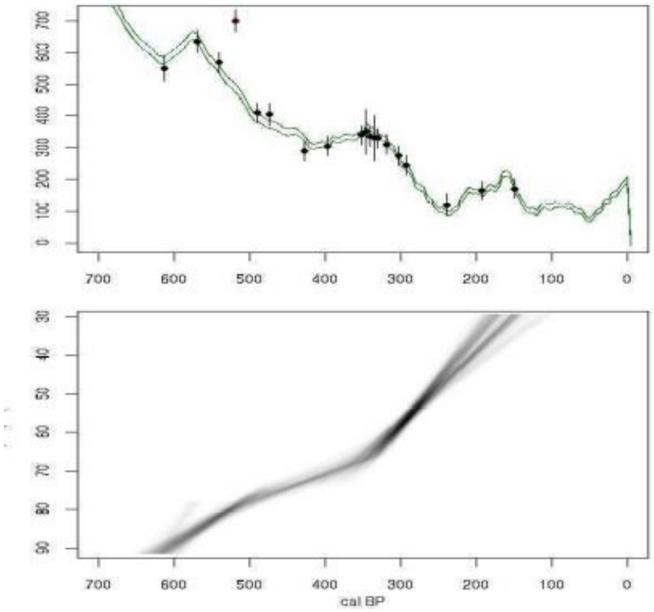
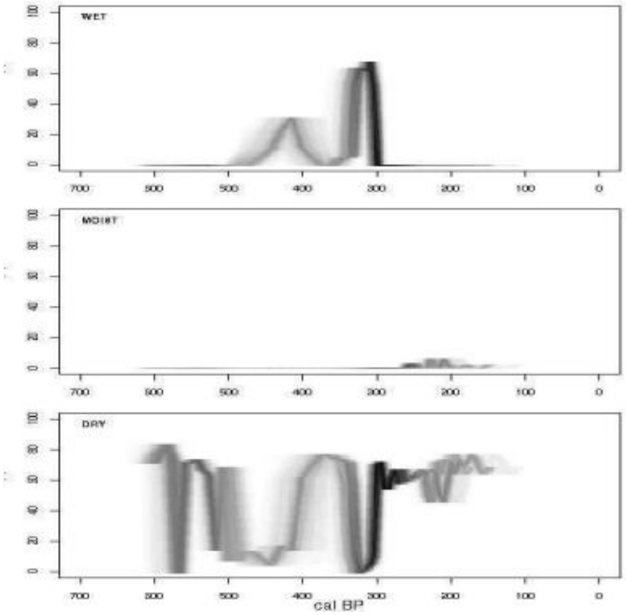
How is uncertainty treated?
Bayesian inference

- Including uncertainties into proxies
- Visual assessment of the sed. rate.





How is uncertainty treated?
Bayesian inference

Some practicals and examples!

Hands on the scripts!

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Depth-age models

What are they for and how to make them?
Some examples using the EPD

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