The University of Sheffield

Department of Probability and Statistics

Uncertainty in Dating Ice Cores

Stories from Ice Cores

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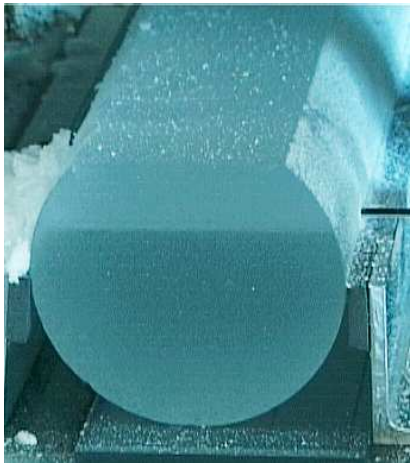
Content

- Introduction to Ice Core Dating
  - Ice Cores as Archives
  - Existing Dating methods
- Some Theory
  - Glaciological Model and its Uncertainty
  - Bayesian Statistics
- Results: Dating Uncertainty in a Toy Example
- Discussion

Introduction to Ice Core Dating

Ice Cores – The Archive

- Preserve valuable information about the climate and environment of the past
- Record chemical composition of snow, dust and atmospheric gases with high resolution for up to 700,000 years and longer [Parrenin et al., 2007]



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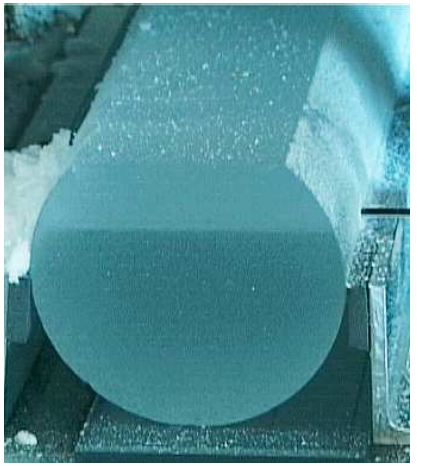

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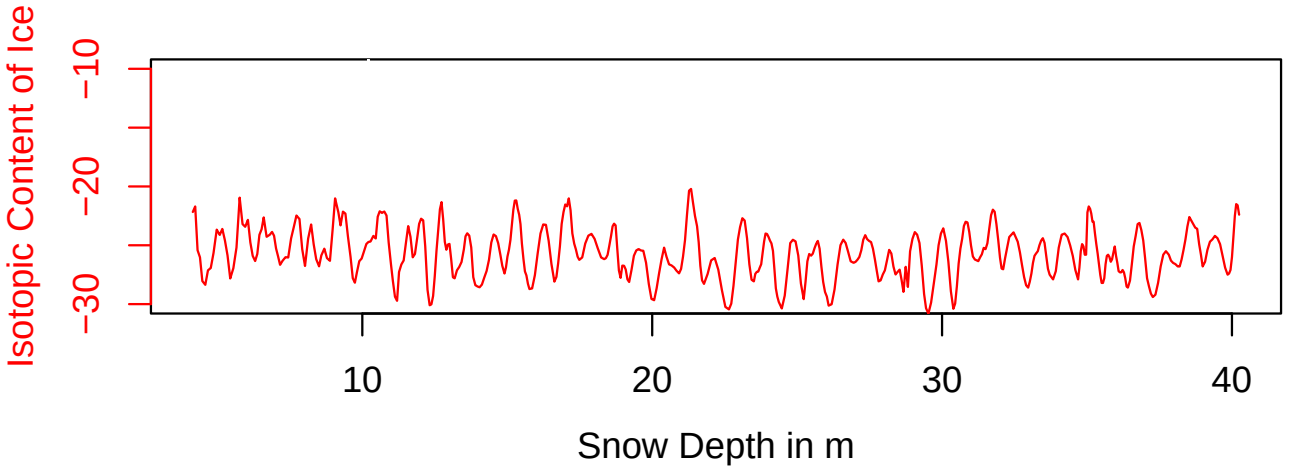

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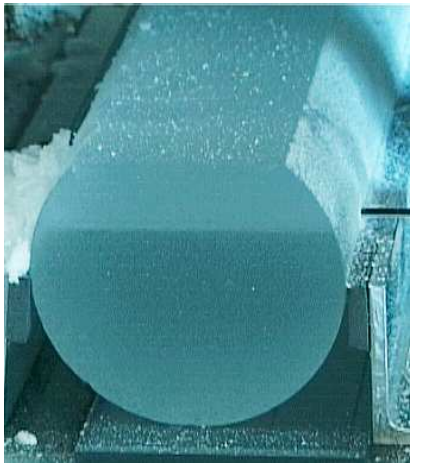

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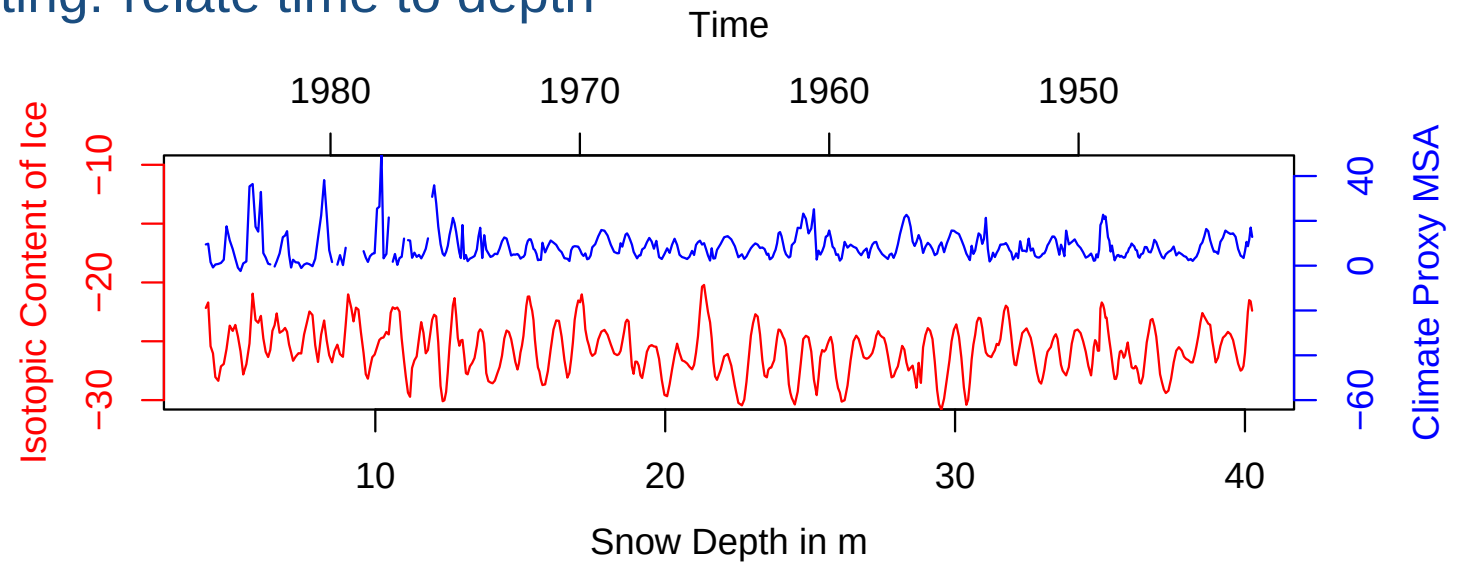

Existing Dating Methods

- layer counting using seasonality in signals

- glaciological modelling
  - model of accumulation:
    estimated from isotopic content of ice
  - model of mechanical processes after accumulation:
    i.e. firn densification, ice flow

- comparison with other dated records
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Uncertainty — a Nuisance?

Comparison with other dated records

- Did certain climatic events occur at different locations?
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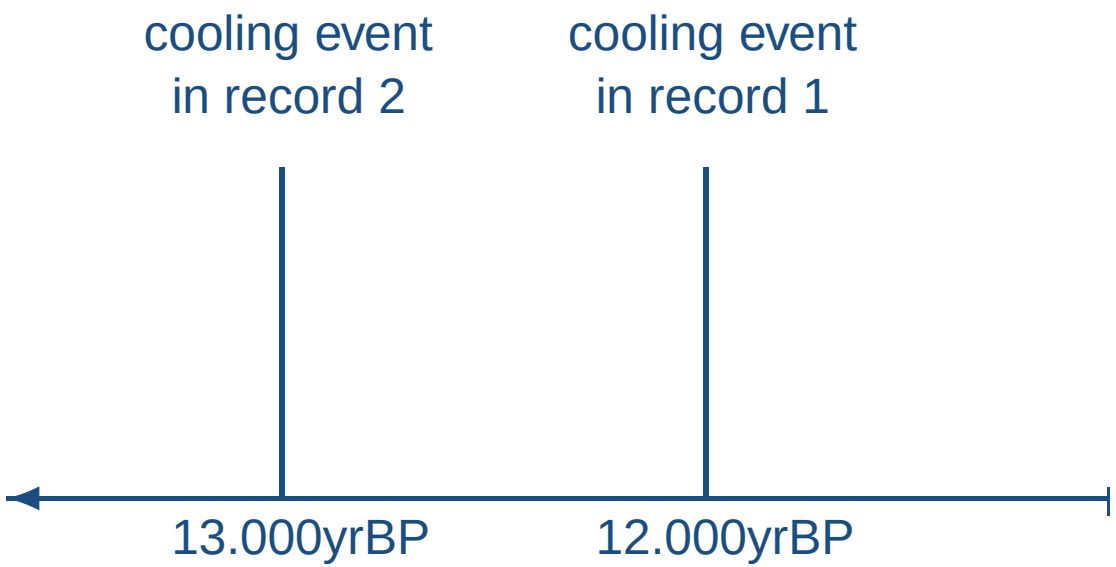

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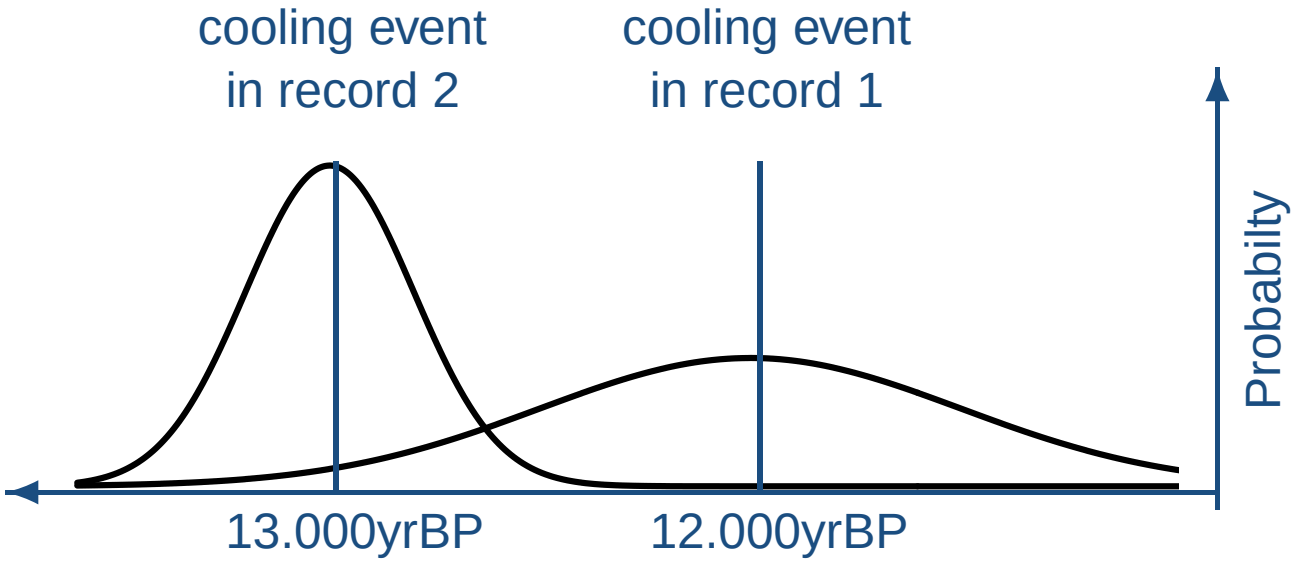

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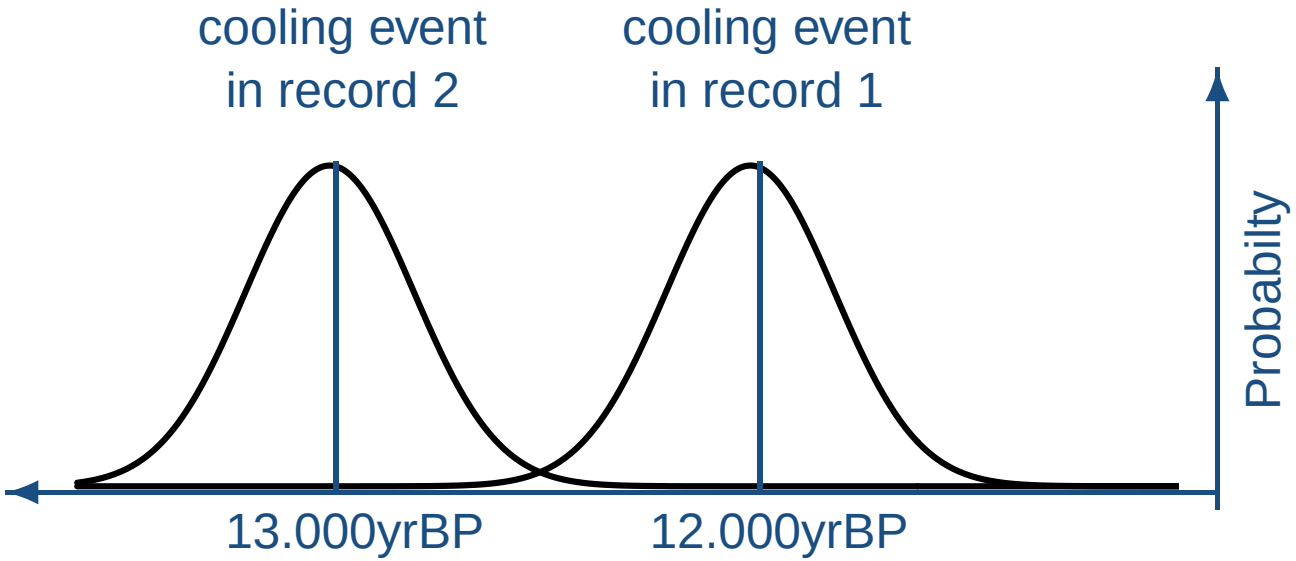

⇒ Quantify uncertainty properly!

Theory in a Nutshell

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Accumulation Model

chemical measurement: isotopic content of ice → annual accumulation rate → times covered by each slice of the core

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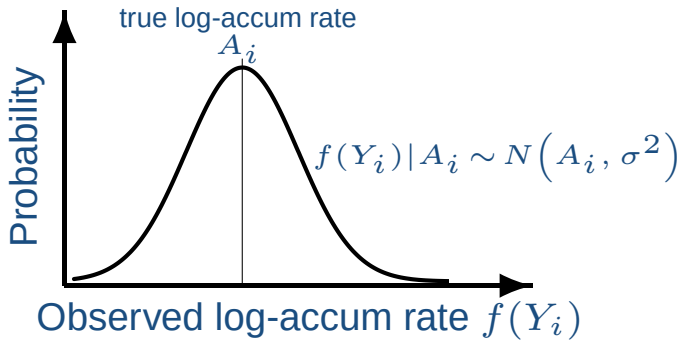
(likelihood)



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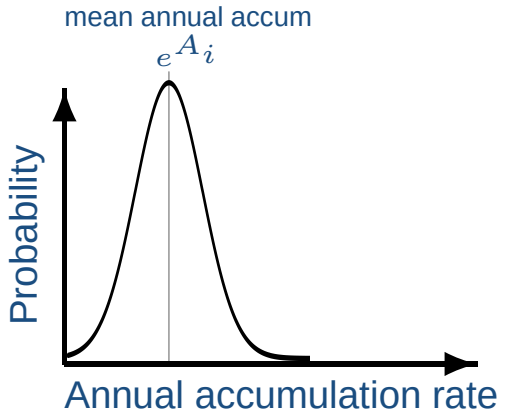

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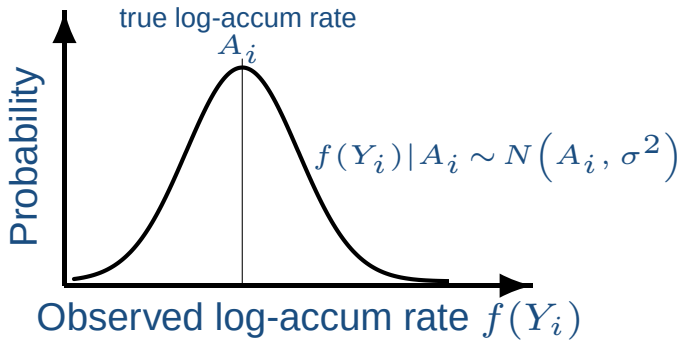

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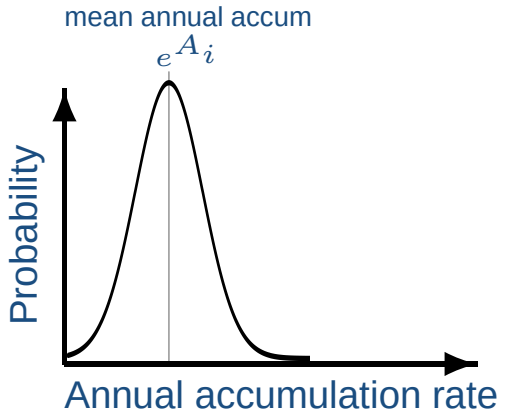

$*$

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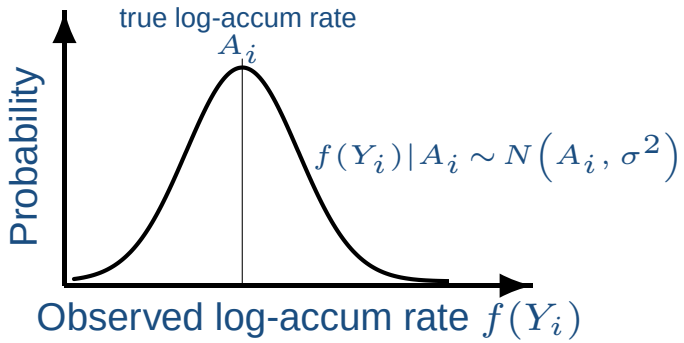
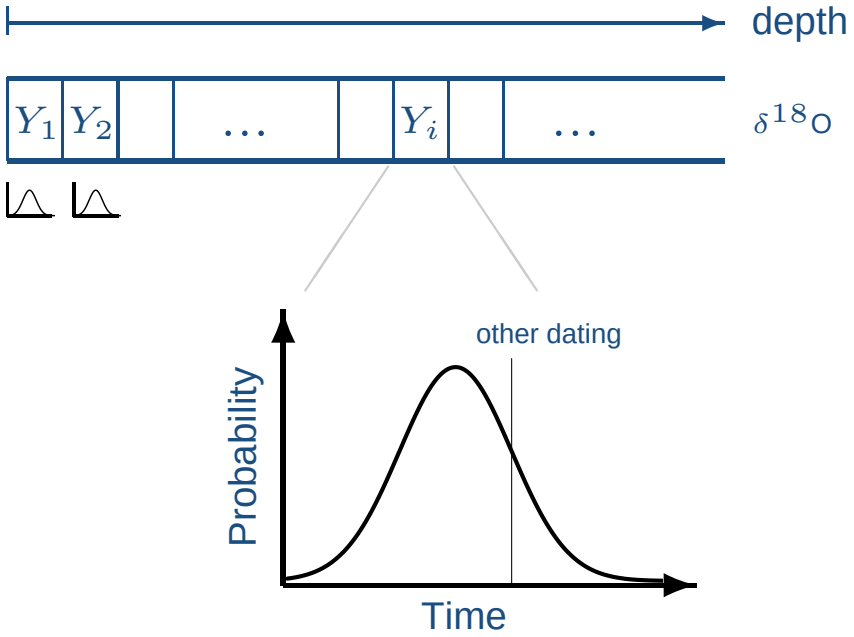


The dating uncertainty

(posterior distribution)



Sources of Prior Knowledge

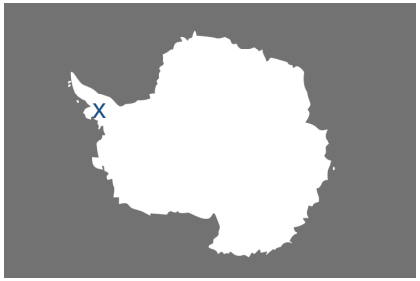
- recent weather records: do not capture climate in polar regions $\longrightarrow$ accumulation model not applicable
- other ice cores: use layer counted (nearby) cores
- same ice core:
  - use $\frac{1}{2}$ of layer counted data to derive prior
  - use $\frac{1}{2}$ of layer counted data to compare our results (to explore the effect of prior assumptions on the dating uncertainty)

The Dating Uncertainty

Effect of Uncertainty in Accumulation

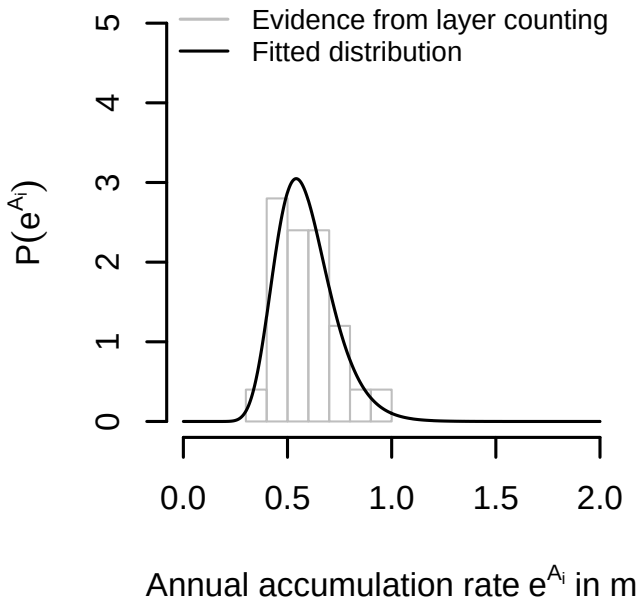
Toy example

A shallow core from Dyer Plateau, Antarctica (70°39'S, 65°01'W)



http:\\en.wikipedia.org\wiki\Image:Flag_of_Antarctica.svg

Accumulation prior



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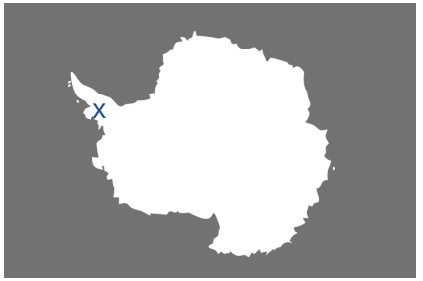

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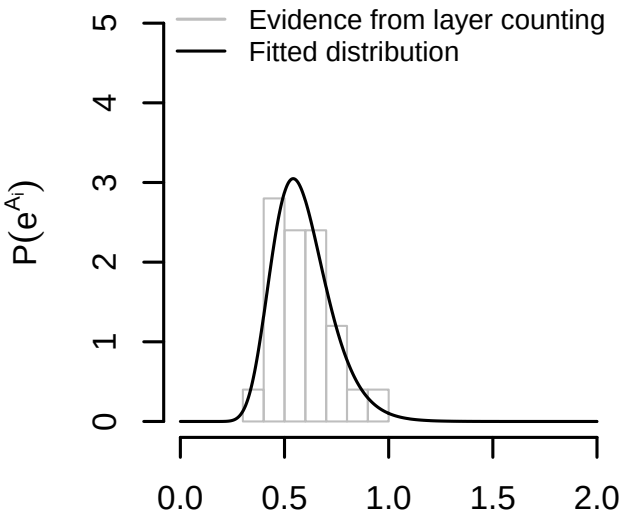
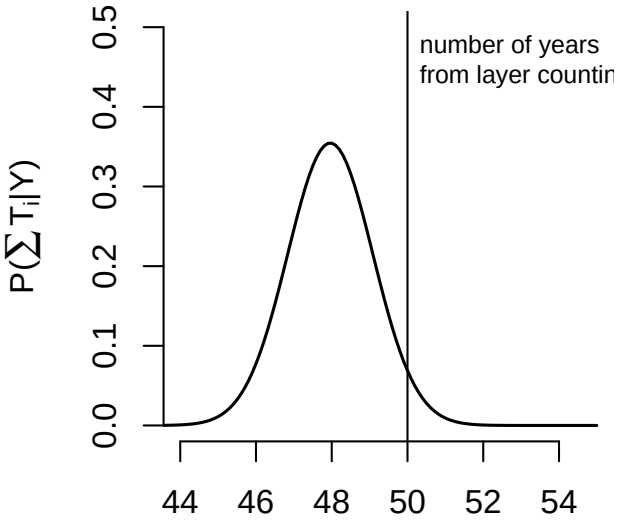


fixed parameters

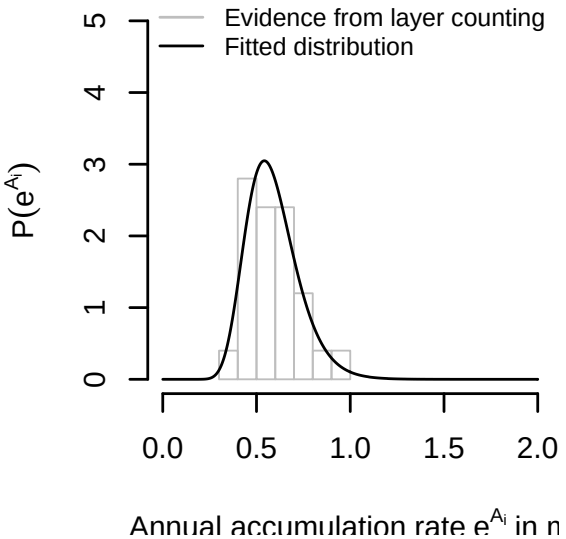
Dating uncertainty



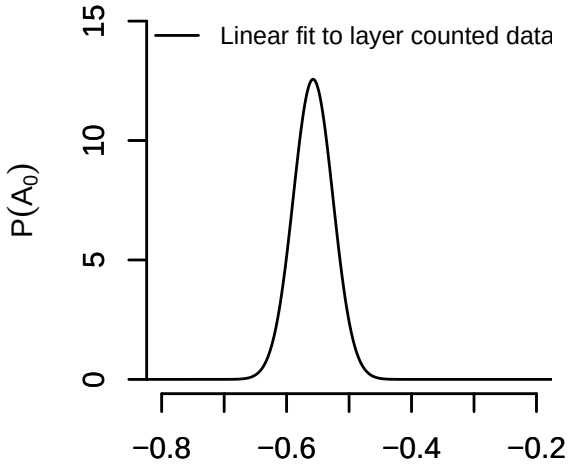
47.96 ± 2.20 years

Effect of all Sources of Uncertainty

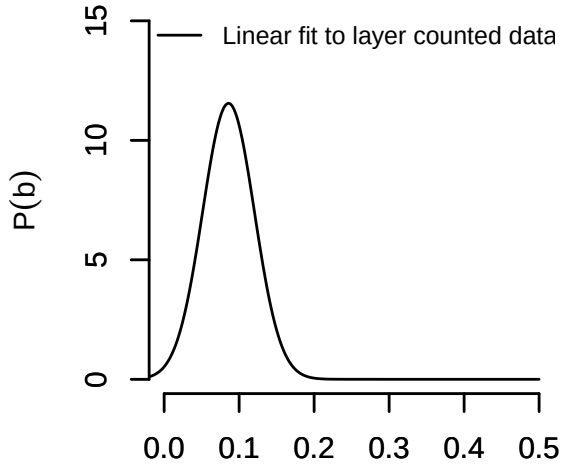
Accumulation prior



Model parameter priors



f linear: [Johnsen et al., 1995]



Dating uncertainty:

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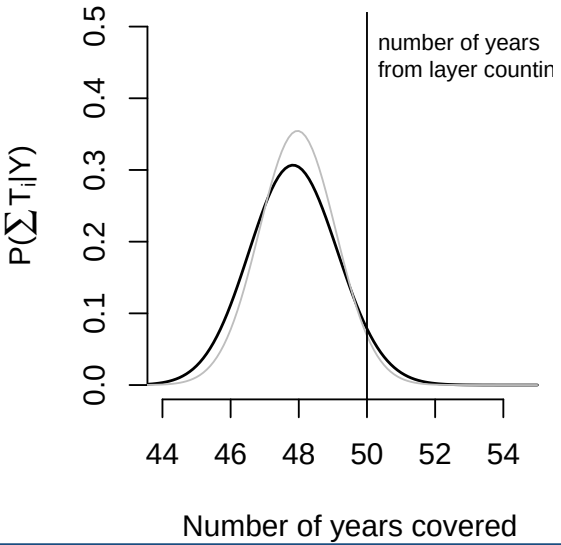

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- problems
  - hiatus: summer melting, ice flow disturbances
  - hard to quantify uncertainty further back in time

Thank you!

Questions and comments ...

[Johnsen et al., 1995] Johnsen, S. J., Dahl-Jensen, D., Dansgaard, W., and Gundestrup, N. (1995). Greenland palaeotemperatures derived from GRIP bore hole temperature and ice core isotope profiles. Tellus B, 47(5):624–629.

[Parrenin et al., 2007] Parrenin, F., Dreyfus, G., Durand, G., Fujita, S., Gagliardini, O., Gillet, F., Jouzel, J., Kawamura, K., Lhomme, N., Masson-Delmotte, V., Ritz, C., Schwander, J., Shoji, H., Uemura, R., Watanabe, O., and Yoshida, N. (2007). 1-d-ice flow modelling at EPICA Dome C and Dome Fuji, East Antarctica. Climate of the Past, 3(Special Issue: The EPICA (EDC and EDML) ice cores age scales):1961.