Nonparametric estimation of age-depth relationship from sedimentological and stratigraphic data

Mind The Gap
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Research problem

Age-depth models (ADMs) are crucial to estimate rates of past environmental change and establish timing of events in the Earth's history. However, current methods to estimate ADMs are based on simplified parametric assumptions on the structure of the stratigraphic record, and can not incorporate complex stratigraphic and sedimentological information.

Contribution

We present two nonparametric methods to estimate Age-depth models from complex stratigraphic and sedimentological information.

## Example 1: Age-depth models from sedimentation rates

Can complex constraints on sedimentation rates from cyclostratigraphy be turned into age-depth models with uncertainties?
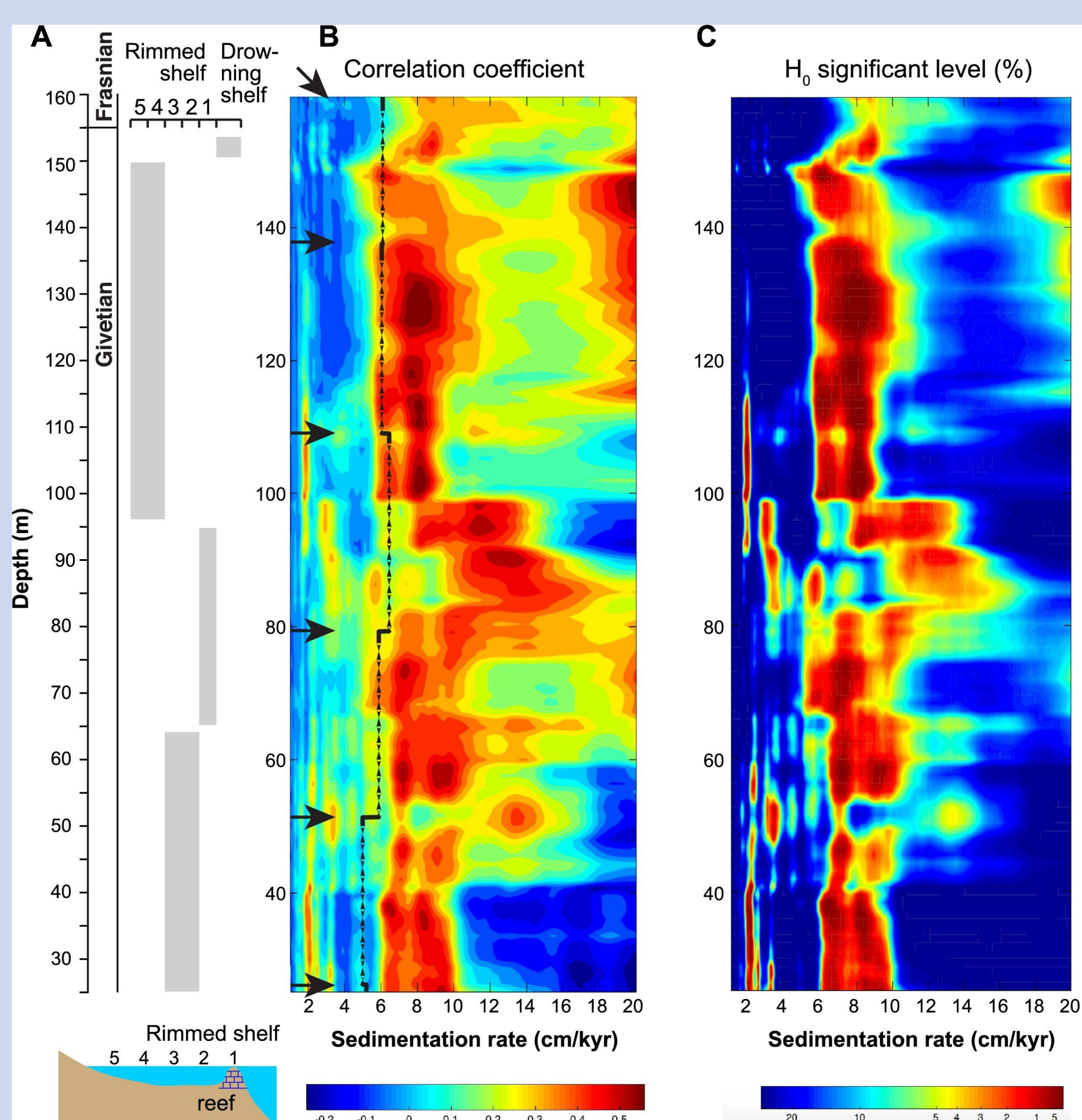
Changes in sedimentation rate in the Devonian La Thure section, Belgium (De Vleeschouwer et al., 2015), estimated using eCOCO (Li et al., 2019). Warmer colors indicate better support for sedimentation rates, which is translated into uncertainties of the sedimentation rates and the age-depth model.

Age-depth model estimated from eCOCO constraints.

Already weak constraints on sedimentation rates can improve age-depth relationships.
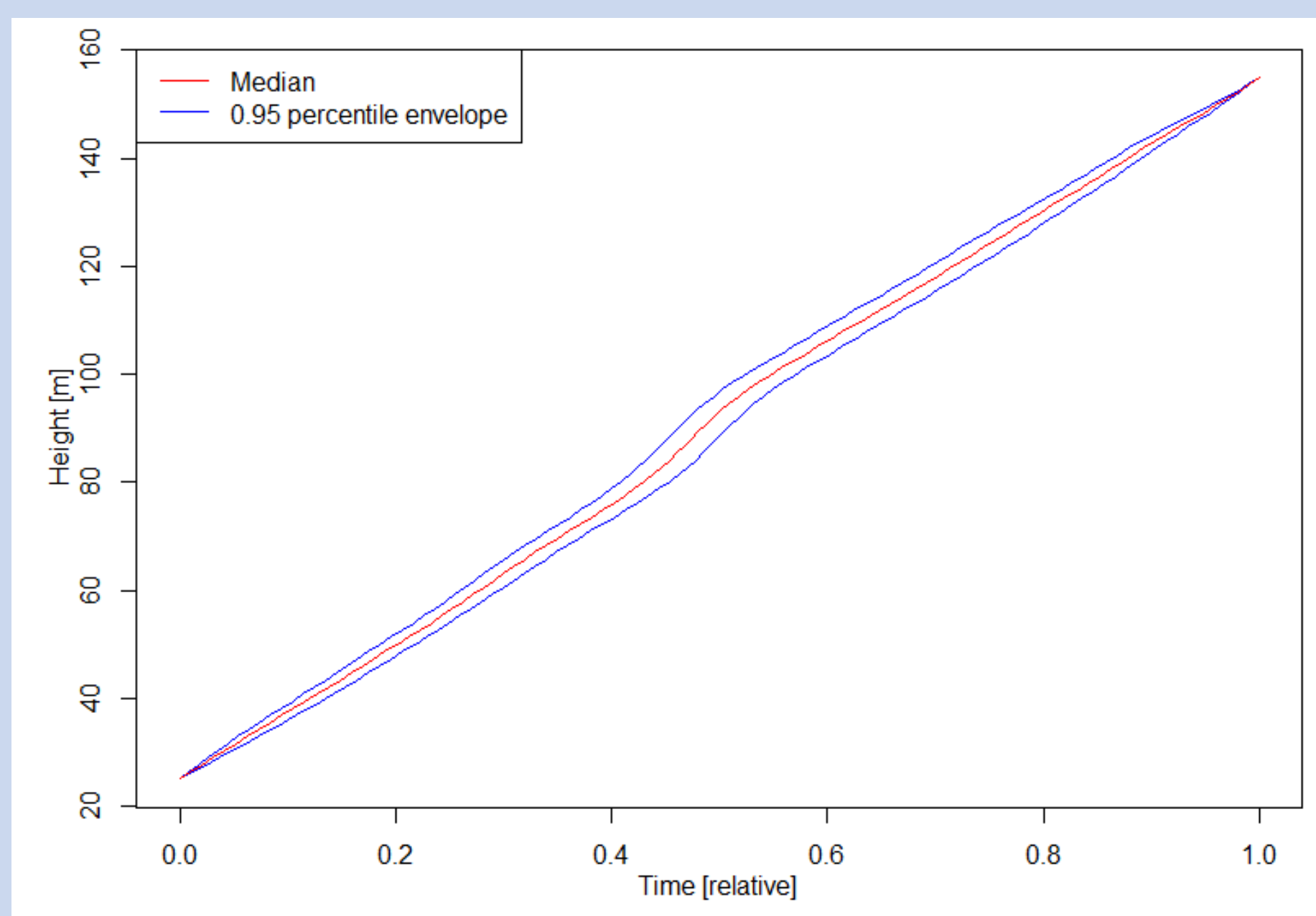
Methodological background: Sedimentation rates determine the amount of time recorded per stratigraphic increment, which can be used to construct an age-depth model. Repeating this multiple times based on the uncertainties derived from the cyclostratigraphic analysis can be used to estimate the uncertainties of the age-depth relationship.

Example 2: Age-depth models from tracer values

How do variation in tracer fluxes change the interpretation of PETM duration?
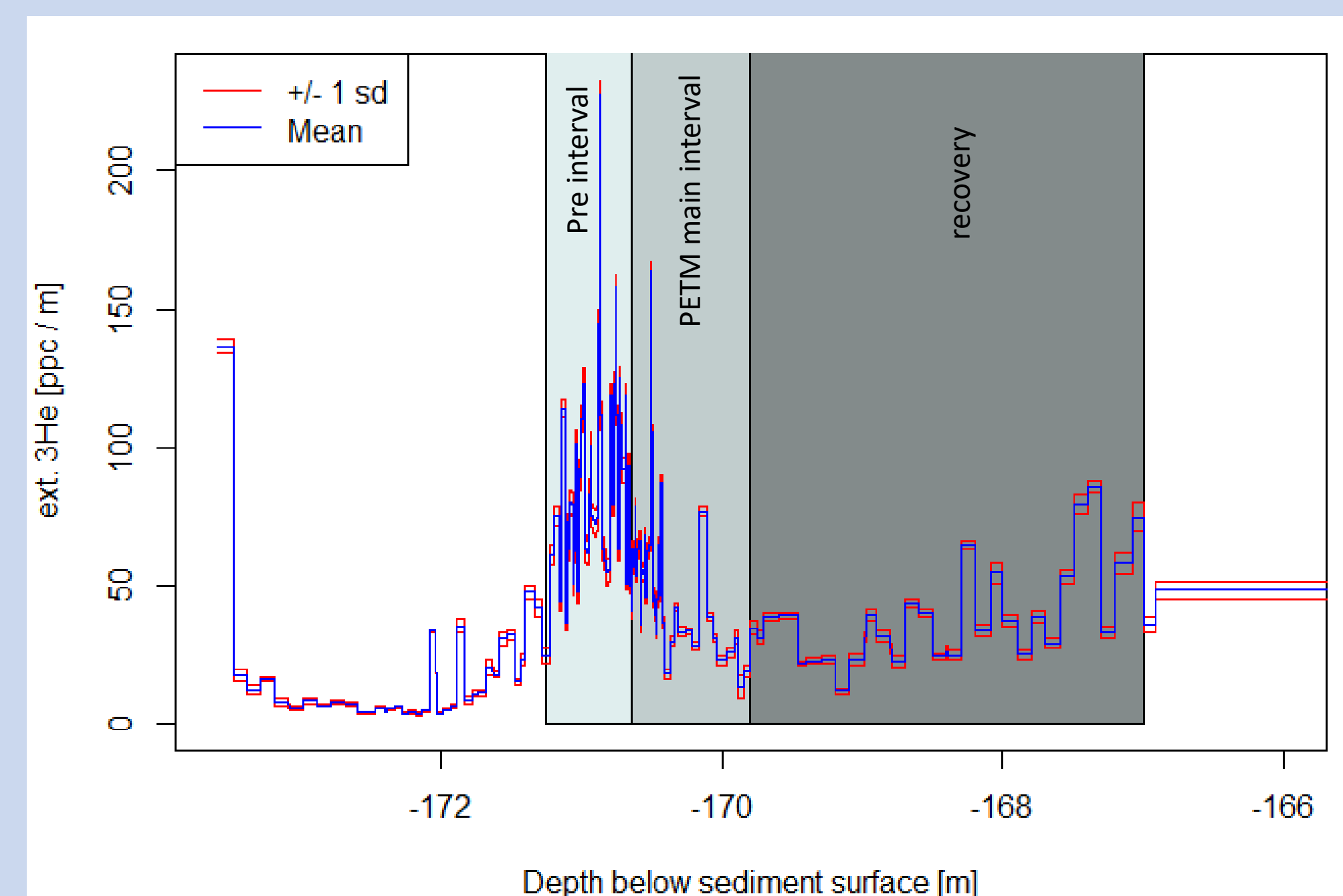
Flux of extraterrestrial ^{3}He from Farley & Eltgroth (2003)
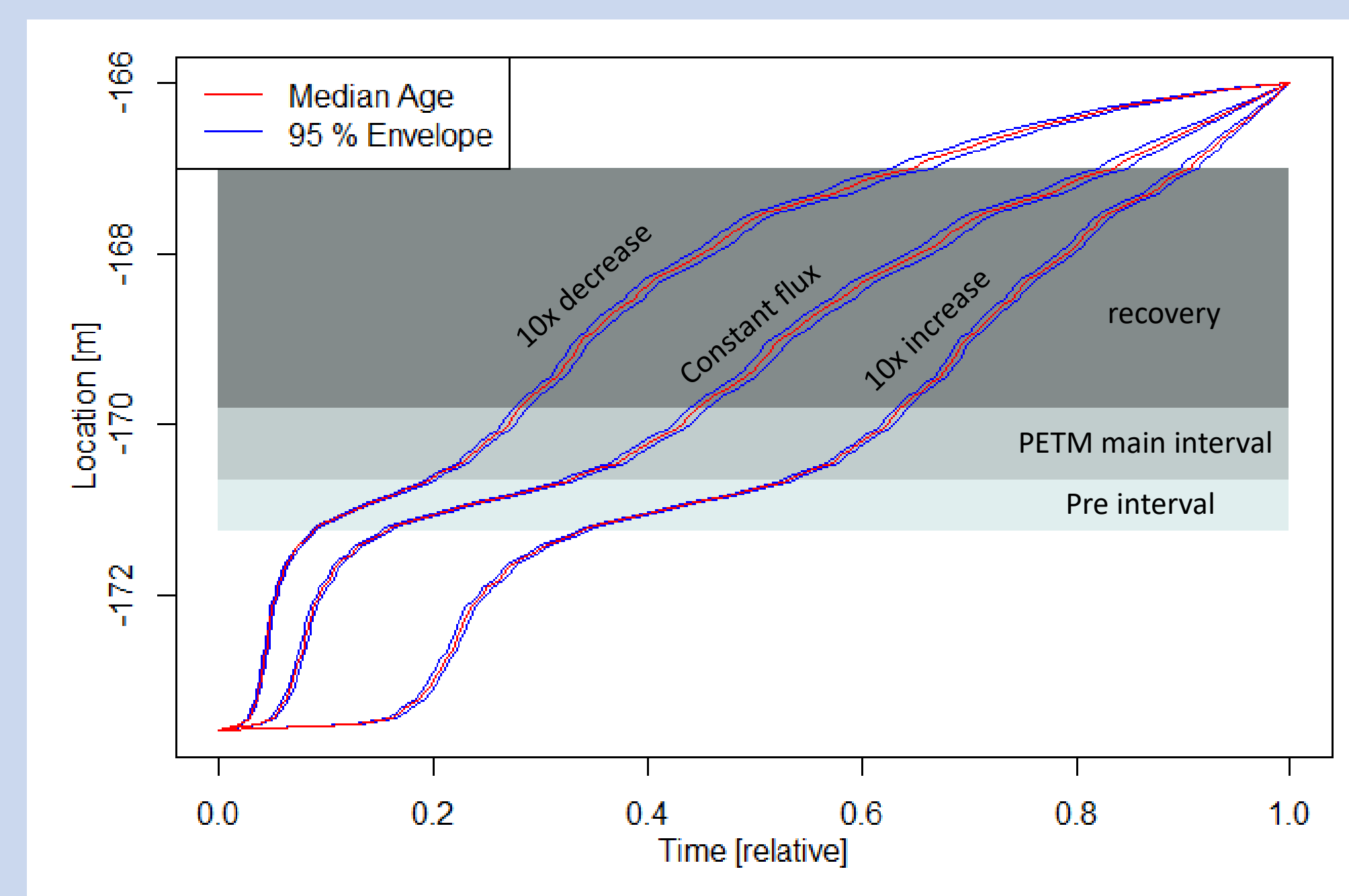
Age-depth models estimated under different assumptions on variations in ^{3}He flux.

Assumptions on fluxes have a larger influence on PETM duration than analytical uncertainties.

Methodological background: Matching observed tracer values with predictions made based on their assumed change in time allows to construct age-depth models. This is repeated multiple times based on the uncertainties of the data and assumptions to estimate age uncertainties.

Implementation

Both methods are implemented in the R package "admtools"(Hohmann 2024) (available on CRAN). The package can also be used to transform complex data such as time series or phylogenetic trees between the time and the stratigraphic domain.

Model Assumptions

The methods assume the law of superposition holds, and that there are no hiatuses. All other model assumptions can be specified by the user. Model expansions that include hiatuses are in development.

Want to learn more?

Package webpage

Check the package webpage for more extended examples, and the GitHub page for code and implementation details. This is an Open Source project, *new contributors are welcome*!

mindthegap-erc.github.io/admtools/

Code repository

github.com/MindTheGap-ERC/admtools

References
Li et al., "Tracking variable sedimentation rates and astronomical forcing in Phanerozoic paleoclimate proxy series with evolutionary correlation coefficients and hypothesis testing", Earth and Planetary Science Letters, 2018. https://doi.org/10.1016/j.epsl.2018.08.041.
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Earth and Planetary Science Letters, 2003. https://doi.org/10.1016/S0012-821X(03)00017-7
Hohmann, R package "admtools", Zenodo, 2024. https://zenodo.org/doi/10.5281/zenodo.10213587

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