Developing prior distributions of sediment accumulation rates for Bayesian age-depth modeling:

A case study of Holocene terrestrial sediments in South Korea

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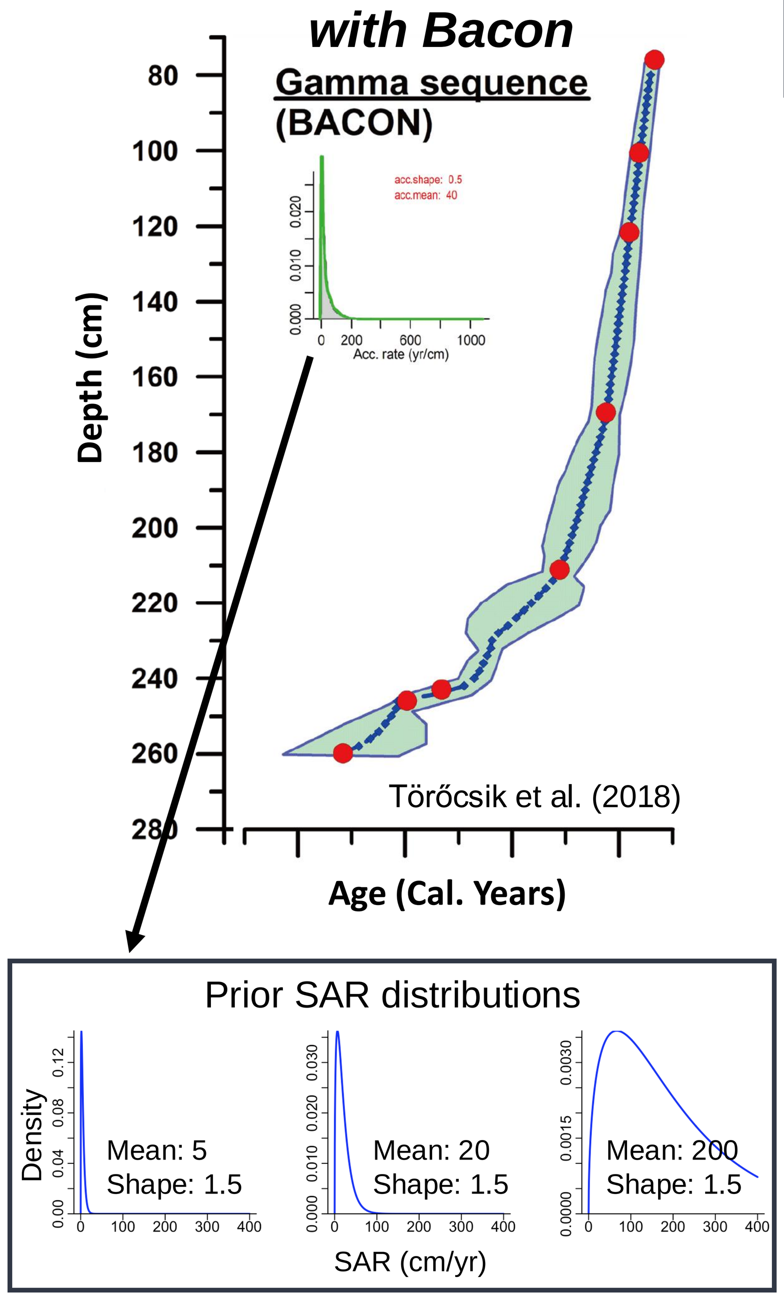
Fig 1. Age-depth model with Bacon



1 Background

Bayesian age-depth modeling is less likely to underestimate uncertainties in age estimates compared to traditional methods (Traschel and Telford, 2016). Among various Bayesian frameworks (e.g., OxCal and Bpeat), Bacon runs iterations of depositional processes using Bayesian priors of sediment accumulation rates (SAR, unit: yr/cm, represented as deposition time in Bacon) (Blaauw et al., 2007) (R package: *rbacon*) (Fig 1). These priors consist of two parameters: mean and shape of a gamma distribution, which characterizes the prior distribution probability of SAR in Bacon. Although alternative values of the SAR mean are suggested when the initial runs show significant deviation from the default settings (mean: 20 yr/cm, shape: 1.5), users still need to select appropriate priors based on previous information on SAR in their study sites. Goring et al. (2012) discussed SAR priors using linear and smooth spline interpolation age-depth models for 204 sites in the Northeastern United States. However, more discussion is needed on practical approaches for approximating the SAR prior derived from previous geochronological data.

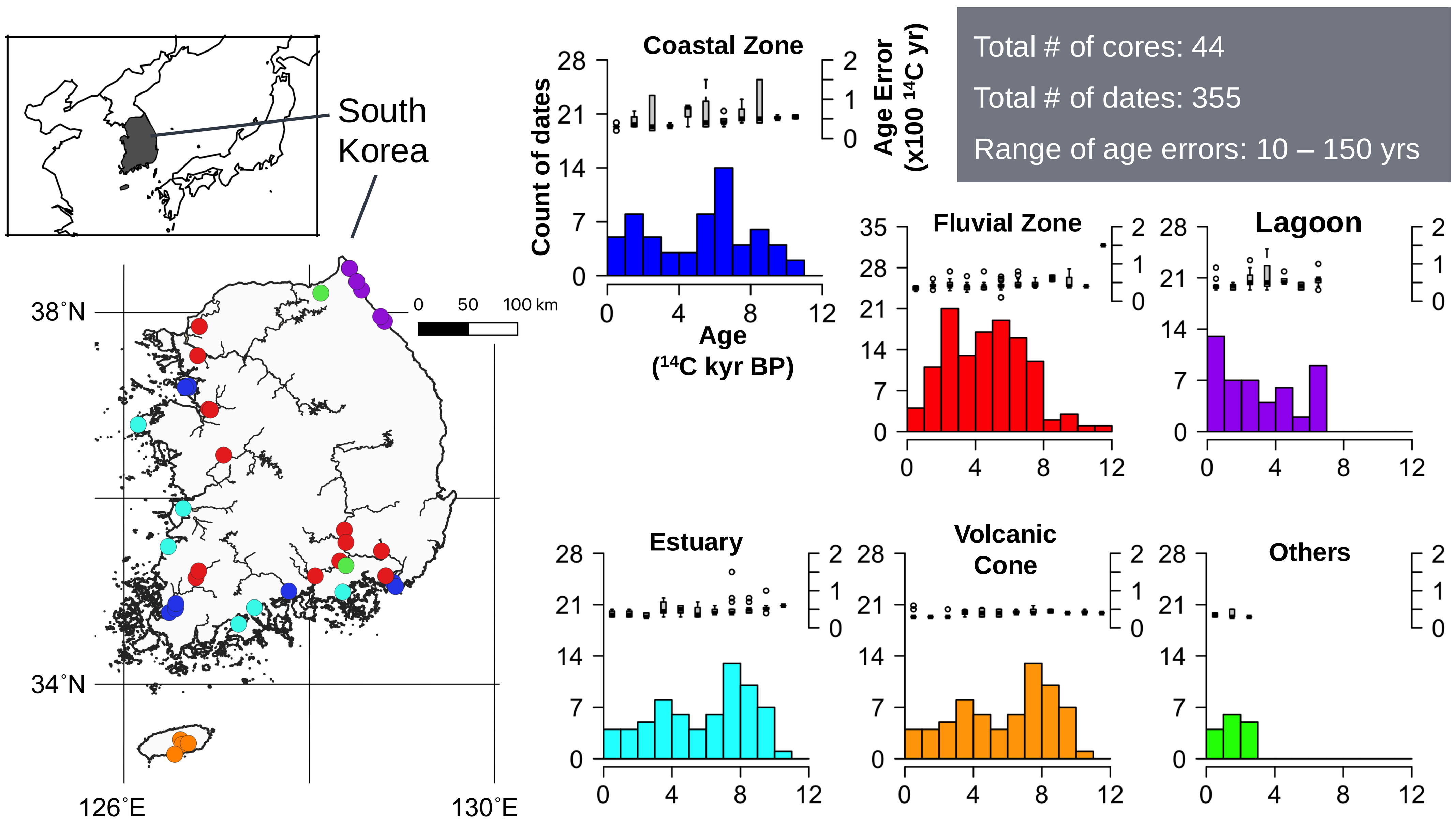
Research objectives

* SAR: Sediment Accumulation Rate, yr/cm

- *Construct prior distributions of SAR using existing geochronological datasets from Holocene sediments in South Korea using linear, quadratic polynomial, and cubic spline*
- *Compare the constructed SAR distributions with Bacon's default (mean: 20 yr/cm, shape: 1.5) and two alternatives (mean: 5 and 50 yr/cm; shape: 1.5)*

2 ^{14}C dates from terrestrial sediments in South Korea

Fig 2. Spatial distribution of cores (left) & temporal distribution of ^{14}C dates (right)



Total # of cores: 44
Total # of dates: 355
Range of age errors: 10 – 150 yrs

3 SAR extracted with three interpolation methods

* SAR: Sediment Accumulation Rate, yr/cm

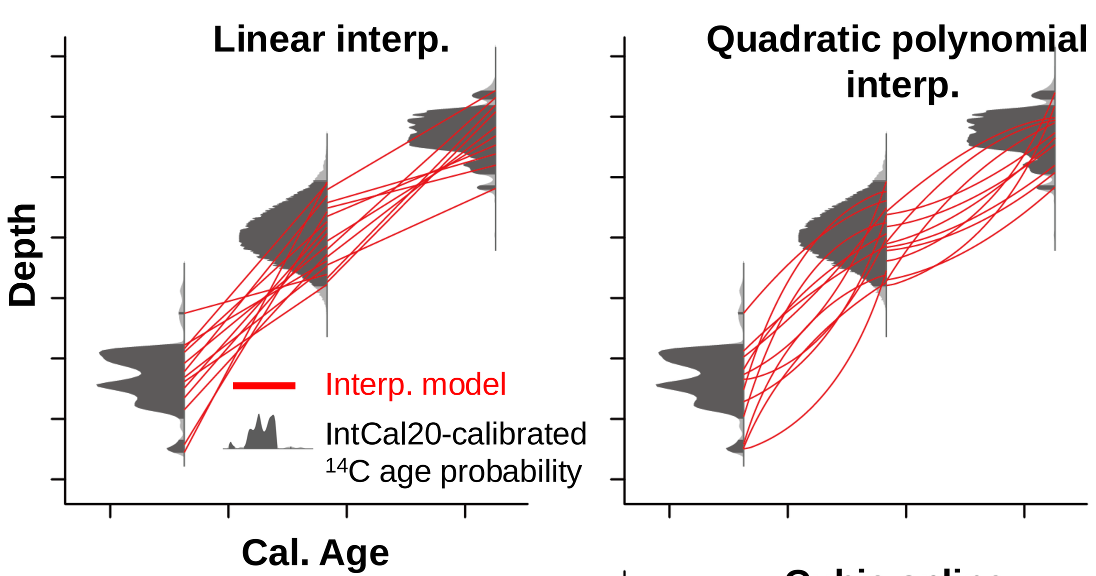
1) Linear & Spline interpolation

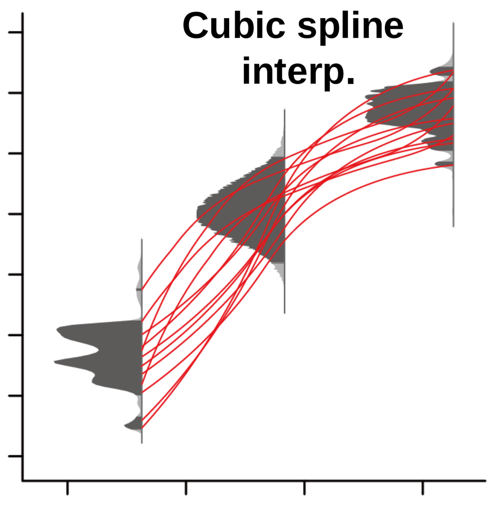
We applied Clam's linear interpolation methods (Blaauw, 2010) with 10K iterations per date-depth interval, sampling ages from Intcal20-calibrated ^{14}C likelihood distributions (Reimer et al. 2000) Iterations with non-positive slopes were discarded to ensure monotonicity. The remaining results provided age and SAR estimates at 0.5 cm depth intervals.
(R packages: Intcal, demography, and dplyr)

2) Quadratic polynomial interpolation

100 iterations of quadratic interpolation between consecutive age-depth points using calibrated 14C dates. The function $f(x) = ax^2 + bx + c$ was constrained to avoid hiatuses and age reversals by selecting a within specified ranges. Each iteration yielded age and SAR estimates at 0.5 cm depth intervals.
(R packages: Intcal and dplyr)

Fig 3. Three interpolation methods





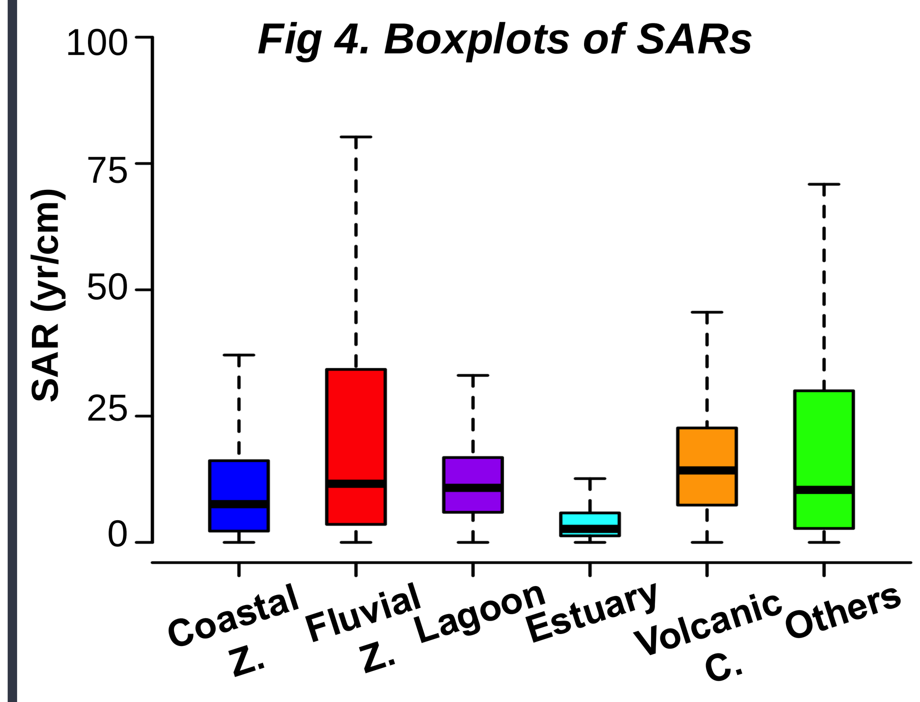
3) 300K SAR estimates per core

Each core yielded 300K SAR estimates (100K per interpolation). Six cores excluded spline interpolation due to all spline iterations with 0 SAR, with 150K estimates each from linear and quadratic interpolation.

4 Results and discussion

1) Normality check by Shapiro-Wilk tests: All SAR distributions from linear, quadratic, and cubic spline methods show p-values <0.05.

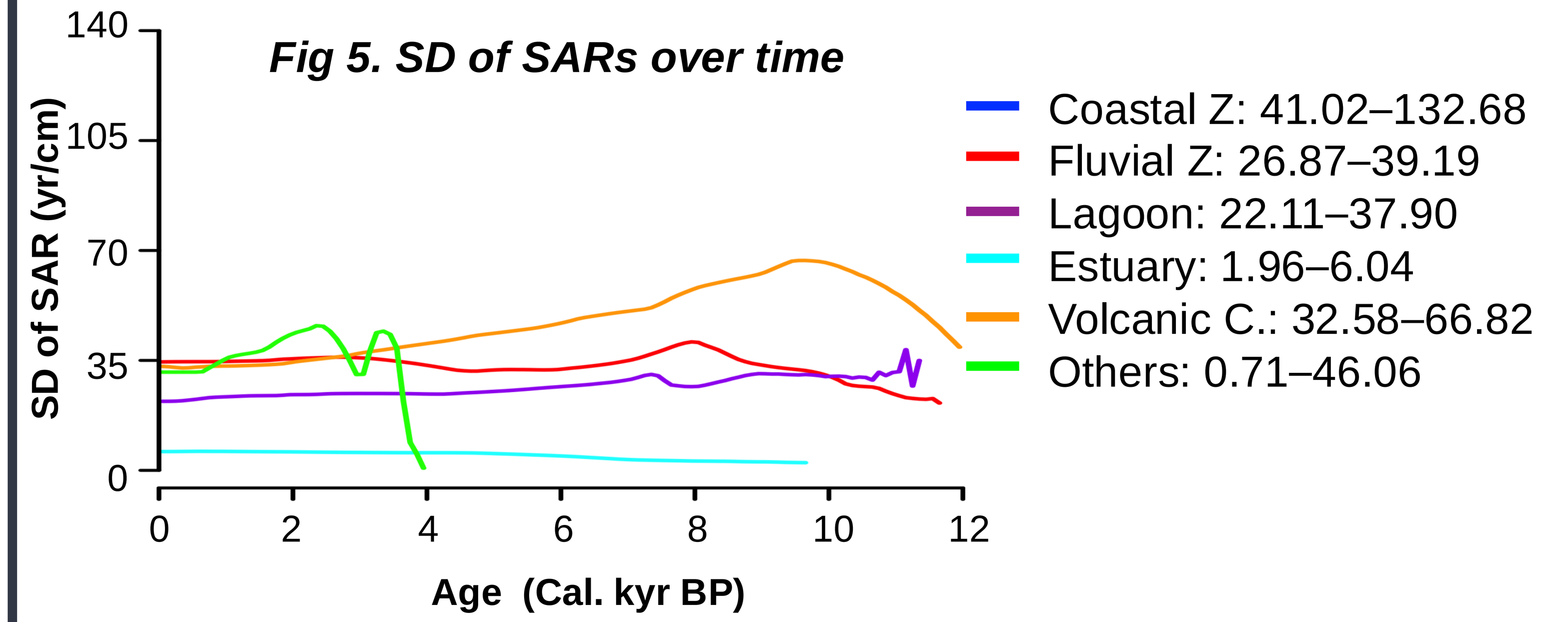
2) Non-parametric tests for SAR differences: **Mann-Whitney tests** on 6 cores (linear vs. quadratic) showed p-values <0.05. For 38 cores, **Kruskal-Wallis tests** (three methods) gave p-values <0.05, but **Dunn's test** found only 2 cores with p-values >0.05 (spline vs. quadratic).



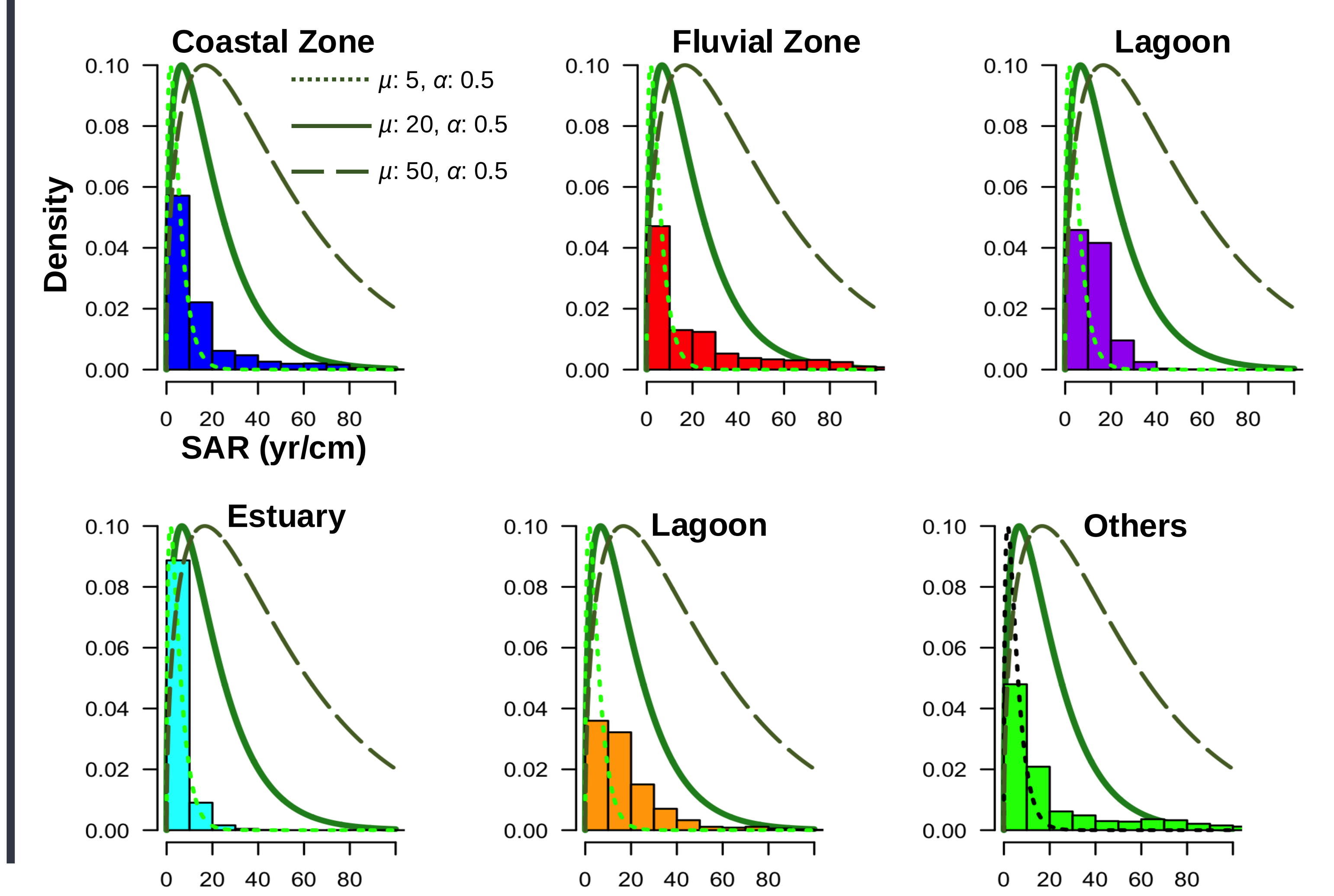
3) SAR (unit: yr/cm) across different depositional settings

Coastal Z.: 0.001–1061.913
Fluvial Z.: 0.001–315.227
Lagoon: <0.001–89.399
Estuary: <0.001–169.695
Volcanic C.: 0.001–662.071
Others: 0.001–281.039

4) Standard deviation (SD) of SAR in 100-year intervals



5) *SARs versus Bacon's default and alternative priors*



6 Current remarks

- All SAR distributions derived from three interpolation methods lack normality.
- While SAR distributions for two cores show similarities between quadratic and spline interpolation, the others are all independent.
- Different SAR priors are required for various depositional settings and time periods.
- The shape parameter of the gamma distribution fitting for the previous SAR distribution needs further evaluation.

References

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