New approaches to radiocarbon calibration arising from statistical developments in IntCal20

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Two issues to be addressed

• Non-normal errors
  - For most calendar ages, curve posterior is approx. normal
  - Summarisation by normal is ok
  - But sometimes it isn’t e.g. ca. 14.75 cal kBP
  - Summarisation by normal not ideal

• Covariance...
Plausible curves
The solution

• Rather than using a curve with an uncertainty
• Use the multiple curve realisations for the IntCal curve directly
• Run models (such as wiggle matches or age-depth models) while sampling from these possible curves.

• Already working in special R-Code for tree-ring sequences
• Being implemented in OxCal...
Additional notes
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Talk Overview

- IntCal20: Pointwise Summaries and Realisations;
- Using realisations in calibration;
- Effect where calibration curve non-normal;
- Effect on joint calibration e.g. length of an interval;
- Input to other models e.g. Marine20
Published IntCal20 provides pointwise summaries (mean and sd)

But method is Bayesian so really have \( N = 2000 \) full realisations

Realisations have lots more information than pointwise summaries

We can calibrate against realisations rather than summaries
Benefits of Realisations I: Non-normal curve posteriors

Obtain pointwise IntCal summaries at any calendar age $\theta$ by fitting normal distribution to the values of realisations at that $\theta$:

- For most calendar ages, curve posterior is approx. normal
- Summarisation by normal is ok

But sometimes it isn’t e.g. ca. 14.75 cal kBP
- Summarisation by normal not ideal
When we create pointwise summaries we lose all covariance information on the curve.

Without covariance, then $^{14}C$ could flip from upper to lower bounds from one year to next (not realistic as $\Delta^{14}C$ is smooth).

LH plot - suppose we knew blue value was correct, then if no covariance, any of red dots equally likely.

RH plot - curve cannot change that much between adjacent years, with covariance can say purple much more likely.
Using Realisations as Model Input e.g. Marine20

- Marine20 used a computer model (BICYCLE) which took NH atmospheric $\Delta^{14}C$ as input variable
- Want to propagate uncertainty in atm $\Delta^{14}C$ input through model
- Use Monte Carlo, run BICYCLE with $N$ sampled IntCal20 $\Delta^{14}C$ realisations as inputs
- Creates ensemble of $N$ model outputs that capture uncertainty

![Diagram showing uncertainty incorporation]

- **Uncertainties Incorporated**
  - Time Varying
    - Atmospheric $\Delta^{14}C$
    - Atmospheric CO$_2$
  - Parameterized processes
    - AMOC
    - Piston Velocity

- **No Uncertainty Incorporated**
  - Other time-dependent forcings (e.g. temperatures) and other parameterized processes (e.g. isotopic fractionation factors)
Using Realisations as Model Input e.g. Marine20

- Each atmospheric $^{14}$C realisation has a paired model output
- Monte Carlo key to rigorous uncertainty quantification