# New approaches to radiocarbon calibration arising from statistical developments in IntCal20

Christopher Bronk Ramsey, Tim Heaton, Maarten Blaauw, Paul Blackwell, Paula Reimer, Ron Reimer, and Marian Scott

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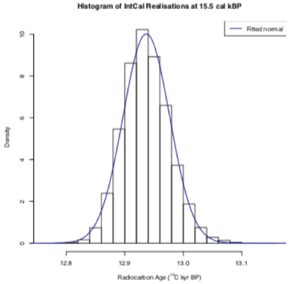
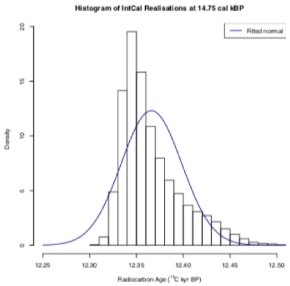
# Two issues to be addressed

- Non-normal errors

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

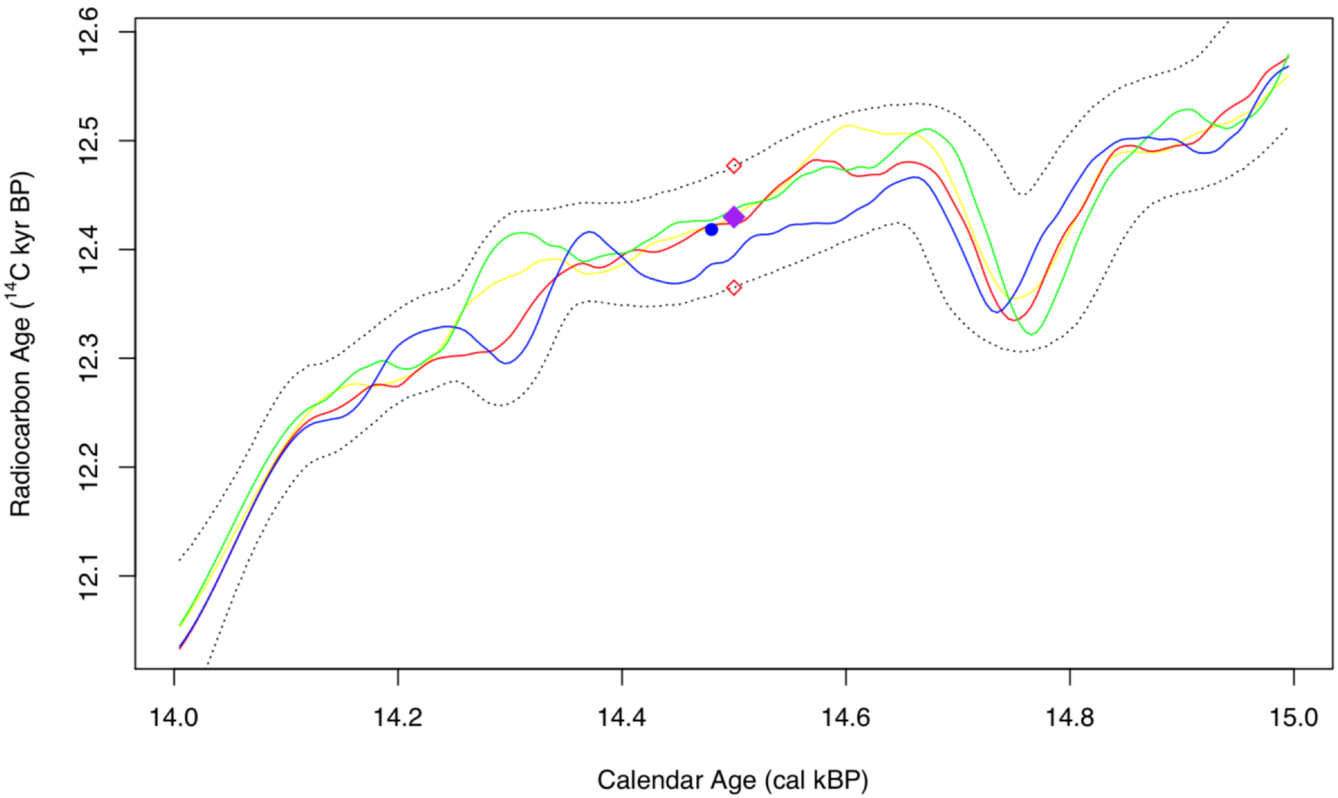



  - But sometimes it isn't e.g. ca. 14.75 cal kBP
  - Summarisation by normal not ideal




- 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

# New approaches to radiocarbon calibration arising from statistical developments in IntCal20

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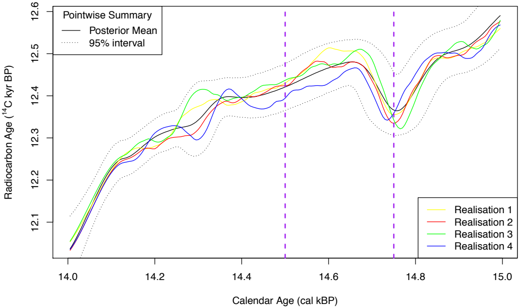
# Talk Overview

- 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

# IntCal20: Pointwise Summaries and Realisations

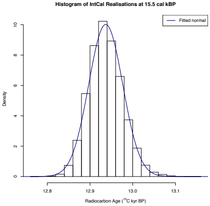



- Published IntCal20 provides pointwise summaries (mean and sd)
- But method is Bayesian so really have $N = 2000$ full realisations
- Realisations have lots more information than pointwise summaries
- We can calibrate against realisations rather than summaries

# 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
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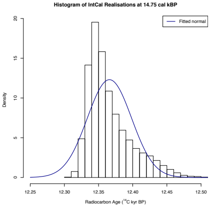
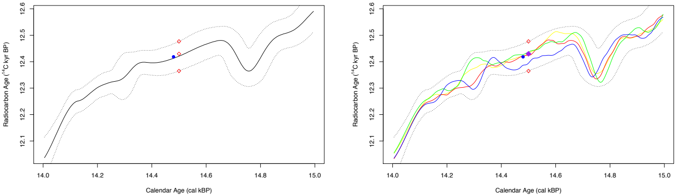


# Benefits of Realisations II: Covariance Information

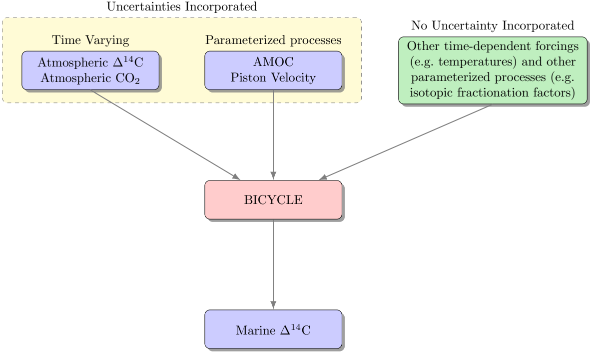
- When we create pointwise summaries we lose all covariance information on the curve




- 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



# 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