# Package: rice (via r-universe)

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**Description** Provides functions for the calibration of radiocarbon dates, as well as options to calculate different radiocarbon realms (C14 age, F14C, pMC, D14C) and estimating the effects of contamination. The methods follow long-established recommendations such as Stuiver and Polach (1977) <doi:10.1017/S0033822200003672> and Reimer et al. (2004) <doi:10.1017/S0033822200033154>. This package accompanies the data package 'rintcal'.

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`rice-package` *rice: Radiocarbon Calibration Equations*

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## Description

Provides functions for the calibration of radiocarbon dates, as well as options to calculate different radiocarbon realms (C14 age, F14C, pMC, D14C) and estimating the effects of contamination. The methods follow long-established recommendations such as Stuiver and Polach (1977) doi:10.1017/S0033822200003672 and Reimer et al. (2004) doi:10.1017/S0033822200033154. This package accompanies the data package 'rintcal'.

## Author(s)

**Maintainer**: Maarten Blaauw <maarten.blaauw@qub.ac.uk> (ORCID)

## age.F14C *Calculate F14C values from C14 ages*

### Description

Calculate F14C values from radiocarbon ages

### Usage

```
age.F14C(mn, sdev = c(), decimals = 5, lambda = 8033)
```

### Arguments

| | |
|---|---|
| mn | Reported mean of the 14C age. |
| sdev | Reported error of the 14C age. If left empty, will translate mn to F14C. |
| decimals | Amount of decimals required for the F14C value. Defaults to 5. |
| lambda | The mean-life of radiocarbon (based on Libby half-life of 5568 years) |

### Details

Post-bomb dates are often reported as F14C or fraction modern carbon. Since Bacon expects radiocarbon ages, this function can be used to calculate F14C values from radiocarbon ages. The reverse function of F14C.age.

### Value

F14C values from C14 ages.

### Examples

```
age.F14C(-2000, 20)
```

## age.pMC *Calculate pMC values from C14 ages*

### Description

Calculate pMC values from radiocarbon ages

### Usage

```
age.pMC(mn, sdev = c(), ratio = 100, decimals = 5, lambda = 8033)
```

### Arguments

| | |
|---|---|
| mn | Reported mean of the 14C age. |
| sdev | Reported error of the 14C age. |
| ratio | Most modern-date values are reported against 100. If it is against 1 instead, a warning is provided; use age.F14C. |
| decimals | Amount of decimals required for the pMC value. Defaults to 5. |
| lambda | The mean-life of radiocarbon (based on Libby half-life of 5568 years) |

### Details

Post-bomb dates are often reported as pMC or percent modern carbon. Since Bacon expects radiocarbon ages, this function can be used to calculate pMC values from radiocarbon ages. The reverse function of pMC.age.

### Value

pMC values from C14 ages.

### Examples

```
age.pMC(-2000, 20)
age.pMC(-2000, 20, 1)
```

---

## calBP.14C *Find the 14C age and error belonging to a cal BP age.*

---

### Description

Given a calendar age, the calibration curve (default cc=1) is interpolated and the corresponding 14C age and error are returned.

### Usage

```
calBP.14C(yr, cc = 1, postbomb = FALSE, rule = 1, cc.dir = NULL)
```

### Arguments

| | |
|---|---|
| yr | The cal BP year. |
| cc | calibration curve for C14 (see caldist()). |
| postbomb | Whether or not to use a postbomb curve (see caldist()). |
| rule | How should R's approx function deal with extrapolation. If rule=1, the default, then NAs are returned for such points and if it is 2, the value at the closest data extreme is used. |
| cc.dir | Directory of the calibration curves. Defaults to where the package's files are stored (system.file), but can be set to, e.g., cc.dir="curves". |

## Details

Interpolation is used, and values outside the calibration curve are given as NA. For negative cal BP ages, a postbomb curve will have to be provided.

## Value

The calibration-curve 14C year belonging to the entered cal BP age

## Author(s)

Maarten Blaauw

## Examples

```
calBP.14C(100)
```

---

`caldist` *Calculate calibrated distribution*

---

## Description

Calculate the calibrated distribution of a radiocarbon date.

## Usage

```
caldist(
  age,
  error,
  cc = 1,
  postbomb = FALSE,
  thiscurve = c(),
  yrsteps = FALSE,
  cc.resample = FALSE,
  dist.res = 200,
  threshold = 0.001,
  normal = TRUE,
  t.a = 3,
  t.b = 4,
  normalise = TRUE,
  BCAD = FALSE,
  rule = 1,
  cc.dir = NULL
)
```

## Arguments

| | |
|---|---|
| age | Uncalibrated radiocarbon age |
| error | Lab error of the radiocarbon age |
| cc | Calibration curve to use. Defaults to IntCal20 (cc=1). |
| postbomb | Whether or not to use a postbomb curve. Required for negative radiocarbon ages. |
| thiscurve | As an alternative to providing cc and/or postbomb, the data of a specific curve can be provided (3 columns: cal BP, C14 age, error). Defaults to FALSE. |
| yrsteps | Steps to use for interpolation. Defaults to the cal BP steps in the calibration curve |
| cc.resample | The IntCal20 curves have different densities (every year between 0 and 5 kcal BP, then every 5 yr up to 15 kcal BP, then every 10 yr up to 25 kcal BP, and then every 20 yr up to 55 kcal BP). If calibrated ages span these density ranges, their drawn heights can differ, as can their total areas (which should ideally all sum to the same size). To account for this, resample to a constant time-span, using, e.g., cc.resample=5 for 5-yr timespanes. |
| dist.res | As an alternative to yrsteps, provide the amount of 'bins' in the distribution |
| threshold | Report only values above a threshold. Defaults to threshold=1e-6. |
| normal | Use the normal distribution to calibrate dates (default TRUE). The alternative is to use the t model (Christen and Perez 2016). |
| t.a | Value a of the t distribution (defaults to 3). |
| t.b | Value a of the t distribution (defaults to 4). |
| normalise | Sum the entire calibrated distribution to 1. Defaults to normalise=TRUE. |
| BCAD | Which calendar scale to use. Defaults to cal BP, BCAD=FALSE. |
| rule | Which extrapolation rule to use. Defaults to rule=1 which returns NAs. |
| cc.dir | Directory of the calibration curves. Defaults to where the package's files are stored (system.file), but can be set to, e.g., cc.dir="curves". |

## Value

The probability distribution(s) as two columns: cal BP ages and their associated probabilities

## Examples

```
calib <- caldist(130,10)
plot(calib, type="l")
postbomb <- caldist(-3030, 20, postbomb=1, BCAD=TRUE)
```

`calibrate` *Plot individual calibrated dates.*

## Description

Calibrate individual 14C dates, plot them and report calibrated ranges.

## Usage

```
calibrate(
  age = 2450,
  error = 50,
  cc = 1,
  postbomb = FALSE,
  bombalert = TRUE,
  reservoir = 0,
  prob = 0.95,
  BCAD = FALSE,
  ka = FALSE,
  cal.lab = c(),
  C14.lab = c(),
  cal.lim = c(),
  C14.lim = c(),
  cc.col = rgb(0, 0.5, 0, 0.7),
  cc.fill = rgb(0, 0.5, 0, 0.7),
  date.col = "red",
  dist.col = rgb(0, 0, 0, 0.2),
  dist.fill = rgb(0, 0, 0, 0.2),
  hpd.fill = rgb(0, 0, 0, 0.3),
  dist.height = 0.3,
  dist.float = c(0.01, 0.01),
  cal.rev = FALSE,
  yr.steps = FALSE,
  threshold = 5e-04,
  edge = TRUE,
  normal = TRUE,
  t.a = 3,
  t.b = 4,
  rounded = 1,
  extend.range = 0.05,
  legend.cex = 0.8,
  legend1.loc = "topleft",
  legend2.loc = "topright",
  mgp = c(2, 1, 0),
  mar = c(3, 3, 1, 1),
  xaxs = "i",
  yaxs = "i",
```

```
  bty = "l",
  cc.dir = NULL,
  ...
)
```

## Arguments

| | |
|---|---|
| age | Mean of the uncalibrated C-14 age. |
| error | Error of the uncalibrated C-14 age. |
| cc | Calibration curve for C-14 dates (1, 2, 3, or 4, or, e.g., "IntCal20", "Marine20", "SHCal20", "nh1", "sh3", or "mixed"). |
| postbomb | Whether or not this is a postbomb age. Defaults to FALSE. |
| bombalert | Warn if a date is close to the lower limit of the IntCal curve. Defaults to `postbomb=TRUE`. |
| reservoir | Reservoir age, or reservoir age and age offset. |
| prob | Probability confidence intervals (between 0 and 1). |
| BCAD | Use BC/AD or cal BP scale (default cal BP). |
| ka | Use thousands of years instead of years in the plots and hpd ranges. Defaults to FALSE. |
| cal.lab | Label of the calendar/horizontal axis. Defaults to the calendar scale, but alternative names can be provided. |
| C14.lab | Label of the C-14/vertical axis. Defaults to the 14C scale, but alternative names can be provided. |
| cal.lim | Minimum and maximum of calendar axis (default calculated automatically). |
| C14.lim | Minimum and maximum of C-14 axis (default calculated automatically). |
| cc.col | Colour of the lines of the calibration curve. Defaults to semi-transparent dark green; `cc.col=rgb(0,.5,0,0.7)`. |
| cc.fill | Colour of the inner part of the calibration curve. Defaults to semi-transparent dark green; `cc.col=rgb(0,.5,0,0.7)`. |
| date.col | Colour of the "dot-bar" plot of the C14 date. Defaults to `date.col="red"`. |
| dist.col | Colour of the outer lines of the distributions. Defaults to semi-transparent grey, `dist.col=rgb(0,0,0,0.2)`. |
| dist.fill | Colour of the inner part of the distributions. Defaults to semi-transparent grey, `dist.col=rgb(0,0,0,0.2)`. |
| hpd.fill | Colour of the highest posterior density. Defaults to semi-transparent grey, `dist.col=rgb(0,0,0,0.3)`. |
| dist.height | Maximum height of the C14 and calibrated distributions (as proportion of the invisible secondary axes). Defaults to 0.3. |
| dist.float | The probability distributions float a bit above the axes by default. Can be set to distinct heights of the axes, e.g.: `dist.float=c(0.05, 0.1)`, or to `dist.float=0`. |
| cal.rev | Whether or not to reverse the direction of the calendar axis. |
| yr.steps | Temporal resolution at which C-14 ages are calibrated (in calendar years). By default follows the spacing in the calibration curve. |

| | |
|---|---|
| threshold | Below which value should probabilities be excluded from calculations. |
| edge | How to treat dates are at or beyond the edge of the calibration curve. If dates are truncated, a warning is given. If they lie beyond the calibration curve, an error is given. |
| normal | Use the normal distribution to calibrate dates (default TRUE). The alternative is to use the t model (Christen and Perez 2016). |
| t.a | Value a of the t distribution (defaults to 3). |
| t.b | Value a of the t distribution (defaults to 4). |
| rounded | Rounding of the percentages of the reported hpd ranges. Defaults to 1 decimal. |
| extend.range | Range by which the axes are extended beyond the data limits. Defaults to 5%. |
| legend.cex | Size of the font of the legends. Defaults to 0.8. |
| legend1.loc | Where the first legend (with the calibration curve name and the uncalibrated date) is plotted. Defaults to topleft. |
| legend2.loc | Where the second legend (with the hpd ranges) is plotted. Defaults to topright. |
| mgp | Axis text margins (where should titles, labels and tick marks be plotted). |
| mar | Plot margins (amount of white space along edges of axes 1-4). |
| xaxs | Whether or not to extend the limits of the horizontal axis. Defaults to `xaxs="i"` which does not extend the limits. |
| yaxs | Whether or not to extend the limits of the vertical axis. Defaults to `yaxs="i"` which does not extend the limits. |
| bty | Draw a box around the graph ("n" for none, and "l", "7", "c", "u", "]" or "o" for correspondingly shaped boxes). |
| cc.dir | Directory of the calibration curves. Defaults to where the package's files are stored (system.file), but can be set to, e.g., `cc.dir="curves"`. |
| ... | Other plotting parameters. |

## Details

Type `calibrate()` to see how a date of 2450 +- 50 14C BP gets calibrated (the calibration curve happens to show a plateau around this 14C age). To calibrate a different date, provide its reported mean and error (1 standard deviation error as reported by the radiocarbon laboratory) as follows: `calibrate(mean, error)`, e.g., for a date of 130 +- 10 14C BP, type calibrate`(age=130, error=10)` or, shorter, `calibrate(130,10)`.

In case the date has a reservoir effect or age offset, e.g. of 100 14C years, provide this as follows: `calibrate(130, 10, reservoir=100)`. If you want to include an uncertainty for this offset, provide this as follows, e.g., for an uncertainty of 50yr, `calibrate(130,10,reservoir=c(100, 50))`. The uncertainty for the age offset will then be added to the error (by taking the square root of the sum of the squared error and the squared offset uncertainty). If the carbon of your sample has mixed marine/terrestrial sources, instead apply the marine offset using mix.curves and calibrate the date using that custom-built curve (cc="mixed").

If you prefer to work with, e.g., 68 % as opposed to the default 95 % confidence intervals, type: `calibrate(130, 10, prob=0.68)` or `calibrate(130, 10,, 0.68)` (the commas between the brackets indicate the position of the option; the standard deviation is the fourth option of the `calibrate`

function). The calibrated distribution can be calculated for every single calendar year (yrsteps=1) within a wide range of the 14C date. Probabilities below a threshold (default threshold=0.0005) will be neglected.

By default the northern hemisphere terrestrial calibration curve is used (cc=1 or cc1="IntCal20"). To use alternative curves, use cc=2 (cc2="Marine20"), cc=3 (cc3="SHCal20C"), cc=4 (cc4="mixed.14C"), or specify a postbomb curve (e.g., cc="nh1").

Calibrate works in cal BP (calendar years before AD 1950) by default, but can work with cal BC/AD through the option BCAD=TRUE.

By default the Gaussian distribution is used to calibrate dates. For use of the t distribution (Christen and Perez 2016) instead, set normal=FALSE provide values for t.a and t.b (defaults to t.a=3 and t.b=4).

Calibrated distributions are usually reduced to their 68% or 95% calibrated ranges, taking into account the asymmetric and multi-peaked shape of these distributions. Calibrated ranges at 68% will obviously result in narrower confidence intervals, and a perceived higher precision, than 95% ranges. However, given the often asymmetric and multi-modal nature of calibrated distributions, the probability that the 'true' calendar date lies outside the 1 standard deviation hpd ranges is considerable (c. 32%). Therefore the use of 95% calibrated ranges is preferable, and default.

Negative radiocarbon ages are calibrated with postbomb curves, but the user needs to tell which curve to use. For example, to use the first of the three northern hemisphere curves, provide the option cc="nh1", cc="nh2", cc="nh3", while for southern hemisphere samples, use cc="sh1-2" or cc="sh3".

A graph of the calibration is produced, and it can be adapted in several ways. The limits of the horizontal (calendar scale) and vertical (14C scale) axes are calculated automatically but can be changed by providing alternative values for the options cal.lim, C14.lim. The titles of both axis can be changed by providing alternative titles to cal.lab and/or C14.lab. The heights of the distributions of the 14C and calibrated ages can be set to alternative values using dist.height (default 0.3 which plots the distribution up to 30% of the height of the entire graph). Parameters for white space around the graph can be changed (default mar=c(3.5, 2, 2, 1) for spacing below, to the left, above and to the right respectively), as can the spacing for the axis labels (mgp=c(2,1,0)). By default, the axes are connected at the lower left, bty="l". Check the R documentation of par() for more options.

The colours of the 14C date, the calibration curve, the distributions, and the highest posterior density (hpd) ranges, can be changed by providing an alternative colour in date.col, cc.col, dist.col, and/or hpd.col, respectively. The default colours are transparent grey for the dates probability distributions (dist.col=rgb(0,0,0, 0.3) and sd.col=rgb(0,0,0, 0.5); change the last value of rgb for different greyscale values), red for the uncalibrated mean and error bars (date.col="red"), and transparent green for the calibration curve (cc.col=rgb(0, 0.5, 0, 0.7)). R's rgb() function expects values between 0 and 1 for red, green and blue, respectively, followed by a value for the semi-transparency (also between 0 and 1). Some graphic devices such as postscript are unable to use transparency; in that case provide different colours or leave the fourth value empty.

## Value

A graph of the raw and calibrated C-14 date, the calibrated ranges and, invisibly, the calibrated distribution and hpd ranges.

## Examples

```
calibrate()
calibrate(130, 10)
cal <- calibrate(2550, 20, reservoir=100)
cal; plot(cal[[1]])
calibrate(130, 10, prob=0.68)
calibrate(age=130, error=10, BCAD=TRUE)
calibrate(4450, 40, reservoir=c(100, 50))
```

---

`contaminate` *Simulate the impact of contamination on a radiocarbon age*

---

## Description

Given a certain radiocarbon age, calculate the observed impact of contamination with a ratio of material with a different 14C content (for example, 1

## Usage

```
contaminate(y, sdev = c(), fraction, F14C, F14C.er = 0, decimals = 5)
```

## Arguments

| | |
|---|---|
| `y` | the true radiocarbon age |
| `sdev` | the error of the true radiocarbon age |
| `fraction` | Relative amount of contamination. Must be between 0 and 1 |
| `F14C` | the F14C of the contamination. Set at 1 for carbon of modern radiocarbon age, at 0 for 14C-free carbon, or anywhere inbetween. |
| `F14C.er` | error of the contamination. Defaults to 0. |
| `decimals` | Rounding of the output. Since details matter here, the default is to provide 5 decimals. |

## Value

The observed radiocarbon age and error

## Author(s)

Maarten Blaauw

## Examples

```
contaminate(5000, 20, .01, 1) # 1% contamination with modern carbon
# Impacts of different amounts of contamination with modern carbon:
real.14C <- seq(0, 50e3, length=200)
contam <- seq(0, .1, length=101) # 0 to 10% contamination
contam.col <- rainbow(length(contam))
plot(0, type="n", xlim=c(0, 55e3),
  xlab="real", ylim=range(real.14C), ylab="observed")
for(i in 1:length(contam))
 lines(real.14C, contaminate(real.14C, c(), contam[i], 1, decimals=5), col=contam.col[i])
contam.legend <- seq(0, .1, length=6)
contam.col <- rainbow(length(contam.legend))
text(52e3, contaminate(50e3, c(), contam.legend, 1), labels=contam.legend, col=contam.col, cex=.7)
```

---

# D14C.F14C *Transform D14C into F14C*

---

## Description

Transform D14C into F14C

## Usage

```
D14C.F14C(D14C, t)
```

## Arguments

| | |
|---|---|
| D14C | The Delta14C value to translate |
| t | the cal BP age |

## Details

As explained by Heaton et al. 2020 (Radiocarbon), 14C measurements are commonly expressed in three domains: Delta14C, F14C and the radiocarbon age. This function translates Delta14C, the historical level of Delta14C in the year t cal BP, to F14C values. Note that per convention, this function uses the Cambridge half-life, not the Libby half-life.

## Value

The corresponding F14C value

## Examples

```
D14C.F14C(-10, 238)
```

draw.ccurve *Draw a calibration curve.*

## Description

Draw one or two of the calibration curves, or add a calibration curve to an existing plot.

## Usage

```
draw.ccurve(
  cal1 = c(),
  cal2 = c(),
  cc1 = "IntCal20",
  cc2 = NA,
  cc1.postbomb = FALSE,
  cc2.postbomb = FALSE,
  BCAD = FALSE,
  cal.lab = NA,
  cal.rev = FALSE,
  c14.lab = NA,
  c14.lim = NA,
  c14.rev = FALSE,
  ka = FALSE,
  add.yaxis = FALSE,
  cc1.col = rgb(0, 0, 1, 0.5),
  cc1.fill = rgb(0, 0, 1, 0.2),
  cc2.col = rgb(0, 0.5, 0, 0.5),
  cc2.fill = rgb(0, 0.5, 0, 0.2),
  add = FALSE,
  bty = "l",
  cc.dir = NULL,
  legend = "topleft",
  ...
)
```

## Arguments

| | |
|---|---|
| cal1 | First calendar year for the plot. Defaults to 0 cal BP. |
| cal2 | Last calendar year for the plot. Defaults to 55,000 cal BP. |
| cc1 | Name of the calibration curve. Can be "IntCal20", "Marine20", "SHCal20", or for the previous curves "IntCal13", "Marine13" or "SHCal13". Can also be "nh1", "nh2", "nh3", "sh1-2", "sh3", "nh1_monthly", "nh1_monthly", "nh2_monthly", "nh3_monthly", "sh1-2_monthly", "sh3_monthly", "Kure", "LevinKromer" or "Santos" for postbomb curves. |
| cc2 | Optional second calibration curve to plot. Can be "IntCal20", "Marine20", "SHCal20", or for the previous curves "IntCal13", "Marine13" or "SHCal13". Defaults to nothing, NA. |

| | |
|---|---|
| cc1.postbomb | Use postbomb=TRUE to get a postbomb calibration curve for cc1 (default cc1.postbomb=FALSE). |
| cc2.postbomb | Use postbomb=TRUE to get a postbomb calibration curve for cc2 (default cc2.postbomb=FALSE). |
| BCAD | The calendar scale of graphs and age output-files is in cal BP (calendar or calibrated years before the present, where the present is AD 1950) by default, but can be changed to BC/AD using BCAD=TRUE. |
| cal.lab | The labels for the calendar axis (default age.lab="cal BP" or "BC/AD" if BCAD=TRUE), or to age.lab="kcal BP" etc. if ka=TRUE. |
| cal.rev | Reverse the calendar axis. |
| c14.lab | Label for the C-14 axis. Defaults to 14C BP (or 14C kBP if ka=TRUE). |
| c14.lim | Axis limits for the C-14 axis. Calculated automatically by default. |
| c14.rev | Reverse the C-14 axis. |
| ka | Use kcal BP (and C14 kBP). |
| add.yaxis | Whether or not to plot the second calibration. Defaults to add.yaxis=FALSE. |
| cc1.col | Colour of the calibration curve (outline). |
| cc1.fill | Colour of the calibration curve (fill). |
| cc2.col | Colour of the calibration curve (outline), if activated (default cc2=NA). |
| cc2.fill | Colour of the calibration curve (fill), if activated (default cc2=NA). |
| add | Whether or not to add the curve(s) to an existing plot. Defaults to FALSE, which draws a new plot |
| bty | Draw a box around a box of a certain shape. Defaults to bty="l". |
| cc.dir | Directory of the calibration curves. Defaults to where the package's files are stored (system.file), but can be set to, e.g., cc.dir="curves". |
| legend | Location of the legend (only activated if more than one curve is plotted). Plotted in the topleft corner by default. Use legend=c() to leave empty |
| ... | Any additional optional plotting parameters. |

## Value

A plot of the calibration curve

## Examples

```
draw.ccurve()
draw.ccurve(1000, 3000, cc2="Marine20")
draw.ccurve(1800, 2020, BCAD=TRUE, cc2="nh1", cc2.postbomb=TRUE)
draw.ccurve(1800, 2010, BCAD=TRUE, cc2="nh1", add.yaxis=TRUE)
```

`draw.contamination` *Draw contamination impacts*

## Description

Show how contamination with different fractions of modern carbon affect observed C-14 ages.

## Usage

```
draw.contamination(
  from = 0,
  to = 50000,
  ka = TRUE,
  age.res = 500,
  xlim = c(),
  ylim = c(),
  colours = rainbow(age.res),
  max.contam = 0.1,
  contam.F14C = 1,
  contam.legend = max.contam * c(1/100, (1:5)/50, (1:4)/5, 1),
  legend.pos = 0.07,
  legend.cex = 0.6,
  grid = TRUE,
  xaxs = "i",
  yaxs = "i"
)
```

## Arguments

| | |
|---|---|
| `from` | Minimum 14C age for the plot. Defaults to 0 |
| `to` | Maximum 14C age for the plot. Defaults to 50e3. |
| `ka` | Use C14 kBP. Defaults to TRUE. |
| `age.res` | Resolution of age scale. Defaults to 500, which results in smooth curves. Higher numbers will take longer to draw. |
| `xlim` | Limits of the horizontal axis. |
| `ylim` | Limits of the vertical axis. |
| `colours` | Colours of the percentages. Defaults to rainbow colours. |
| `max.contam` | Maximum contamination level as a fraction of the sample. Defaults to 0.1 (10%). |
| `contam.F14C` | 14C activity of the sample. Defaults to 'modern' 14C, F14C=1. |
| `contam.legend` | Percentages for which numbers will be plotted. |
| `legend.pos` | horizontal position beyond which the percentage values will be plotted |
| `legend.cex` | font size of the legend |

| | |
|---|---|
| grid | Whether to plot a grid. Defaults to TRUE |
| xaxs | Whether or not to extend the limits of the horizontal axis. Defaults to xaxs="i" which does not extend. |
| yaxs | Whether or not to extend the limits of the vertical axis. Defaults to yaxs="i" which does not extend. |

## Value

A plot of real and observed (contamination-impacted) C14 ages.

## Examples

```
draw.contamination()
draw.contamination(40e3, 50e3, ka=FALSE)
```

---

# draw.D14C *Draw d14C and the calibration curve.*

---

## Description

Draw a proxy of the atmospheric 14C concentration (d14C) as well as the calibration curve.

## Usage

```
draw.D14C(
  cal1 = c(),
  cal2 = c(),
  cc = rintcal::ccurve(),
  BCAD = FALSE,
  mar = c(4, 4, 1, 4),
  mgp = c(2.5, 1, 0),
  xaxs = "r",
  yaxs = "r",
  bty = "u",
  ka = FALSE,
  cal.lab = c(),
  cal.rev = FALSE,
  C14.lab = c(),
  C14.lim = c(),
  cc.col = rgb(0, 0.5, 0, 0.5),
  cc.border = rgb(0, 0.5, 0, 0.5),
  D14C.lab = c(),
  D14C.lim = c(),
  D14C.col = rgb(0, 0, 1, 0.5),
  D14C.border = rgb(0, 0, 1, 0.5)
)
```

## Arguments

| | |
|---|---|
| cal1 | First calendar year for the plot. Defaults to youngest calendar age of the calibration curve |
| cal2 | Last calendar year for the plot. Defaults to oldest calendar age of the calibration curve |
| cc | The calibration curve to use. Defaults to IntCal20 |
| BCAD | The calendar scale of graphs and age output-files is in cal BP (calendar or calibrated years before the present, where the present is AD 1950) by default, but can be changed to BC/AD using BCAD=TRUE. |
| mar | Plot margins (amount of white space along edges of axes 1-4). |
| mgp | Axis text margins (where should titles, labels and tick marks be plotted). |
| xaxs | Whether or not to extend the limits of the horizontal axis. Defaults to xaxs="r" which extends it by R's default. |
| yaxs | Whether or not to extend the limits of the vertical axis. Defaults to yaxs="r" which extends it by R's default. |
| bty | Draw a box around the graph ("n" for none, and "l", "7", "c", "u", "]" or "o" for correspondingly shaped boxes). |
| ka | Use kcal BP (and C14 kBP). Defaults to FALSE. |
| cal.lab | The labels for the calendar axis (default age.lab="cal BP" or "BC/AD" if BCAD=TRUE), or to age.lab="kcal BP" etc. if ka=TRUE. |
| cal.rev | Reverse the calendar axis (defaults to FALSE). |
| C14.lab | Label for the C-14 axis. Defaults to 14C BP (or 14C kBP if ka=TRUE). |
| C14.lim | Limits for the C-14 axis. Calculated automatically by default. |
| cc.col | Colour of the calibration curve (fill). |
| cc.border | Colour of the calibration curve (border). |
| D14C.lab | Label for the D14C axis. |
| D14C.lim | Axis limits for the D14C axis. Calculated automatically by default. |
| D14C.col | Colour of the D14C curve (fill). |
| D14C.border | Colour of the D14C curve (border). |

## Value

A plot of d14C and the calibration curve

## Examples

```
draw.D14C()
draw.D14C(30e3, 55e3, ka=TRUE)
draw.D14C(cc=rintcal::ccurve("NH1_monthly"), BCAD=TRUE)
```

`draw.dates` *add calibrated distributions to a plot.*

## Description

Add individual or multiple calibrated dates to a plot.

## Usage

```
draw.dates(
  age,
  error,
  depth,
  cc = 1,
  postbomb = FALSE,
  reservoir = c(),
  normal = TRUE,
  t.a = 3,
  t.b = 4,
  prob = 0.95,
  threshold = 0.001,
  BCAD = FALSE,
  draw.hpd = TRUE,
  hpd.lwd = 2,
  hpd.col = rgb(0, 0, 1, 0.7),
  cal.hpd.col = rgb(0, 0.5, 0.5, 0.35),
  mirror = TRUE,
  up = FALSE,
  draw.base = TRUE,
  col = rgb(0, 0, 1, 0.3),
  border = rgb(0, 0, 1, 0.5),
  cal.col = rgb(0, 0.5, 0.5, 0.35),
  cal.border = rgb(0, 0.5, 0.5, 0.35),
  add = FALSE,
  ka = FALSE,
  rotate.axes = FALSE,
  ex = 1,
  normalise = TRUE,
  cc.resample = 5,
  age.lab = c(),
  age.lim = c(),
  age.rev = FALSE,
  d.lab = c(),
  d.lim = c(),
  d.rev = TRUE,
  labels = c(),
  label.x = 1,
```

```
  label.y = c(),
  label.cex = 0.8,
  label.col = border,
  label.offset = c(0, 0),
  label.adj = c(1, 0),
  label.rot = 0,
  cc.dir = NULL,
  dist.res = 100,
  ...
)
```

## Arguments

| | |
|---|---|
| age | Mean of the uncalibrated C-14 age (or multiple ages). |
| error | Error of the uncalibrated C-14 age (or ages). |
| depth | Depth(s) of the date(s). Can also be their relative positions if no depths are available. |
| cc | Calibration curve for C-14 dates (1, 2, 3, or 4, or, e.g., "IntCal20", "Marine20", "SHCal20", "nh1", "sh3", or "mixed"). If there are multiple dates but all use the same calibration curve, one value can be provided. |
| postbomb | Whether or not this is a postbomb age. Defaults to FALSE. |
| reservoir | Reservoir age, or reservoir age and age offset. |
| normal | Use the normal distribution to calibrate dates (default TRUE). The alternative is to use the t model (Christen and Perez 2009). |
| t.a | Value a of the t distribution (defaults to 3). |
| t.b | Value a of the t distribution (defaults to 4). |
| prob | Probability confidence intervals (between 0 and 1). |
| threshold | Report only values above a threshold. Defaults to `threshold=0.001`. |
| BCAD | Use BC/AD or cal BP scale (default cal BP). |
| draw.hpd | Whether or not to draw the hpd ranges as a line |
| hpd.lwd | Width of the line of the hpd ranges |
| hpd.col | Colour of the hpd rectangle for all dates or radiocarbon dates |
| cal.hpd.col | Colour of the hpd rectangle for cal BP dates |
| mirror | Plot distributions mirrored, a bit like a swan. Confuses some people but looks nice to the author so is the default. |
| up | If mirror is set to FALSE, the distribution can be plotted up or down, depending on the direction of the axis. |
| draw.base | By default, the base of the calibrated distributions is plotted. This can be avoided by supplying `draw.base=FALSE` as an option. |
| col | Colour of the inside of the distribution |
| border | Colour of the border of the distribution |
| cal.col | Colour of the inside of distribution of non-radiocarbon dates that didn't need calibration |

| | |
|---|---|
| cal.border | Colour of the border of the distribution of non-radiocarbon dates that didn't need calibration |
| add | Whether or not to add the dates to an existing plot. If set to FALSE (default), a plot will be set up. |
| ka | Whether or not to plot ages as thousands of years. Defaults to ka=FALSE. |
| rotate.axes | By default, the calendar age axis is plotted on the horizontal axis, and depth/position on the vertical one. Use rotate.axes=TRUE to rotate the axes. |
| ex | Exaggeration of the height of the distribution, defaults to ex=1. |
| normalise | If TRUE, the age distributions are normalised by plotting each distribution with the same total area. Precise dates will therefore peak higher than less precise dates (default). If normalise=FALSE, the peak of each date will be drawn at the same height. |
| cc.resample | The IntCal20 curves have different densities (every year between 0 and 5 kcal BP, then every 5 yr up to 15 kcal BP, then every 10 yr up to 25 kcal BP, and then every 20 yr up to 55 kcal BP). If calibrated ages span these density ranges, their drawn heights can differ, as can their total areas (which should ideally all sum to the same size). To account for this, resample to a constant time-span, using, e.g., cc.resample=5 for 5-yr timespanes. |
| age.lab | Title of the calendar axis (if present) |
| age.lim | Limits of the calendar axis (if present) |
| age.rev | Reverse the age axis. Defaults to TRUE |
| d.lab | Title of the vertical axis (if present) |
| d.lim | Limits of the vertical axis (if present) |
| d.rev | Reverse the y-axis. Defaults to TRUE |
| labels | Add labels to the dates. Empty by default. |
| label.x | Horizontal position of the date labels. By default draws them before the youngest age (1), but can also draw them after the oldest age (2), or above its mean (3). |
| label.y | Vertical positions of the depths/labels. Defaults to 0 (or 1 if label.x is 3 or 4). |
| label.cex | Size of labels. |
| label.col | Colour of the labels. Defaults to the colour given to the borders of the dates. |
| label.offset | Offsets of the positions of the depths/labels, giving the x and y offsets. Defaults to c(0,0). |
| label.adj | Justification of the labels. Follows R's adj option: A value of "0" produces left-justified text, "0.5" (the default) centered text and "1" right-justified text. |
| label.rot | Rotation of the label. 0 by default (horizontal). |
| cc.dir | Directory of the calibration curves. Defaults to where the package's files are stored (system.file), but can be set to, e.g., cc.dir="curves". |
| dist.res | Resolution of the distribution polygons. Defaults to dist.res=100. |
| ... | Additional plotting options |

## Value

A plot of the (calibrated) dates

### Examples

```
plot(0, xlim=c(500,0), ylim=c(0, 2))
draw.dates(130, 20, depth=1)
x <- sort(runif(10, 1000, 10000)) # draw 10 random calendar ages
cc <- rintcal::ccurve() # get the calibration curve
y <- approx(cc[,1], cc[,2], x)$y # find the IntCal 14C ages
er <- .01 * y
draw.dates(y, er, 1:length(x))
draw.dates(y, er, y, d.lab="Radiocarbon age (BP)")
draw.ccurve(add=TRUE, cc1.col=rgb(0,.5,0,.5))
```

---

## F14C.age *Calculate C14 ages from F14C values.*

---

### Description

Calculate C14 ages from F14C values of radiocarbon dates.

### Usage

```
F14C.age(mn, sdev = c(), decimals = 5, lambda = 8033)
```

### Arguments

| | |
|---|---|
| mn | Reported mean of the F14C |
| sdev | Reported error of the F14C. Returns just the mean if left empty. |
| decimals | Amount of decimals required for the radiocarbon age. Quite sensitive, defaults to 5. |
| lambda | The mean-life of radiocarbon (based on Libby half-life of 5568 years) |

### Details

Post-bomb dates are often reported as F14C or fraction modern carbon. Since Bacon expects radiocarbon ages, this function can be used to calculate radiocarbon ages from F14C values. The reverse function is age.F14C.

### Value

Radiocarbon ages from F14C values. If F14C values are above 100%, the resulting radiocarbon ages will be negative.

### Examples

```
F14C.age(1.10, 0.5) # a postbomb date, so with a negative 14C age
F14C.age(.80, 0.5) # prebomb dates can also be calculated
```

F14C.D14C *Transform F14C into D14C*

## Description

Transform F14C into D14C

## Usage

```
F14C.D14C(F14C, t)
```

## Arguments

| | |
|---|---|
| F14C | The F14C value to translate |
| t | the cal BP age |

## Details

As explained by Heaton et al. 2020 (Radiocarbon), 14C measurements are commonly expressed in three domains: Delta14C, F14C and the radiocarbon age. This function translates F14C values into Delta14C, the historical level of Delta14C in the year t cal BP. Note that per convention, this function uses the Cambridge half-life, not the Libby half-life.

## Value

The corresponding D14C value

## Examples

```
F14C.D14C(0.985, 222)
cc <- rintcal::ccurve()
# plot IntCal20 as D14C:
cc.Fmin <- age.F14C(cc[,2]+cc[,3])
cc.Fmax <- age.F14C(cc[,2]-cc[,3])
cc.D14Cmin <- F14C.D14C(cc.Fmin, cc[,1])
cc.D14Cmax <- F14C.D14C(cc.Fmax, cc[,1])
plot(cc[,1]/1e3, cc.D14Cmax, type="l", xlab="kcal BP", ylab=expression(paste(Delta, ""^{14}, "C")))
lines(cc[,1]/1e3, cc.D14Cmin)
```

## hpd *Calculate highest posterior density*

### Description

Calculate highest posterior density ranges of calibrated distribution

### Usage

```
hpd(calib, prob = 0.95, return.raw = FALSE, rounded = 1)
```

### Arguments

| | |
|---|---|
| calib | The calibrated distribution, as returned from caldist() |
| prob | Probability range which should be calculated. Default prob=0.95. |
| return.raw | The raw data to calculate hpds can be returned, e.g. to draw polygons of the calibrated distributions. Defaults to return.raw=FALSE. |
| rounded | Rounding for reported probabilities. Defaults to 1 decimal. |

### Value

The highest posterior density ranges, as three columns: from age, to age, and the corresponding percentage(s) of the range(s)

### Examples

```
hpd(caldist(130,20))
plot(tmp <- caldist(2450,50), type='l')
abline(v=hpd(tmp)[,1:2], col=4)
```

## l.calib *Find the calibrated probability of a calendar age for a 14C date.*

### Description

Find the calibrated probability of a cal BP age for a radiocarbon date. Can handle either multiple calendar ages for a single radiocarbon date, or a single calendar age for multiple radiocarbon dates.

## Usage

```
l.calib(
  yr,
  y,
  er,
  cc = rintcal::ccurve(1, FALSE),
  normal = TRUE,
  t.a = 3,
  t.b = 4
)
```

## Arguments

| | |
|---|---|
| yr | The cal BP year. |
| y | The radiocarbon date's mean. |
| er | The radiocarbon date's lab error. |
| cc | calibration curve for the radiocarbon date(s) (see the rintcal package). |
| normal | Use the normal distribution to calibrate dates (default TRUE). The alternative is to use the t model (Christen and Perez 2016). |
| t.a | Value a of the t distribution (defaults to 3). |
| t.b | Value b of the t distribution (defaults to 4). |

## Details

The function cannot deal with multiple calibration curves if multiple calendar years or radiocarbon dates are entered.

## Value

The calibrated probability of a calendar age for a 14C age

## Author(s)

Maarten Blaauw

## Examples

```
l.calib(100, 130, 20)
l.calib(100:110, 130, 20) # multiple calendar ages of a single date
l.calib(100, c(130,150), c(15,20)) # multiple radiocarbon ages and a single calendar age
```

`older` *Find the probability of a calibrated date being older than a certain age*

## Description

Find the probability of a calibrated date being older than an age x.

Find the probability that a sample is older than a certain calendar age x, by calculating the proportion of the calibrated distribution 'after' x (i.e., 1 - the summed calibrated distribution up to year x).

## Usage

```
older(
  x,
  y,
  er,
  cc = 1,
  postbomb = FALSE,
  normal = TRUE,
  t.a = 3,
  t.b = 4,
  BCAD = FALSE,
  threshold = 0
)
```

## Arguments

| | |
|---|---|
| `x` | The year of interest, in cal BP by default. |
| `y` | The radiocarbon date's mean. |
| `er` | The radiocarbon date's lab error. |
| `cc` | calibration curve for the radiocarbon date(s) (see the `rintcal` package). |
| `postbomb` | Whether or not to use a postbomb curve (see `caldist()`). |
| `normal` | Use the normal distribution to calibrate dates (default TRUE). The alternative is to use the t model (Christen and Perez 2016). |
| `t.a` | Value a of the t distribution (defaults to 3). |
| `t.b` | Value b of the t distribution (defaults to 4). |
| `BCAD` | Which calendar scale to use. Defaults to cal BP, `BCAD=FALSE`. |
| `threshold` | Report only values above a threshold. Defaults to `threshold=0`. |

## Details

The function can only deal with one date at a time.

## Value

The probability of a date being older than a certain calendar age.

### Author(s)

Maarten Blaauw

### Examples

```
older(2800, 2450, 20)
older(2400, 2450, 20)
calibrate(160, 20, BCAD=TRUE)
older(1750, 160, 20, BCAD=TRUE)
```

---

## pMC.age *Calculate C14 ages from pMC values.*

---

### Description

Calculate C14 ages from pMC values of radiocarbon dates.

### Usage

```
pMC.age(mn, sdev = c(), ratio = 100, decimals = 0, lambda = 8033)
```

### Arguments

| | |
|---|---|
| mn | Reported mean of the pMC. |
| sdev | Reported error of the pMC. |
| ratio | Most modern-date values are reported against 100. If it is against 1 instead, use 1 here. |
| decimals | Amount of decimals required for the radiocarbon age. |
| lambda | The mean-life of radiocarbon (based on Libby half-life of 5568 years) |

### Details

Post-bomb dates are often reported as pMC or percent modern carbon. Since Bacon expects radiocarbon ages, this function can be used to calculate radiocarbon ages from pMC values. The reverse function is age.pMC.

### Value

Radiocarbon ages from pMC values. If pMC values are above 100%, the resulting radiocarbon ages will be negative.

### Examples

```
pMC.age(110, 0.5) # a postbomb date, so with a negative 14C age
pMC.age(80, 0.5) # prebomb dates can also be calculated
pMC.age(.8, 0.005, ratio=1) # throws a warning, use F14C.age instead
```

`point.estimates` *Calculate a point estimate*

## Description

Calculate a point estimate of a calibrated distribution - either the weighted mean, the median or the mode (maximum). Note that point estimates often tend to be very poor representations of entire calibrated distributions, so please be careful and do not reduce entire calibrated distributions to just 1 point value.

## Usage

```
point.estimates(
  calib,
  wmean = TRUE,
  median = TRUE,
  mode = TRUE,
  midpoint = TRUE,
  prob = 0.95,
  rounded = 1
)
```

## Arguments

| | |
|---|---|
| `calib` | The calibrated distribution, as returned from caldist() |
| `wmean` | Report the weighted mean (defaults to TRUE) |
| `median` | Report the median (defaults to TRUE) |
| `mode` | Report the mode, which is the year with the maximum probability (defaults to TRUE) |
| `midpoint` | Report the midpoint of the hpd range(s) |
| `prob` | probability range for the hpd range(s) |
| `rounded` | Rounding for reported probabilities. Defaults to 1 decimal. |

## Value

The chosen point estimates

## Examples

```
point.estimates(caldist(130,20))
plot(tmp <- caldist(2450,50), type='l')
abline(v=point.estimates(tmp), col=1:4)
```

younger *Find the probability of a calibrated date being of a certain age or younger than it*

## Description

Find the probability that a sample is of a certain calendar age x or younger than it, by calculating the proportion of the calibrated distribution up to and including x (i.e., summing the calibrated distribution up to year x).

## Usage

```
younger(
  x,
  y,
  er,
  cc = 1,
  postbomb = FALSE,
  normal = TRUE,
  t.a = 3,
  t.b = 4,
  BCAD = FALSE,
  threshold = 0
)
```

## Arguments

| | |
|---|---|
| x | The year of interest, in cal BP by default. |
| y | The radiocarbon date's mean. |
| er | The radiocarbon date's lab error. |
| cc | calibration curve for the radiocarbon date(s) (see the `rintcal` package). |
| postbomb | Whether or not to use a postbomb curve (see `caldist()`). |
| normal | Use the normal distribution to calibrate dates (default TRUE). The alternative is to use the t model (Christen and Perez 2016). |
| t.a | Value a of the t distribution (defaults to 3). |
| t.b | Value b of the t distribution (defaults to 4). |
| BCAD | Which calendar scale to use. Defaults to cal BP, `BCAD=FALSE`. |
| threshold | Report only values above a threshold. Defaults to `threshold=0`. |

## Details

The function can only deal with one date at a time.

## Value

The probability of a date being of a certain calendar age or younger than it.

## Author(s)

Maarten Blaauw

## Examples

```
younger(2800, 2450, 20)
younger(2400, 2450, 20)
calibrate(160, 20, BCAD=TRUE)
younger(1750, 160, 20, BCAD=TRUE)
```

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