IOSACal Documentation

Release 0.4.0

Stefano Costa

Jun 23, 2018

Contents

IOSACal is an open source tool for radiocarbon calibration. It has a command-line program:

```
$ iosacal -d 7505 -s 93 --id "P-769"
```

which also creates nice plots like this:

```
$ iosacal -d 7505 -s 93 --id "P-769" -p
```
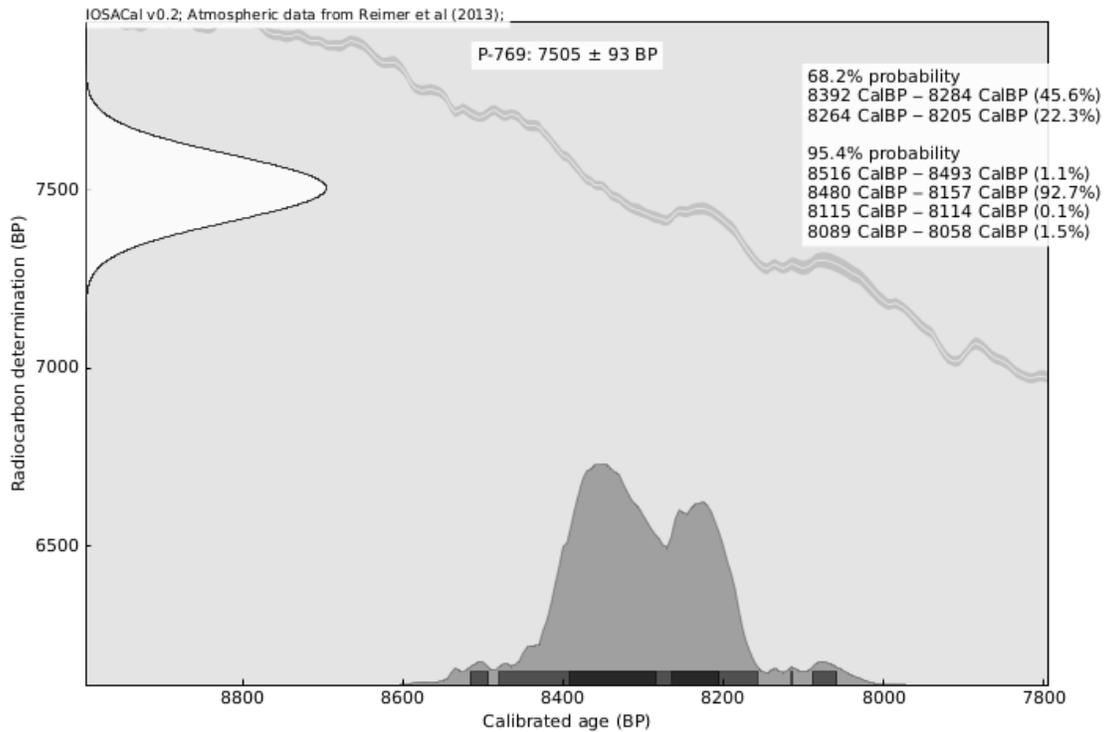

The same features are available as a Python 3 library:

```
>>> from iosacal import R
>>> from iosacal.text import single_text
>>> r = R(7505, 93, 'P-769')
>>> cal_r = r.calibrate('intcal13')
>>> single_text(cal_r)

# P-769

Calibration of P-769: 7505 ± 93 BP

## Calibrated age

Atmospheric data from Reimer et al (2013);

### 68.2% probability

* 8392 CalBP [U+2012] 8284 CalBP (45.6%)
* 8264 CalBP [U+2012] 8205 CalBP (22.3%)
```

```
### 95.4% probability

* 8516 CalBP [U+2012] 8493 CalBP (1.1%)
* 8480 CalBP [U+2012] 8157 CalBP (92.7%)
* 8115 CalBP [U+2012] 8114 CalBP (0.1%)
* 8089 CalBP [U+2012] 8058 CalBP (1.5%)
```

Multiple determinations from the same event can be checked for consistency and combined:

```
>>> from iosacal import R, combine
>>> from iosacal.text import single_text
>>> r1 = R(4430, 100, 'Birm-637')
>>> r2 = R(4430, 120, 'Birm-638')
>>> r3 = R(4400, 100, 'Birm-639')
>>> r4 = R(4350, 130, 'Birm-636')
>>> r_combined = combine([r1, r2, r3, r4])
>>> print(r_combined)

RadiocarbonSample( Combined from Birm-637, Birm-638, Birm-639, Birm-636 with test␣
→statistic 0.287 : 4406 ± 55 )

>>> r_combined_cal = r_combined.calibrate('intcal13')
>>> print(single_text(r_combined_cal))

# Combined from Birm-637, Birm-638, Birm-639, Birm-636 with test statistic 0.287

Calibration of Combined from Birm-637, Birm-638, Birm-639, Birm-636 with test␣
→statistic 0.287: 4406.465763017056 ± 55.163983474505095 BP

## Calibrated age

Atmospheric data from Reimer et al (2013);

### 68.2% probability

* 5210 CalBP [U+2012] 5203 CalBP (2.2%)
* 5047 CalBP [U+2012] 4870 CalBP (65.8%)

### 95.4% probability

* 5280 CalBP [U+2012] 5164 CalBP (19.3%)
* 5135 CalBP [U+2012] 5105 CalBP (3.6%)
* 5077 CalBP [U+2012] 4855 CalBP (72.5%)
```

IOSACal can be used interactively with Jupyter Notebook (formerly known as IPython Notebook).

Install

If you have Python 3 just:

```
pip3 install iosacal
```

or get the source at https://gitlab.com/iosa/iosacal.

If none of the above makes sense, follow the *Installation* instructions.

Why another 14C calibration software ?

Most available programs for radiocarbon calibration, like OxCal, CALIB and others, are *freeware*. You don't have to pay for them, but on the other side you're not free to modify them as you need, nor to access and study the source code.

This is the main motivation behind IOSACal: creating a free-as-in-freedom radiocarbon calibration software, with a clean programming library, that enables experiments and integration in existing archaeological information systems.

Furthermore, writing this software from scratch is an alternative way of learning how 14C calibration works, not only in strict mathematical terms, but also from a practical point of view.

Features

IOSACal takes a radiocarbon determination and outputs a calibrated age as a set of probability intervals. A radiocarbon date is represented by a date in years BP (before present, that is before 1950 AD) and a standard deviation, like 2430±170. The combination of these two values is a numerical representation of a laboratory measure performed on the original organic material.

The main task of the calibration process is to convert this measure into a set of calendar dates by means of a calibration curve. Users can choose whether they want results as a plot, a short textual summary or both (the plot includes the summary).

IOSACal reads calibration curves in the common `.14c` format used also by other programs. Should you have calibration data in another format, it would be easy to either convert them to that format or modify the source code of IOSACal to adapt it to your needs.

IOSACal is based on current calibration methods, like those described in *[RAM2008]*.

Can I use IOSACal for my research?

Yes, IOSACal has been used in research projects with large numbers of radiocarbon dates. Using IOSACal with Jupyter Notebooks is ideal for reproducible research that can be easily shared. Furthermore, it takes little effort to customize and adapt the existing code to your specific needs. IOSACal is reasonably fast, especially for batch processing.

The web application is ideal for quick checks on single radiocarbon dates, and requires no registration.

If you make use of IOSACal in your work, please cite it with the appropriate reference *[IOSACAL_Zenodo]*. This helps us get some recognition for creating and maintaining this software free for everyone.

Site contents

5.1 User's manual

Contents

- *User's manual*
  - *Basic usage*
  - *Other calibration curves*
  - *Multiple dates*
  - *Command line options*
    * *Plot output*
    * *BP or calendar dates*

The current version of IOSACal is in beta state (i.e. suitable for experimental production use), but has already all the basic functionality, like calibration, generation of publication-quality plots and determination of probability intervals.

5.1.1 Basic usage

The command line program is called `iosacal`. It can generate both text output and image plots.

The typical usage is:

```
$ iosacal -d 7505 -s 93 --id "P-769"
```

Output will look like the following:

```
# P-769

Calibration of P-769: 7505 ± 93 BP

## Calibrated age

Atmospheric data from Reimer et al (2013);

### 68.2% probability

* 8392 CalBP [U+2012] 8284 CalBP (45.6%)
* 8264 CalBP [U+2012] 8205 CalBP (22.3%)

### 95.4% probability

* 8516 CalBP [U+2012] 8493 CalBP (1.1%)
* 8480 CalBP [U+2012] 8157 CalBP (92.7%)
* 8115 CalBP [U+2012] 8114 CalBP (0.1%)
* 8089 CalBP [U+2012] 8058 CalBP (1.5%)
```
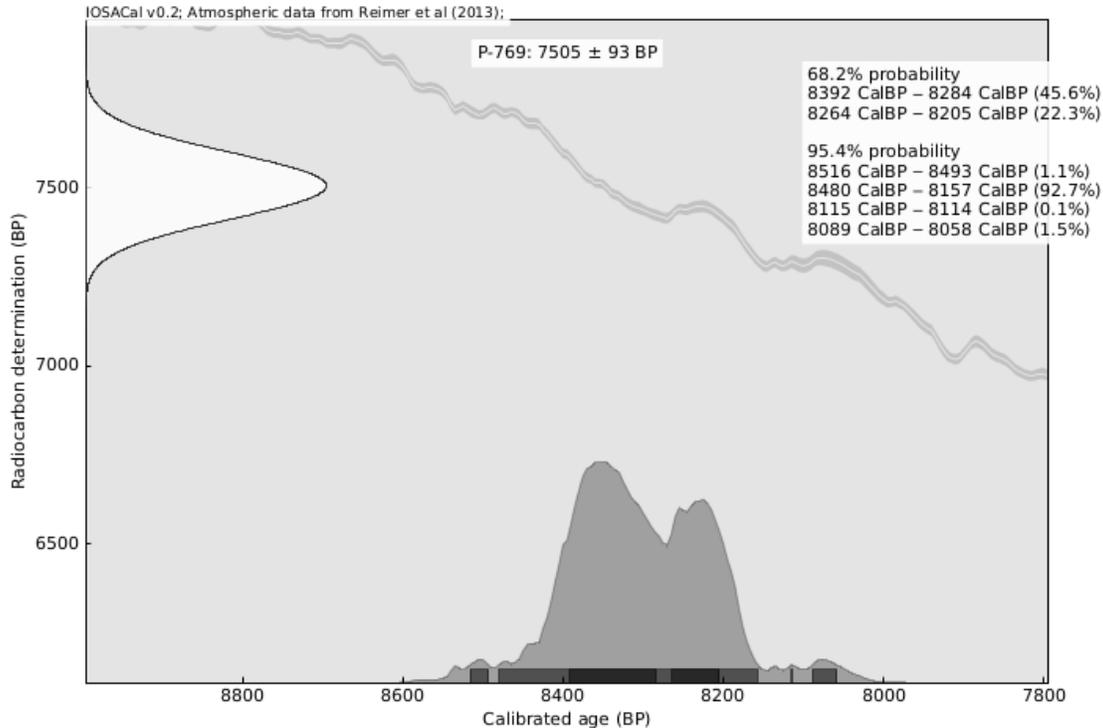
If you want an image instead of text output, just add the -p flag:

```
$ iosacal -d 7505 -s 93 --id "P-769" -p
```

The result will be saved into the image file named P-769_7505_93.pdf in the same directory. It will look more or less like this:

5.1.2 Other calibration curves

By default, `iosacal` uses the *IntCal13* calibration curve. IOSACal is however able to read *any* calibration curve that uses the same format as `intcal13.14c`, like those available on <http://www.radiocarbon.org/>. If you want to specify a different calibration curve provide the canonical name of the curve in lower case (e.g. `intcal09`, `marine09`).

To specify a calibration curve, use the `-c` command line option:

```
$ iosacal -d 7505 -s 93 --id "P-769" -p -c intcal04
```

Please note that IOSACal already includes the calibration curves listed below:

- *IntCal13*
- *Marine13*
- *ShCal13*
- *IntCal09*
- *Marine09*
- *IntCal04*
- *Marine04*
- *ShCal04*
- *IntCal98*
- *Marine98*

5.1.3 Multiple dates

It is also possible to give IOSACal more than one radiocarbon determination, to see how 2 or more samples relate between themselves.

To use the multiple dates feature, just pass multiple `-d`, `-s` and `--id` options on the command line:

```
$ iosacal \
  -d 7729 -s 80 --id "P-1365" \
  -d 7661 -s 99 --id "P-1375" \
  -d 7579 -s 86 --id "P-827" \
  -d 7572 -s 92 --id "P-772" \
  -d 7538 -s 89 --id "P-778" \
  -d 7505 -s 93 --id "P-769" \
  -p -m -n "Catalhöyük East level VI A"
```

The order in which values are passed to IOSACal matters, so the first date will be matched to the first standard deviation and so on.

This way, you will get 6 different single plots. The `-m` flag is used to indicate you want a **compound plot**. It's also useful to use the `-n` option to give a name to the image and a title to the plot.

The resulting compound plot looks like this:

Catalhöyük East level VI A
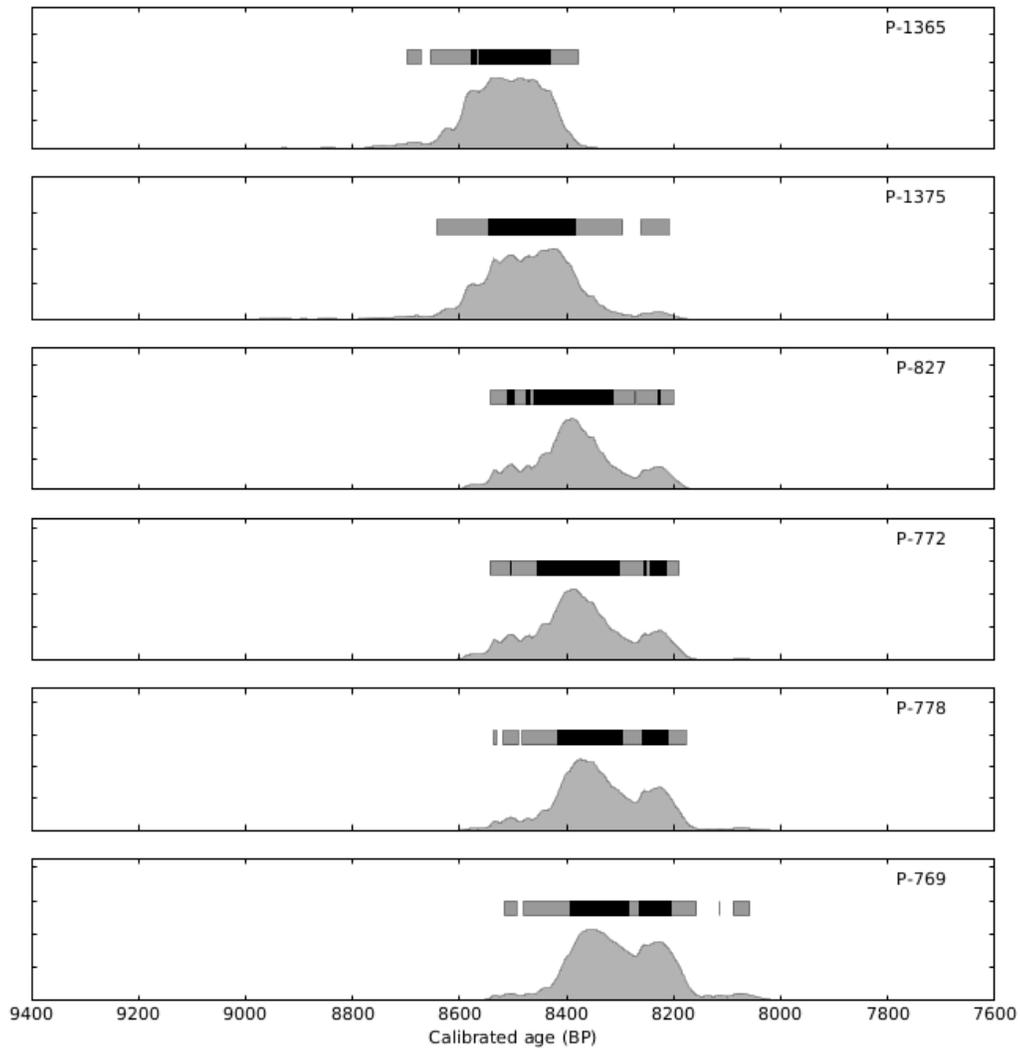
Warning: Currently IOSACal doesn't perform any Bayesian matching of calibrated ages. This feature will be added in future versions.

5.1.4 Command line options

IOSACal works from the command line. These are the available options.

-h
    Show an help message and exit

-d <date>, **--date**=<date>
    Conventional radiocarbon age, i.e. the non-calibrated radiocarbon BP date for the sample

-s <sigma>, **--sigma**=<sigma>
> Error at 1 standard deviation for the non-calibrated date given with the above option.

--id <sample_id>
> Lab ID of the sample, e.g. *P-1244*, *OxA-3311* or *BETA-248559*

-c <curve>, **--curve**=<curve>
> Calibration curve to be used [default: `intcal13`]

> If you want to specify a different calibration curve provide the curve canonical name in lower case (e.g. `intcal09`, `marine13`).

Plot output

-p, --plot
> Enables the graphical plot output.

-o, --oxcal
> Plots will be more similar to OxCal [default: False]

-n <name>, **--name** <name>
> Specify a name for the output plot [default: "iosacal"]

-1, --single
> Generate single plots for each sample. The default action.

--no-single
> Don't generate single plots for each sample.

-m, --stacked
> Generate stacked plot with all samples.

BP or calendar dates

Use these mutually exclusive options to choose which type of dates you like as output.

--bp
> Express date in Calibrated BP Age (default action)

--ad
> Express date in Calibrated BC/AD calendar Age

--ce
> Express date in Calibrated BCE/CE calendar Age

5.2 Installation

Simple things simple: to run IOSACal you need the following software on your computer:

- Python
- NumPy
- Matplotlib

All are available for major platforms. Order of installation matters.

5.2.1 Download

As of version 0.3 (released in 2016) IOSACal is in beta stage. You can always get the *development version* from the git repository, either with the complete project history or download the latest *released version* as a simple source archive.

5.2.2 Installing

Just extract the downloaded archive, move to the main directory and:

```
python setup.py install
```

from the main directory. Using pip and virtualenv is strongly recommended.

After the install has completed, the iosacal binary will be available.

5.2.3 Specific operating system instructions

Debian/Ubuntu

From a terminal:

```
sudo apt-get install python3-matplotlib
```

(this installs also Python, Numpy and all other requirements).

Windows

You might find more convenient to use a dedicated Python distribution instead of separately installing all packages:

- Enthought Python Distribution (a commercial distribution for scientific computing)
- Python(x,y) (a free distribution for scientific and engineering computing)

5.3 Implementation

IOSACal is written in Python 3, and it makes heavy use of the NumPy library for the internal management of calibration curves and calibrated samples. Calibration curves, radiocarbon dates and calibrated curves are handled internally as ndarray objects. ndarray objects are matrices that can be easily manipulated through slicing, flipping, summing and other typical operations.

Generation of plots is done through Matplotlib, another Python library built on top of NumPy. Matplotlib can natively read ndarray objects and plot them in a graphical form. Far from being just a set of plotting functions, Matplotlib allows the drawing of complex plots like those created by IOSACal.

Development happens in a public git repository at GitLab.

5.3.1 Interpolation

The *IntCal09* calibration curve has a varying resolution: data spacing changes from 5 years for the range from 0 to 11.2 to cal kBP, 10 yrs for 11.2–15 cal kBP, 20 yrs for 15–25 cal kBP, 50 yrs for 25–40 cal kBP, and 100 yrs for 40–50 cal kBP *[REI2009]*. Other curves follow a similar pattern.

This means that the output intervals would follow these limitations. IOSACal uses the *interp* function of *NumPy* to perform linear interpolation of the calibration curves and obtain more fine-grained results, particularly concerning probability intervals.

5.4 C14 and calibration resources

There are some interesting websites to learn about radiocarbon calibration and related topics. Some of them have been useful during the development of this software.

5.4.1 Other software

- OxCal is developed by the Oxford Radiocarbon Accelerator Unit: it's by far the most used calibration program
- CALIB is a radiocarbon calibration program. A command-line Linux version is available (non-free software, but works well)
- BCal is an on-line Bayesian radiocarbon calibration tool hosted by the Department of Probability and Statistics at the University of Sheffield

5.4.2 Reference websites

- Oxford Radiocarbon Accelerator Unit contains a detailed explanation of how to use C14 datings and how calibration works
- Radiocarbon is the main international journal of record for research articles and date lists relevant to 14C and other radioisotopes and techniques used in archaeological, geophysical, oceanographic, and related dating techniques
- radiocarbon WEB-info provides online information concerning the radiocarbon dating method

5.4.3 Calibration curves

Calibration curves are released in the public domain and can be downloaded in their native format, a slightly customised CSV:

- IntCal13 Supplemental Data to get the most recent **calibration curves** in `.14c` ASCII format
- IntCal09 Supplemental Data is the previous version of the same data

Please note that IOSACal already includes the calibration curves listed below:

- *IntCal13*
- *Marine13*
- *ShCal13*
- *IntCal09*
- *Marine09*
- *IntCal04*
- *Marine04*
- *ShCal04*
- *IntCal98*

- *Marine98*

Older calibration curves are useful to reproduce calibration results found in published literature.

5.4.4 Radiocarbon databases

There are a few databases of radiocarbon dates that are available as **open data**, and can be easily downloaded as CSV files for further processing.

- EUROEVOL

- Mediterranean radiocarbon dates

Both databases are useful to experiment with many dates and apart from their specific research aims and spatio-temporal coordinates, they are incredibly useful as a learning resource.

Other databases are usually released under restrictive license terms or unavailable to the public.

5.5 What's new in IOSACal

Release news for IOSACal.

5.5.1 Release 0.4 (released 2018-05-08)

The main highlight of this release are the new classes for summed probability distributions (SPD) and paleodemography, contributed by Mario Gutiérrez-Roig as part of his work for the PALEODEM project at IPHES.

On the technical side:

- requires NumPy 1.14, SciPy 1.1 and Matplotlib 2.2

- removed dependencies on obsolete functions

- improved the command line interface

5.5.2 Release 0.3 (released 2016-04-15)

- use `genfromtxt` to import calibration curves

- improved documentation

- intervals as a well-defined type

- restore AD/BC dates in both text and graphic output

5.5.3 Release 0.2 (released 2014-02-14)

Main highlights:

- new function to combine multiple determinations (Ward & Wilson 1978)

- a simple and straightforward set of commands to get started

- amazing interactive mode with IPython Notebook

- plotting multiple dates in a stacked plot actually works

- added several older calibration curves (useful to check published data)

On the technical side:

- works with Python 3 only, dropped compatibility with Python 2

- requires NumPy 1.8 and Matplotlib 1.3

- calibration curves and calibrated ages are `ndarray` objects, super-easy to work with

Known issues:

- AD/BC dates in output are not available, all dates are given as CalBP

5.6 License

IOSACal is free software: you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation, either version 3 of the License, or (at your option) any later version.

IOSACal is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details.

You should have received a copy of the GNU General Public License along with IOSACal. If not, see <http://www.gnu.org/licenses/>.

[RAM2008] C. Bronk Ramsey, Radiocarbon dating: revolutions in understanding, Archaeometry 50,2 (2008) pp. 249–275 http://dx.doi.org/10.1111/j.1475-4754.2008.00394.x

[IOSACAL_Zenodo] https://doi.org/10.5281/zenodo.630455

[REI2009] Reimer PJ, Baillie MGL, Bard E, Bayliss A, Beck JW, Blackwell PG, Bronk Ramsey C, Buck CE, Burr GS, Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Hajdas I, Heaton TJ, Hogg AG, Hughen KA, Kaiser KF, Kromer B, McCormac FG, Manning SW, Reimer RW, Richards DA, Southon JR, Talamo S, Turney CSM, van der Plicht J, Weyhenmeyer CE. 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal BP. Radiocarbon 51(4):1111–50.

Symbols