# *Undatable* User Manual

## Manual for Version 1.0 of software

Lougheed, B. C. and Obrochta, S. P. (2019), A rapid, deterministic age-depth modelling routine for geological sequences with inherent depth uncertainty. Paleoceanography and Paleoclimatology. Accepted Author Manuscript. doi:10.1029/2018PA003457

# Table of Contents

# 1.0 Requirements and Installation

## 1.1 System Requirements

Matlab version

*Undatable* was authored and tested using the following Matlab versions:

Windows 7 64-bit: Matlab versions 2012a and 2017b.
Linux Ubuntu: Matlab versions 2014a and 2015b.
Mac OS 10.13.4 64-bit: Matlab version 2015b (Note: 2014a and earlier are incompatible with this version of Mac OS).

Other versions of Matlab may work, but have not been tested.

Required Matlab toolboxes

*Undatable* requires the "Statistics and Machine Learning Toolbox"

Recommended Computer System and Memory

*Undatable* is optimised for 64-bit systems (which covers almost all computers built in the past decade), but will work, albeit slower, on 32-bit systems. *Undatable* uses a CPU-efficient coding approach which stores relatively large amounts of data in RAM. We generally recommend running the software on computers with at least 8 GB of RAM. Computers with less RAM will be sufficient in many cases, but users may run into problems when running simulations with large amounts of model iterations and/or age-depth constraints.

## 1.2 Installation

To install *Undatable*, first place all the files and folders you downloaded from the *Undatable* software repository to a folder on your hard drive (e.g. yourharddrive/yourfolder/undatablefolder/). The folder on your hard drive should not be called 'undatable', otherwise Matlab may become confused. In the example we have given, the folder is called 'undatablefolder'.

Subsequently, open Matlab, type the following into the Matlab command window prompt (replacing the part between the ' ' with the correct directory path) and press the Enter key:

```
addpath('yourharddrive/yourfolder/undatablefolder/'); savepath
```

To test for successful installation, type the following into the Matlab command window and press enter:

```
undatableGUI
```

If the install has been successful, then the GUI should appear.

# 2.0 Preparing input files

*Undatable* requires input files in the form of tab delimited text (.txt) files. A template input file (*udinput_template.txt*) file has been provided for users to edit and save a copy of. Such files can easily be edited and saved using plain text editors or spreadsheet applications (Microsoft Excel, LibreOffice Calc, Spread32, etc.). Remember to always save using the tab delimited text file format.

The template input file is shown below, with input instructions described per column in the following text.

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Sample ID | Depth 1 | Depth 2 | Age | Age error | Date type | Calibration | Resage | Reserr | Bootstrap |
| 2 | Lab-1234 | 20 | 21 | 1000 | 30 | 14C marine fossil | Marine13 | 100 | 100 | Yes |
| 3 | Lab-1235 | 30 | 31 | 2000 | 30 | 14C marine fossil | Marine13 | 150 | 100 | Yes |
| 4 | Lab-1236 | 41 | 42 | 3000 | 40 | 14C marine fossil | Marine13 | 250 | 150 | No |
| 5 | Lab-1237 | 54 | 56 | 4000 | 80 | 14C marine fossil | Marine13 | 300 | 200 | Yes |
| 6 | Hekla-4 | 58.2 | 58.6 | 4260 | 20 | tephra | None | NaN | NaN | No |
| 7 | Lab-1238 | 61 | 62 | 5500 | 80 | 14C terrestrial fossil | IntCal13 | NaN | NaN | Yes |
| 8 | Lab-1239 | 69 | 70 | 4900 | 60 | 14C terrestrial fossil | IntCal13 | NaN | NaN | Yes |
| 9 | Lab-1240 | 75 | 76 | 6000 | 80 | 14C terrestrial fossil | IntCal13 | NaN | NaN | Yes |
| 10 | Lab-1241 | 87 | 88 | 7000 | 110 | 14C terrestrial fossil | IntCal13 | NaN | NaN | Yes |
| 11 | Lab-1242 | 91 | 92 | 7900 | 110 | 14C sediment | Marine13 | 400 | 200 | Yes |
| 12 | Lab-1243 | 95 | 96 | 8500 | 115 | 14C marine fossil | Marine13 | 500 | 200 | Yes |
| 13 | Lab-1244 | 106 | 107 | 10000 | 120 | 14C marine fossil | Marine13 | 600 | 200 | Yes |
| 14 | Bob's NGRIP tie point | 118 | 5 | 11650 | 100 | tie point | None | NaN | NaN | Yes |
| 15 | Mary's U/Th date | 150 | 160 | 18950 | 250 | other | None | NaN | NaN | Yes |

**“Sample ID” column**

Labels unique to each age-depth constraint can be entered in this column. These are currently not used by the software, but we encourage users to label all their age-depth constraints for referencing purposes.

**“Depth 1” and “Depth 2” columns**

These columns are used to specify the depth interval for each date. There are three possible depth scenarios that the user can consider:

(1) *Discrete depth interval (most common scenario).* In this case the user simply enters the upper bound of the depth interval in *Depth1* and the lower bound of the depth interval in *Depth2.* For example, if an age-depth constraint is based on foraminifera picked between 100 and 102 cm core depth, simply enter 100 for *depth1* and 102 for *depth2*. Depth uncertainty will then be represented as a uniform function between 101 and 102.

(2) *No depth uncertainty.* Should you wish, for whatever reason, to have an age-depth constraint with no associated depth uncertainty, simply enter the same value for *depth1* and *depth2.*

(3) *Gaussian depth uncertainty.* In the case of "wiggle matching" or "tie-points", it can be difficult to determine with high precision to which core depth interval one is matching to. In this case it is possible to represent the depth interval using a Gaussian function. For example, if the user enters a value of 200 for *depth1* and a value of 5 for *depth2,* the depth uncertainty will be represented as a Gaussian function with a mean of 200 cm and 1σ value of 5 cm. Please note: Gaussian functions are automatically activated when the software detects that *depth2* is less than *depth1*.

**"Age" column**

Here the user can enter the age associated with the age-depth constraint.

Calendar age constraints should be entered as years before 1950 CE (AD).

Radiocarbon age constraints should be entered as uncalibrated $^{14}$C age BP.

**"Age error" column**

Here the user can enter the 1σ uncertainty associated with the inputted age. The input can either be in calendar years (in the case of calendar age constraints) or $^{14}$C years (in the case of radiocarbon age constraints).

**"Date type" column**

The date type specified in this column is used for colour coding the age-depth constraints in the output plot. The following date types are possible:

| | | |
|---|---|---|
| 14C marine fossil | 14C terrestrial fossil | 14C sediment |
| tephra | tie point | palaeomagnetism* |
| U/Th | other | |

*Both US and UK spelling are recognised.

**"Calibration" column**

In this column the user can specify if the entered age constraint should be radiocarbon calibrated or not. If the age constraint is a calendar age and should not be calibrated, simply enter *none*. Otherwise, specify the $^{14}$C calibration curve you want to calibrate. The entries are not case sensitive, but must not contain typos. The following entries are possible:

| | | | | | |
|---|---|---|---|---|---|
| none | IntCal13 | Marine13 | SHCal13 | IntCal09 | Marine09 |
| IntCal04 | Marine04 | SHCal04 | IntCal98 | Marine98 | |

**"Resage" column**

In this column, the user can enter the reservoir age associated with a radiocarbon age constraint. Reservoir ages should be entered as $^{14}$C years

relative to the calibration curve being used, i.e. as “ΔR” in the case of the Marine curves or “R(t)” in the case of the IntCal and SHCal curves.

If you do not want to enter a reservoir age, you may enter NaN or 0 for this column. Any reservoir age entered for non-radiocarbon age-depth constraints (i.e. calibration set to ‘none’) will automatically be ignored.

**“Reserr” column**

The user can enter a 1σ uncertainty (in $^{14}C$ years) associated with the selected reservoir age.

In the case of non-radiocarbon age constraints, this input will be ignored.

**“Bootstrap” column**

In this column, the user can choose to selectively include or exclude certain age-depth constraints from the bootstrapping process. See Lougheed and Obrochta, (2019) for more information about the bootstrapping process.

To include an age-depth constraint in the bootstrapping process, enter Yes for this column. To exclude an age-depth constraint from the bootstrapping process, enter No for this column.

Note! The deepest and shallowest dates will automatically be excluded from the bootstrapping process so that the age-depth iterations always have a begin and end point.

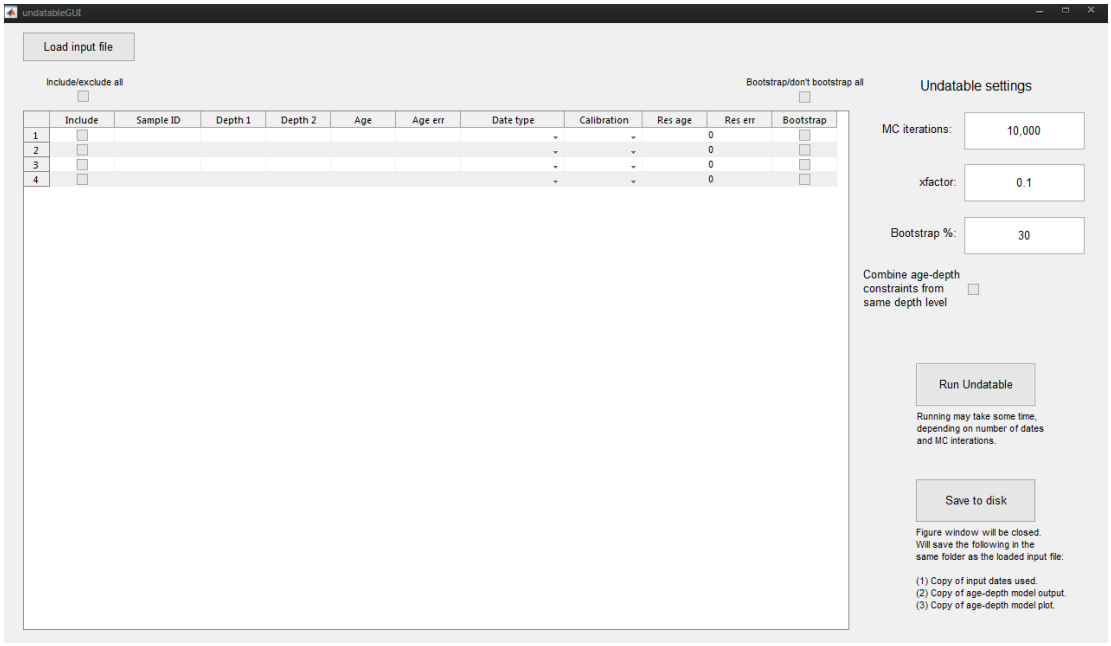
# 3.0 Running *Undatable* using the Graphical User Interface

## 3.1 Loading and running an age-depth model

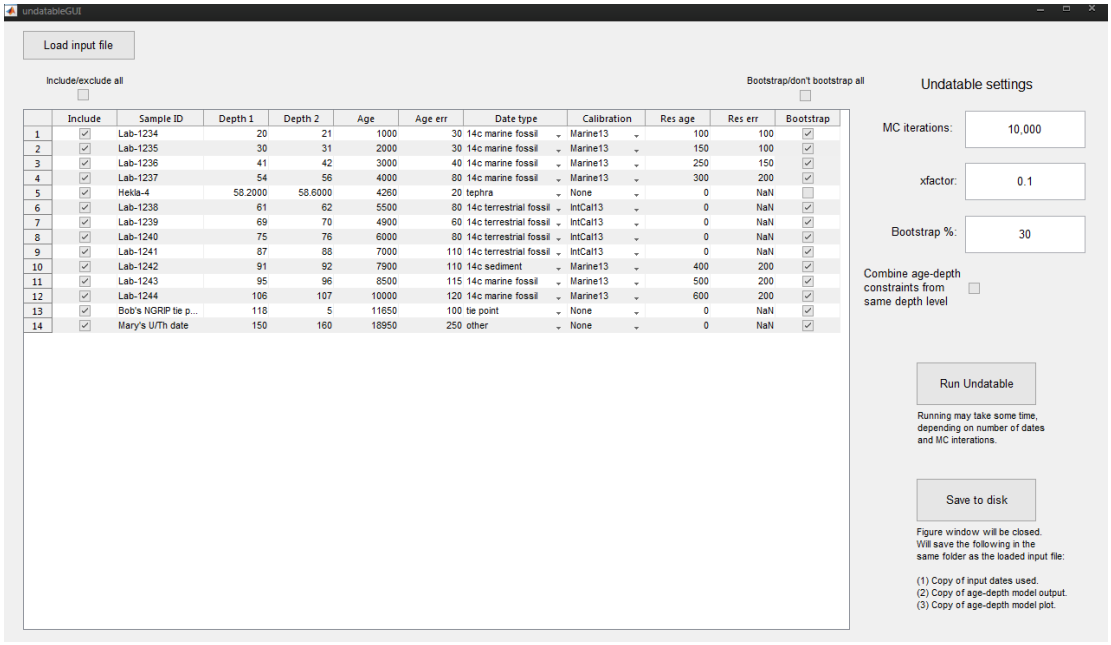
To start the graphical user interface, type the following into the Matlab Command Window prompt and press enter:

```
undatableGUI
```

The *Undatable* GUI interface will now be launched:



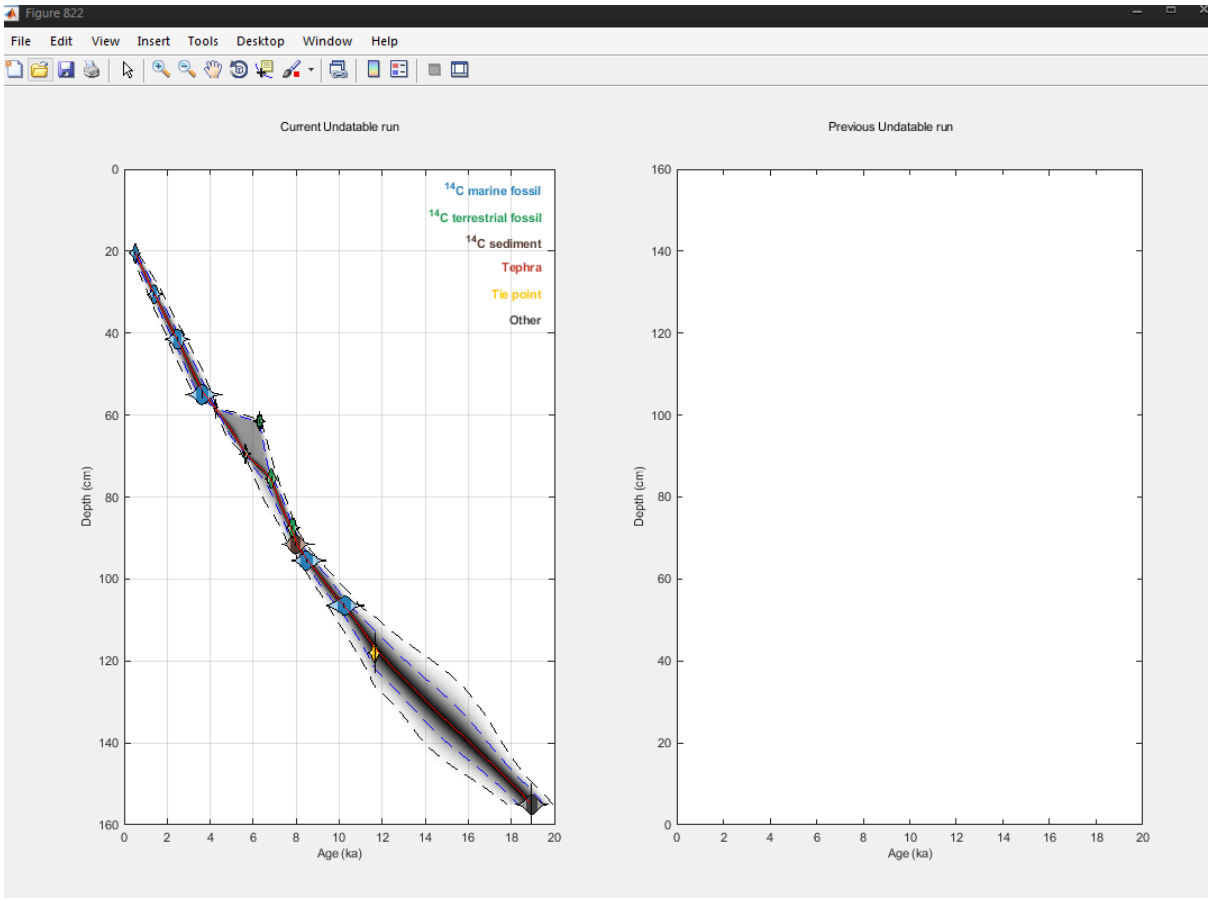

Click 'Load Input File' to navigate to and load a pre-prepared input file. In this case we will use the provided template file (*udinput_template.txt).*



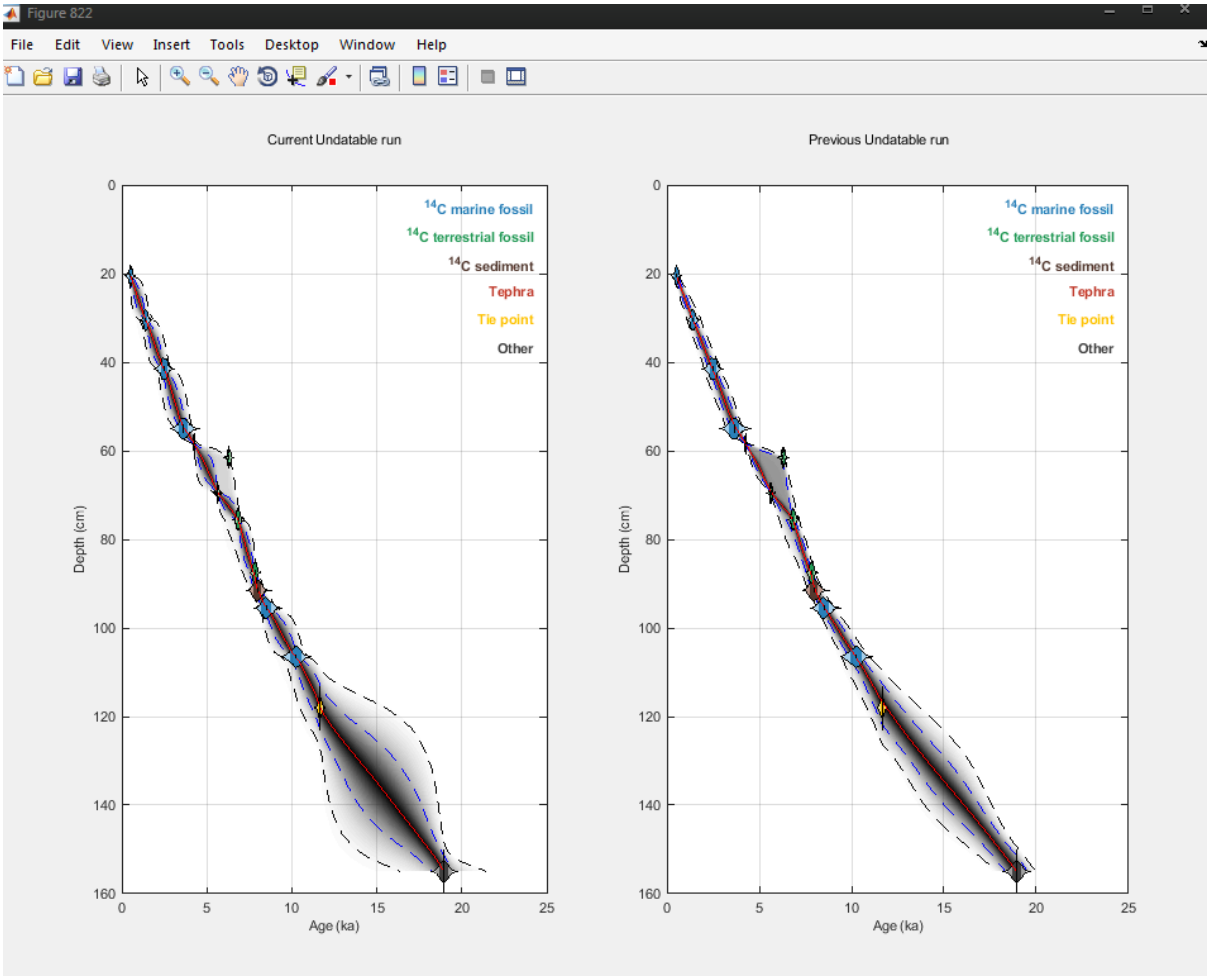

| | Include | Sample ID | Depth 1 | Depth 2 | Age | Age err | Date type | Calibration | Res age | Res err | Bootstrap |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ☑ | Lab-1234 | 20 | 21 | 1000 | 30 | 14c marine fossil | Marine13 | 100 | 100 | ☑ |
| 2 | ☑ | Lab-1235 | 30 | 31 | 2000 | 30 | 14c marine fossil | Marine13 | 150 | 100 | ☑ |
| 3 | ☑ | Lab-1236 | 41 | 42 | 3000 | 40 | 14c marine fossil | Marine13 | 250 | 150 | ☑ |
| 4 | ☑ | Lab-1237 | 54 | 56 | 4000 | 80 | 14c marine fossil | Marine13 | 300 | 200 | ☑ |
| 5 | ☑ | Hekla-4 | 58.2000 | 58.6000 | 4260 | 20 | tephra | None | 0 | NaN | ☐ |
| 6 | ☑ | Lab-1238 | 61 | 62 | 5500 | 80 | 14c terrestrial fossil | IntCal13 | 0 | NaN | ☑ |
| 7 | ☑ | Lab-1239 | 69 | 70 | 4900 | 60 | 14c terrestrial fossil | IntCal13 | 0 | NaN | ☑ |
| 8 | ☑ | Lab-1240 | 75 | 76 | 6000 | 80 | 14c terrestrial fossil | IntCal13 | 0 | NaN | ☑ |
| 9 | ☑ | Lab-1241 | 87 | 88 | 7000 | 110 | 14c terrestrial fossil | IntCal13 | 0 | NaN | ☑ |
| 10 | ☑ | Lab-1242 | 91 | 92 | 7900 | 110 | 14c sediment | Marine13 | 400 | 200 | ☑ |
| 11 | ☑ | Lab-1243 | 95 | 96 | 8500 | 115 | 14c marine fossil | Marine13 | 500 | 200 | ☑ |
| 12 | ☑ | Lab-1244 | 106 | 107 | 10000 | 120 | 14c marine fossil | Marine13 | 600 | 200 | ☑ |
| 13 | ☑ | Bob's NGRIP tie p... | 118 | 5 | 11650 | 100 | tie point | None | 0 | NaN | ☑ |
| 14 | ☑ | Mary's U/Th date | 150 | 160 | 18950 | 250 | other | None | 0 | NaN | ☑ |

For now, let's set the number of MC iterations to 10,000 to ensure that the age-depth model runs quickly for evaluation purposes. Set the xfactor to 0.1

and the Bootstrap % to 30 (for information about what these settings do and guidance on how to set them, please consult Sections 3.1 and 4.0 of Lougheed and Obrochta [2019]). We can run *Undatable* by pressing "Run Undatable". A new window should soon appear that shows the age-depth model run:




To carry out a new age-depth run, return to the *Undatable* GUI interface window (without closing the figure window!) and readjust the run settings. This time, let's run with 10,000 MC iterations, an xfactor of 0.3 and a bootstrap % of 10. Now the figure window will be updated to show the latest *Undatable* age-depth model in the left panel, and the previous age-depth model in the right panel (see next page).




By using both the GUI interface window and the figure window, it is possible to iteratively explore multiple age-depth model settings and possibilities. Using the data table within the GUI interface is it is possible to edit the input data on the fly, as well as to selectively include and exclude age-depth constraints from the bootstrapping process, or the entire age-modelling process altogether, by clicking or unclicking the relevant checkboxes.

Users with dual computer monitors could consider having the figure window in full-screen in one screen, and the GUI interface in the other screen.

## 3.2 Finalising and saving an age-depth model

When you have found the settings that give a desired age-depth model, it is recommended to re-run the simulation with 100,000 MC iterations. This process will take slightly longer due to the increased number of iterations.

Once the age-depth model has finished running, click “Save to Disk” to save a copy of the current age-depth model output and plot to your hard drive. Three files will be saved, in the same folder as the intput file that you loaded into the *Undatable* GUI interface:

*yourinputfilename admodel (YYYMMDDTIME).txt*
(Age-depth model output file)

*yourinputfilename inputfile (YYYMMDDTIME).txt*
(A copy of the input data used for the age-depth model)

*yourinputfilename adplot (YYYMMDDTIME).pdf*
(An Adobe PDF of the age-depth plot)

It is possible to customise the plot size and font size used for the Adobe PDF file, i.e. so that it fits the size requirements of a journal. To change the sizes, open the file *udplotoptions.m* in a text editor and adjust the self-explanatory numerical values (see below). Once you have saved the file, when you run *Undatable* again, any saved PDF files will adhere to the new size specifications.

```
plotwidth  = 18    ; % centimetres
plotheight = 18    ; % centimetres

textsize   = 8     ; % font size (like in MS Word)
```

## 4.0 Running *Undatable* using Matlab command line

*Undatable* can also be run from the command line, which is ideal for doing batch age-depth models or simply if the user prefers to use the command line interface.

As is custom with command line Matlab functions, a documentation for command line users is contained within the header of the *undatable.m* file and can be accessed from the command line using:

```
help undatable
```

## 5.0 Power feature: saving all variables to the Matlab workspace

Using either the GUI or command line versions of *Undatable*, it is possible to save a .mat file containing all the major variables created within undatable.m during the age-depth model run. This file will be saved as yourinputname_output.mat .