iceTEA (Tools for Exposure Ages)

Manual for the MATLAB© code

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A suite of eight tools calculate, analyse and/or plot cosmogenic-nuclide surface-exposure data from ice-marginal environments:

- Calculate and plot ages (`Calc_Plot_age.m`)
- Import and plot ages (`Import_Plot_age.m`)
- Remove outliers (included as part of `Calc_Plot_age.m` and `Import_Plot_age.m`)
- Plot two-isotope concentrations (`Plot_concs.m`)
- Correct for surface cover (`Cover_correct_ages.m`)
- Correct for elevation change (`Elev_correct_ages.m`)
- Estimate retreat/thinning rates – linear model (`Analyse_linear_rates.m`)
- Estimate retreat/thinning rates – continuous models (`Analyse_continuous_rates.m`)

A supplemental function also calculates a topographic shielding factor (`Topographic_shielding.m`).

This manual outlines the MATLAB© code, while an accompanying paper (Jones *et al*., 2019, *Quaternary Geochronology*) describes the tools and potential applications in more detail.

Information on required or optional input variables are available within the help for each function (right-click on a specific function and select: Help on "*function name*").

The code is currently set up for just ^{10}Be and ^{26}Al concentrations and ages (other nuclides may follow).

All tools have been tested successfully with MATLAB© versions R2016 and R2017. Some of the code may not work for earlier versions, or for Octave©.

Using iceTEA code in MATLAB©

To start using the iceTEA tools, users need to:

1. Have MATLAB© installed on their computer (ideally version R2016 or R2017).
2. Download the iceTEA package (including all scripts and sub-directories) to a suitable location on their computer.
3. Launch MATLAB© and make the downloaded iceTEA folder the current directory.
4. Open the desired front-end tool script (listed above).
5. Edit the necessary options (e.g. name of dataset file), and run each section within the script.

It is also recommended to move any exported files (e.g. .mat, .png, .eps) to a new directory (e.g. 'Outputs') within the iceTEA directory.

To find out what version of iceTEA you are using, type `get_version` into the MATLAB© command window (note, you will need the tools on the path, using `addpath(genpath(pwd))` when in your local iceTEA directory).

Input data

Sample data is required as a Microsoft© Excel© (.xlsx) or comma-separated values (.csv) spreadsheet, or in a tab-delimited text file (.txt) without column headings. Templates for entering this information are available. All of the tools except the 'Plot two-isotope concentrations' tool require either 15 or 22 columns of sample information:

1. Sample name
2. Latitude (decimal degrees)
3. Longitude (decimal degrees)
4. Elevation (m asl)
5. Pressure (hPa) (zero if not known)
6. Elevation uncertainty (m) (zero if not known, in which case 5 m is used)
7. Relative position (distance from terminus, km; elevation above ice, m) (zero or NaN if not relevant or known)
8. Sample thickness (cm)
9. Bulk density ($g\ cm^3$)
10. Shielding factor for terrain, snow, etc. (unitless)
11. Sample 10-Be concentration (atoms of 10-Be/g) (zero if not measured)
12. Sample 10-Be concentration 1 sigma uncertainty (atoms of 10-Be/g) (zero if not measured)
13. Sample 26-Al concentration (atoms of 26-Al/g) (zero if not measured)
14. Sample 26-Al concentration 1 sigma uncertainty (atoms of 26-Al/g) (zero if not measured)
15. Year the sample was collected (calendar year)

Optional information that is required for importing previously calculated ages (zeros can be used if the nuclide was not measured):

16. Sample 10-Be exposure age (mean; years)
17. Sample 10-Be exposure 1 sigma uncertainty (internal; years)
18. Sample 10-Be exposure 1 sigma uncertainty (external; years)
19. Sample 26-Al exposure age (mean; years)
20. Sample 26-Al exposure 1 sigma uncertainty (internal; years)
21. Sample 26-Al exposure 1 sigma uncertainty (external; years)
22. Scaling model used (i.e. DE', 'DU', 'LI', 'ST', 'Lm', 'LSD', 'LSDn')

The sample data for plotting two-isotope concentrations (`Plot_concs.m`) should be in 17 columns:

1. Sample name
2. Latitude (decimal degrees)
3. Longitude (decimal degrees)
4. Elevation (m asl)
5. Pressure (hPa) (zero if not known)

6. Relative position (distance from terminus, km; elevation above ice, m)
7. Sample thickness (cm)
8. Bulk density (g cm^3)
9. Shielding factor for terrain, snow, etc. (unitless)
10. Sample 10-Be concentration (atoms of 10-Be/g)
11. Sample 10-Be concentration 1 sigma uncertainty (atoms of 10-Be/g)
12. Sample 26-Al concentration (atoms of 26-Al/g)
13. Sample 26-Al concentration 1 sigma uncertainty (atoms of 26-Al/g)
14. Top depth of sample (cm)
15. Bottom depth of sample (cm)
16. Final mineral weight (g)
17. Year the sample was collected (calendar year)

Front-end tool scripts

`Calc_Plot_age.m`

Calculates exposure ages data from input sample data using a specified scaling model. A new file is then created with those ages.

Optionally identifies and removes outliers if ages are from a single feature.

Plots those exposure ages as a kernel density estimate, with statistics computed if the ages are for a single feature, or as a (horizontal or vertical) transect. The figures can be automatically saved using the given output name (ages_name), nuclide and scaling method.

`get_data.m` loads and sorts data from the spreadsheet.

`age_calc.m` performs the age calculation using a modified version of the CRONUScalc framework.

`plot_prod_time.m` plots the computed sample-specific production rates through time.

`export_calcages.m` exports the calculated exposure ages to a Microsoft© Excel© (.xlsx) spreadsheet or a tab-delimited .txt file.

`plot_kernel.m` plots the calculated exposure ages as kernel density estimates and performs statistical analyses if the dataset is from a ‘feature’.

`find_outliers.m` performs a generalised extreme Studentized deviate test to find and then remove any outliers within the dataset.

`plot_outlier_kernel.m` plots the calculated exposure ages as kernel density estimates following identification of outliers, and performs statistical analyses if the dataset is from a ‘feature’. Outliers can be additionally plotted in grey.

`plot_transect.m` plots the exposure ages as either a horizontal or vertical transect.

`Import_Plot_age.m`

Imports exposure ages data from input sample data, and saves a new file with those ages. Exposure age data previously saved to a .mat file can be loaded and re-plotted by specifying `ages_name` ([name]_ages.mat) and then running the particular plotting section.

Plots the exposure ages as a kernel density estimate, with statistics computed if the ages are for a single feature, or as a (horizontal or vertical) transect. The figures can be automatically saved using the given output name (ages_name), nuclide and scaling method.

Optionally identifies and removes outliers if ages are from a single feature.

`get_data.m` loads and sorts data from the spreadsheet.

`get_ages.m` extracts and organises the imported exposure ages.

`plot_kernel.m` plots the imported exposure ages as kernel density estimates and performs statistical analyses if the dataset is from a 'feature'.

`find_outliers.m` performs a generalised extreme Studentized deviate test to find and then remove any outliers within the dataset.

`plot_outlier_kernel.m` plots the imported exposure ages as kernel density estimates following identification of outliers, and performs statistical analyses if the dataset is from a 'feature'. Outliers can be additionally plotted in grey.

`plot_transect.m` plots the exposure ages as either a horizontal or vertical transect.

`Plot_concs.m`

Plots nuclide concentrations using input sample data.

Sample concentrations can be plotted on a two-isotope diagram (currently, $^{26}Al/^{10}Be$ vs. ^{10}Be), or plotted against depth (designed for cores), which can be automatically saved.

`get_data_complex.m` loads and sorts data from the spreadsheet (note, requires different sample information to the other tools).

`get_pars.m` gets the sample-specific parameters, scaling factors and physical constants for the dataset. This uses the CRONUScalc framework.

`plot_2iso_concs.m` plots the (normalised) sample concentrations on a two-isotope diagram with typical steady-state erosion island and burial/exposure isochrones. The intervals of the isochrones can be optionally specified.

`plot_concs_depth.m` plots the nuclide concentrations with depth.

Cover_correct_ages.m

Calculates surface cover shielding factors from input sample data using selected surface cover type or manual cover density, and a specified cover depth and scaling model. Also, optionally calculates the resulting exposure ages.

Plots the corrected exposure ages as a kernel density estimate.

`get_data.m` loads and sorts data from the spreadsheet.

`cov_correct.m` computes the shielding factor for a specified depth of cover and either a selected cover type (snow, fresh water, sea water, loess, till, soil, ash) or manually entered density of the surface cover, and then calculates the corresponding exposure ages.

`export_coverages.m` exports the calculated exposure ages and cover correction information to a Microsoft© Excel© (.xlsx) spreadsheet or a tab-delimited .txt file.

`plot_kernel.m` plots the corrected exposure ages as kernel density estimates and performs statistical analyses if the dataset is from a 'feature'.

Elev_correct_ages.m

Calculates time-dependent scaling factors and exposure ages from input sample data using selected glacial isostatic adjustment (GIA) model or rate of elevation change, and a specified scaling model.

Plots the elevation-corrected production through time, and the corrected exposure ages as a kernel density estimate.

`get_data.m` loads and sorts data from the spreadsheet.

`elev_correct.m` computes corrected time-dependent elevation for each sample according to the specified method, and then calculates the corresponding exposure ages.

`plot_prod_time.m` plots the computed sample-specific production rates through time for both the uncorrected and correction sample elevations.

`export_elevcorr_results.m` exports the results to either a Microsoft© Excel© (.xlsx) spreadsheet or a tab-delimited .txt file.

`plot_corr_kernel.m` plots the corrected exposure ages as kernel density estimates together with the uncorrected exposure ages (calculated or imported with `Calc_Plot_age.m` or `Import_Plot_age.m`).

`Analyse_linear_rates.m`

Determines linear estimates of retreat/thinning rates for exposure age data in a horizontal or vertical transect. Least-squares regression is applied randomly to normally-distributed exposure ages (2 sigma) through a Monte Carlo simulation. Input data in columns 8-15 are not essential for this analysis, and columns 2-6 are not required for a horizontal transect; zeros can be used for these columns.

Plots the probability distribution of computed rates, with estimates at 68% and 95% confidence bounds, and the models and bounds as a transect, with or without corresponding exposure ages.

Exposure ages need to be in a correctly structured MATLAB file (_ages.mat). This can be done using `Calc_Plot_age.m` or `Import_Plot_age.m`, to calculate ages or import existing ages, respectively.

`transect_regress_linear.m` performs the linear regression analysis on the dataset. Also plots the estimated rates as a histogram.

`plot_transect_linear_regress.m` plots the computed rates as a transect, with or without the exposure ages.

`Analyse_continuous_rates.m`

Determines continuous estimates of retreat/thinning rates for exposure age data in a horizontal or vertical transect, using either Fourier Series analysis or penalised spline regression. Input data in columns 8-15 are not essential for this analysis, and columns 2-6 are not required for a horizontal transect; zeros can be used for these columns. The penalised spline regression analysis can also be performed using open-source software R (AnalyseContinuousRates_spline.R).

Fourier Series analysis uses only mean values, and neither the exposure age or sample position uncertainties are used.

Penalised spline regression uses both the normally-distributed exposure ages (2 sigma) and sample elevation uncertainties within a Bayesian framework, and assumes that exposure ages represent either stability or continuous retreat/thinning through time (i.e. no advance/thickening occurs). Just Another Gibbs Sampler (JAGS) is used to efficiently perform the analysis. If not found, then the program is downloaded and installed.

Plots the modelled retreat/thinning profile, with or without corresponding exposure ages, and the corresponding rates through time.

Exposure ages need to be in a correctly structured MATLAB file (_ages.mat). This can be done using `Calc_Plot_age.m` or `Import_Plot_age.m`, to calculate ages or import existing ages, respectively.

`transect_regress_fourier.m` performs the Fourier-based regression analysis on the dataset.

`transect_regress_spline.m` performs the p-spline analysis on the dataset. Also provides the option to download JAGS if it cannot be found on the system.

`plot_transect_continuous_rates.m` plots the computed regression profile, with or without the exposure ages, and the corresponding rates. Also determines the minimum and maximum rates for the period.

`Topographic_shielding.m`

Determines a sample's topographic shielding factor for cosmogenic nuclide production based on given horizon and dip values.

`get_topo.m` calculates the shielding factor. CRONUScalc function, modified from the Balco et al. (2008) `skyline.m` function.