# The three scripts in the supplement should be run in the following order:

1. produceHistories.m: generates glacier exposure histories
2. monteCarlo.m: calculates 10Be and 14C concentrations that result from each exposure history and saves histories within uncertainty of with measured data
3. plotResults.m: produces figures of viable exposure histories and erosion rates

# 1. produceHistories.m

## Introduction

This script generates a series of unique glacier exposure histories, which are used as input to the monteCarlo.m script. Each time step in a history is assigned exposure (1) or burial (0) based on a specified probability (P) that it matches the designation (burial or exposure) of the previous time step. We used a range of P values to generate histories with varying amounts of autocorrelation. The input parameters on lines 11-15 need to be specified to run the code.

## Input variables to be adjusted by user

nHistories: This input determines the number of exposure and burial histories that will be created by the script. A minimum of 100,000 solutions is recommended.

nCenturies: This input determines the number of centuries in each history. We chose 110 to represent the length of the Holocene.

minP = The smallest P value used in generating histories. We chose 0.61 because we found that values below this produced histories with too much high frequency variability to fit our data.

maxP = The largest P value used in generating histories. We chose 0.99.

nHistoriesperP = the number of histories produced per P value.

## Output

This code outputs a variable called exposureBurialHistories saved in the file exposureBurialHistories.mat. This variable is a matrix of dimensions nHistories x nCenturies. Each row represents a unique exposure history, while each column represents a century in that history. A value of 1 indicates exposure and a value of 0 indicates burial.

# 2. monteCarlo.m

## Introduction

## This script uses the exposureBurialHistories matrix generated in produceHistories.m and models the 14C and 10Be concentrations that would result from each exposure history. It then saves the exposure histories that produce surface nuclide concentrations within a specified uncertainty of measured data. The 14C and 10Be concentrations are modeled in a 5 m depth profile and the simulations are run at a range of user-specified subglacial erosion rates.

## Input files

Production rates: The user needs to load nuclide production rate profiles in line 12, where our example file name currently exists.

exposureBurialHistories.mat: This is the file output by produceHistories. It is loaded in line 13 where our example currently exists.

## Input variables to be adjusted by user

The input variables that need to be adjusted by the user can be found in lines 15-24.

sampleNames: This is where the user should input their sample names. The names need to be entered in double quotations and exactly as they are seen in the production rate structure exported from the Cronus Production Rates Calculator.

sampleTarget10Be: This is where the user should enter the measured 10Be concentration of each sample in atoms/gram. These values need to be separated by commas and in the same order as the names are given in sampleNames.

sampleUncertaintyBe: This is where the user should enter the 1σ 10Be analytical uncertainty for each sample in atoms/gram. The uncertainties must be separated by commas and in the same order as the names are given in sampleNames.

sampleTarget14C: This is where the user should enter the measured 14C concentration of each sample in atoms/gram. These values need to be separated by commas and in the same order as the names are given in sampleNames.

sampleUncertainty14C: This is where the user should enter the 1σ 14C analytical uncertainty for each sample in atoms/gram. The uncertainties must be separated by commas and in the same order as the names are given in sampleNames.

sampleDensity: This is where the user should enter the sample density in g/cm3. The densities must be separated by commas and in the same order as the names are given in sampleNames.

sampleThickness: This is where the user should enter each sample thickness in mm. The thicknesses must be separated by commas and in the same order as the names are given in sampleNames.

sampleShielding: This is where the user should enter the sample shielding factor for each sample. These values must be separated by commas and in the same order as the names are given in sampleNames.

erosionRate: This variable tells the program which subglacial erosion rates to try for each sample being tested in units of mm/century. Our example “0:1:2500” indicates that the program will try each integer between 0 and 2500 mm/century in steps of 1. Trial and error will be the best way for the user to identify which erosion rates are appropriate at their particular field site.

fileName: This is where the user can identify what they’d like their output file to be called. The name must be in double quotations and must end in “.mat”.

## Output

This code outputs a structure, monteCarloResults, containing an individual structure named by the sample’s name for each input sample (Figure 1). Within each sampleName structure, the following fields exist:

exposureBurialSolutions: This field contains a matrix of the exposure histories that produced nuclide concentrations within the specified uncertainty of the measured data. In this matrix, each row is a unique history. Because each history was tested with a number of possible erosion rates, it is saved once for every erosion rate that produced a solution. For example, if a history is viable at 5 different erosion rates, the history will appear 5 times. The row index of each solution where therefore align with the vector index of the corresponding erosion rate in erosionRateSolutions.

erosionRateSolutions: This field contains a vector with the erosion rates that correspond to each history in exposureBurialSolutions. The position of each erosion rate in the vector corresponds to the same row number in exposureBurialSolutions.

final14C: This field contains the simulated 14C concentration that resulted from each solution in exposureBurialSolutions. Similarly to erosionRateSolutions, the vector indices align with the exposureBurialSolutions row numbers.

final10Be: This field contains the simulated 10Be concentration that resulted from each solution in exposureBurialSolutions. Similarly to erosionRateSolutions, the vector indices align with the exposureBurialSolutions row numbers.

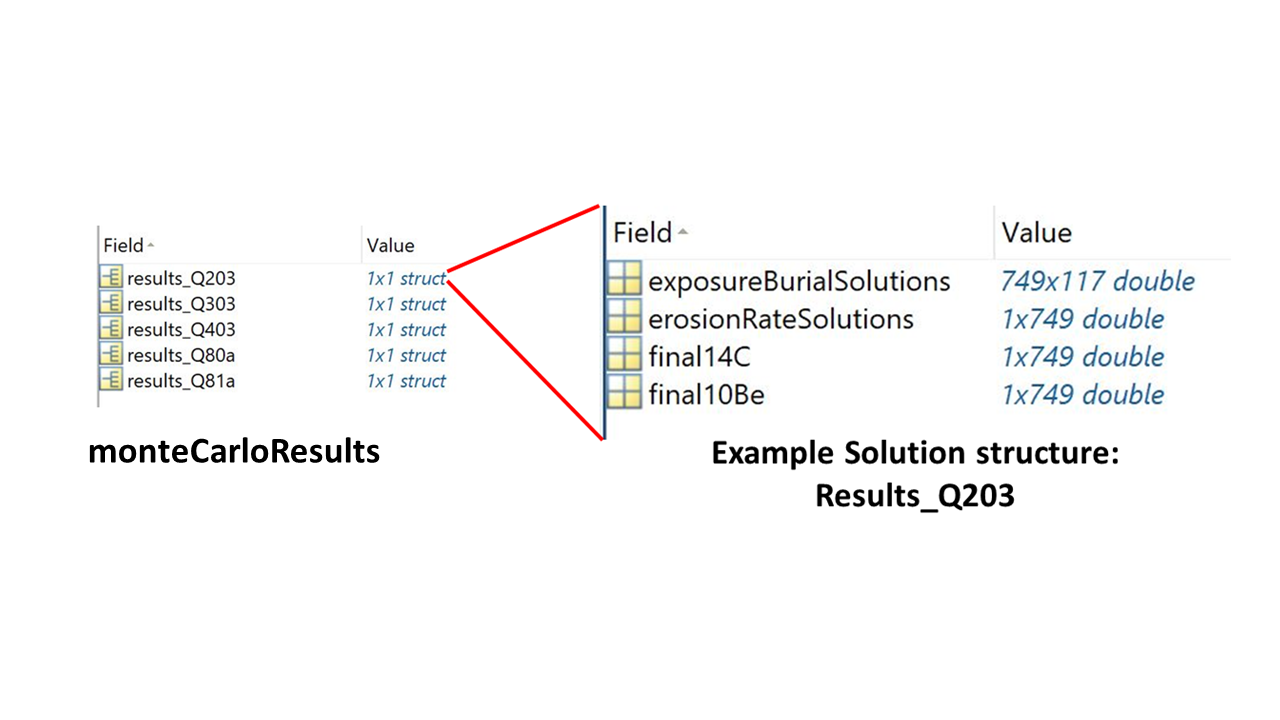
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Figure 1. Diagram showing the internal structure of the variable exposureBurialSolutions output by the program monteCarlo.mat. The structure exposureBurialSolutions contains a structure for each sample input to the program. Each of these solution structures will have the fields exposureBurialSolutions, erosionRateSolutions, final14C, and final10Be.

# 3. plotResults.m

## Introduction

This code shows how figures were made with our Quelccaya data. Additional visual processing was done in Adobe Illustrator.

## Input Files

monteCarloResults.mat: This is the file output from monteCarlo.m. This file is loaded in line 6.

## Input variables to be adjusted by user

Samplenames4graph: This is where the user can specify how they’d like the names of their samples to be displayed in the figures produced by this code. The names must be entered between double quotations and separated by commas.

exposureBurialGraphName: This is where the user can enter a title for their exposure history visualization.

erosionPlotGraphName: This is where the user can enter a title for their erosion rate histogram plot.

## Output

Exposure visualization: This graph shows all of the solutions for each sample where, for each sample, the x-axis is time, and each increment in the y-axis is a different solution. In the diagram, blue represents burial, and yellow represents exposure. The program automatically plots a graph with “overlap” right after your samples. This graph shows solutions for all samples. The program also produces a graph titled Probability of Exposure as the final panel, which shows the fraction of solutions that simulate exposure for each century in the “overlap” plot. A value of 1, or completely blue, indicates that all solutions in the “overlap” plot found exposure, while a 0, or completely yellow, indicates that they all found burial. If any samples do not have any solutions from monteCarlo.m, then this diagram will be blank.

If your model includes more than 11,000 years of simulated time, you may need to adjust the number of ticks in your diagram as well. This can be adjusted in lines 70-71.

Erosion Plot: This diagram is a plot of the erosion rates for your samples. If your data is considerably different than ours, you may want to adjust the limits of the x-axis. This can be done in line 84, where the two numbers in brackets identify the lower and upper bound of the axis.