FlexMC

v. 2.1

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1. Introduction

FlexMC is a MATLAB-based graphical user interface (GUI) designed to implement a Monte Carlo estimation of the load and lithospheric parameters that would yield an observed basin geometry. The software assumes that loading is entirely flexurally compensated. The software assumes that the plate and load are infinite in the z-direction (i.e., into the plane of the screen). Equations for deflection of an infinite plate are based on Wangen (2010), and those for the broken plate are based on Hetenyi (1979).

2. Setup

FlexMC version 2.1 was compiled using MATLAB R2019a and so requires installation of the MATLAB Compiler Runtime (MCR) version 9.6. This compiler allows the DZnmf GUI to run on the user's computer without having MATLAB.

Download the MCR for Windows here:
https://www.mathworks.com/products/compiler/matlab-runtime.html

Select all the default settings and install (this takes some time, usually about 15 minutes). The MCR will create a new directory on the user's machine that will be accessed in the background when the GUI is running; it will not interact with any existing versions of MATLAB or other versions of the MCR on the user's machine.

The FlexMC GUI does not require any installation other than the MCR compiler. Once the MCR is installed, download the FlexMC GUI and example data sets from the Supplemental

The GUI file can be saved to any location on the user's computer. As long as the default settings were selected for the MCR it will be accessible by the FlexMC GUI. Occasionally there is an error in the MCR installation, which will throw the error message in Figure 1.

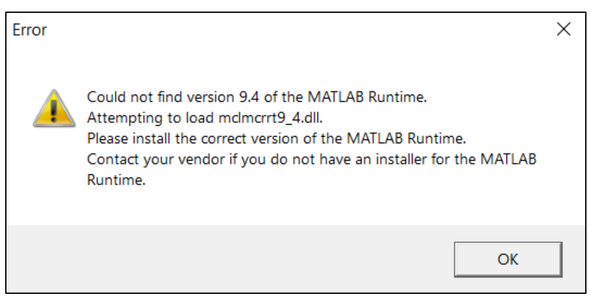

Figure 1. *Error message generated when the GUI cannot access the MATLAB Runtime compiler (MCR).*

If the error message in Figure 1 or a similar error message is thrown, it means the FlexMC GUI cannot find and/or access the MCR. If this happens there are two possible solutions to troubleshoot: (1) restart the machine and try again, or (2) reinstall the MCR (the MCR may need to be completely removed and directory deleted before reinstalling rather than simply overwriting). If these options do not work please contact one of the first two authors.

Upon executing, the FlexMC GUI will open a new window with the default settings (Figure 2). All of the program functionality (i.e., analysis, plotting, exporting, etc.) is contained within this single main page.

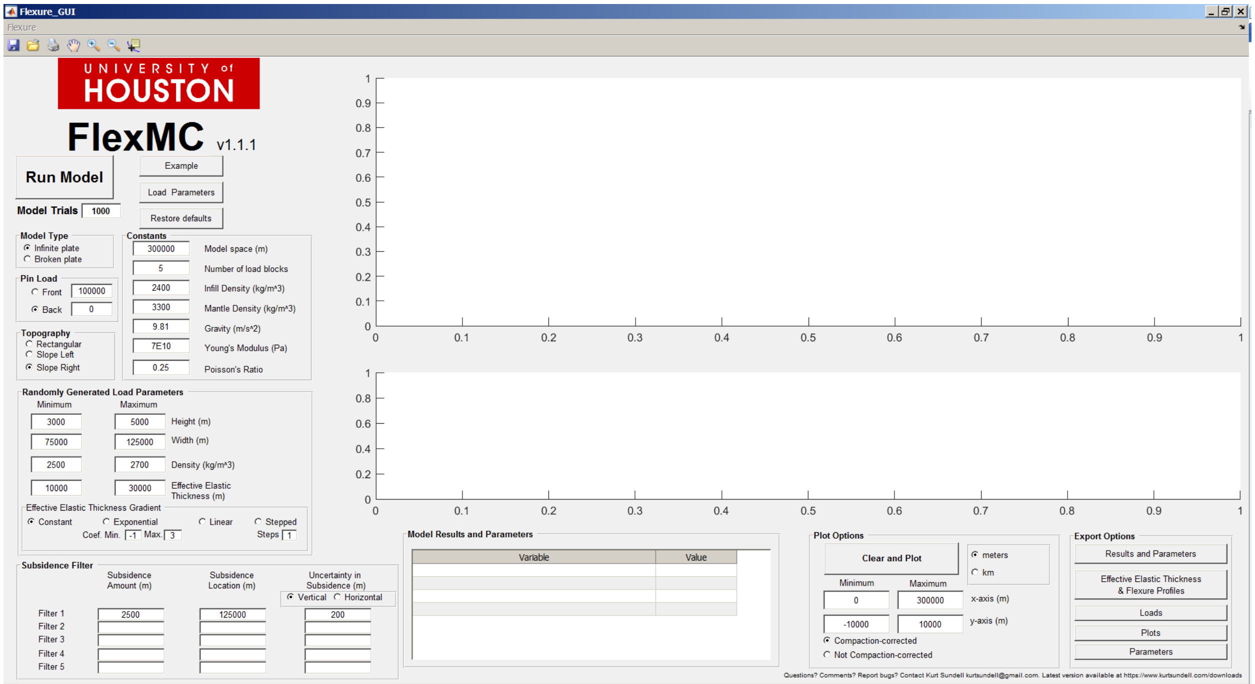

Figure 2. *FlexMC GUI main page*

3. Constants

Prior to running the model, users should verify the constant parameters (Figure 3).

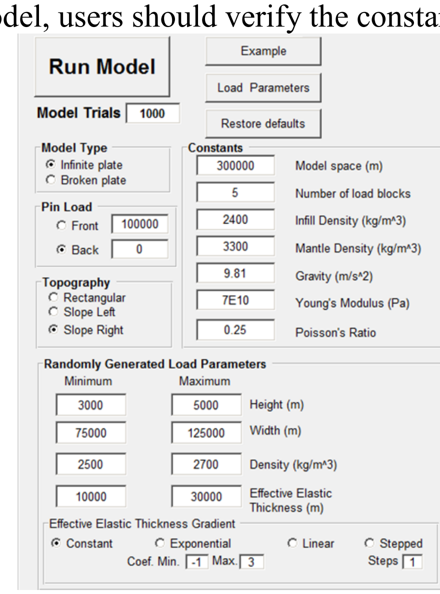

Figure 3. *Constant and variable input panel for FlexMC.*

The default constants are highlighted in Figure 4. These can be varied, but are not randomly selected during modelling.

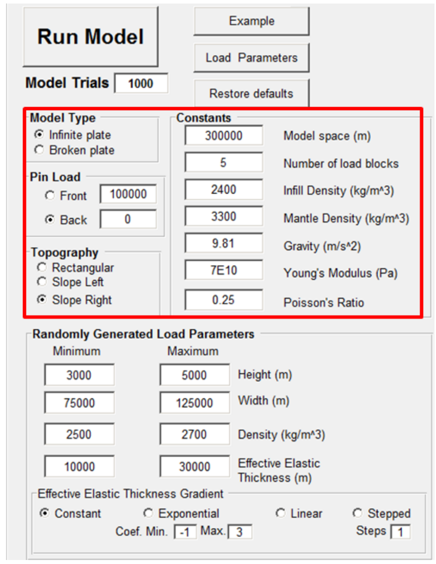

Figure 4. *Default constants for FlexMC*

Constants include:

Model Space:

The full horizontal extent of the model (all lengths are in m). If this parameter is too small, it will yield an error while modelling.

Number of load blocks:

This is the number of blocks that the load is divided into (Figure 5).

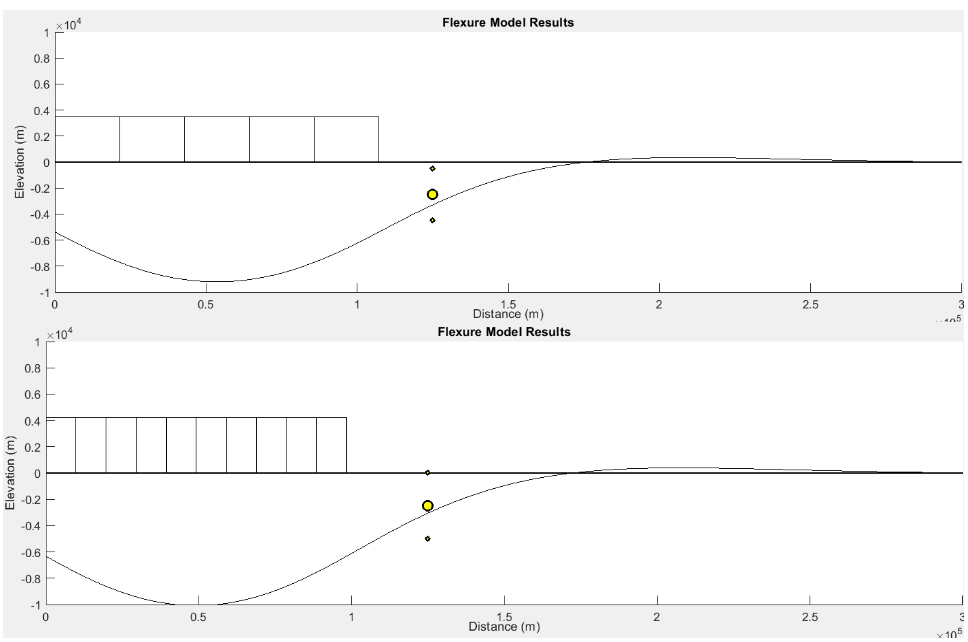

Figure 5. *Flexural modelling of five (top) and ten (bottom) load blocks and a rectangular load geometry. Only one Model Trial was run for each of these examples.*

Potential errors associated with the number of load blocks:

1) The maximum number of load blocks currently enabled is 10. If a number higher than 10 is entered, the GUI will throw an error.
2) Load blocks must be at least 1 km wide. If the minimum load width (in “Randomly Generated Load Parameters”) is < 1000 times the number of load blocks the GUI will throw an error.

Infill Density:

This is the density of the material that fills all deflected space.

Mantle Density:

This is the density of the inviscid fluid that the plate floats on (in kg/m^3) and which provides the isostatic restoring force for the deflected lithospheric beam.

Gravity:

This is the acceleration due to gravity (in m/s^2).

Young’s Modulus:

This is the ratio of uniaxial stress to strain (in Pa), and is a measure of the stiffness of the bending plate.

Poisson’s ratio:

This is the ratio of transverse to axial strain, and is a measure of how compressible the rocks of the bending plate are.

Model Type:

This radiobutton selects whether the bending plate is modelled as infinite or broken in the x-direction. If broken, the break in the plate is at x=0.

Pin Load:

This radiobutton selects whether the load is pinned at the back or the front. If “Back” is selected, the load is pinned at the selected distance from x=0, and the load is allowed to be a random width to the right of that point (Figure 6, top). If “Front” is selected, the load is pinned at the selected distance from x=0, and the load is allowed to be a random width to the left of that point (Figure 6, bottom).

Note: The distances for the filters are all referenced to the distance selected for the pin.

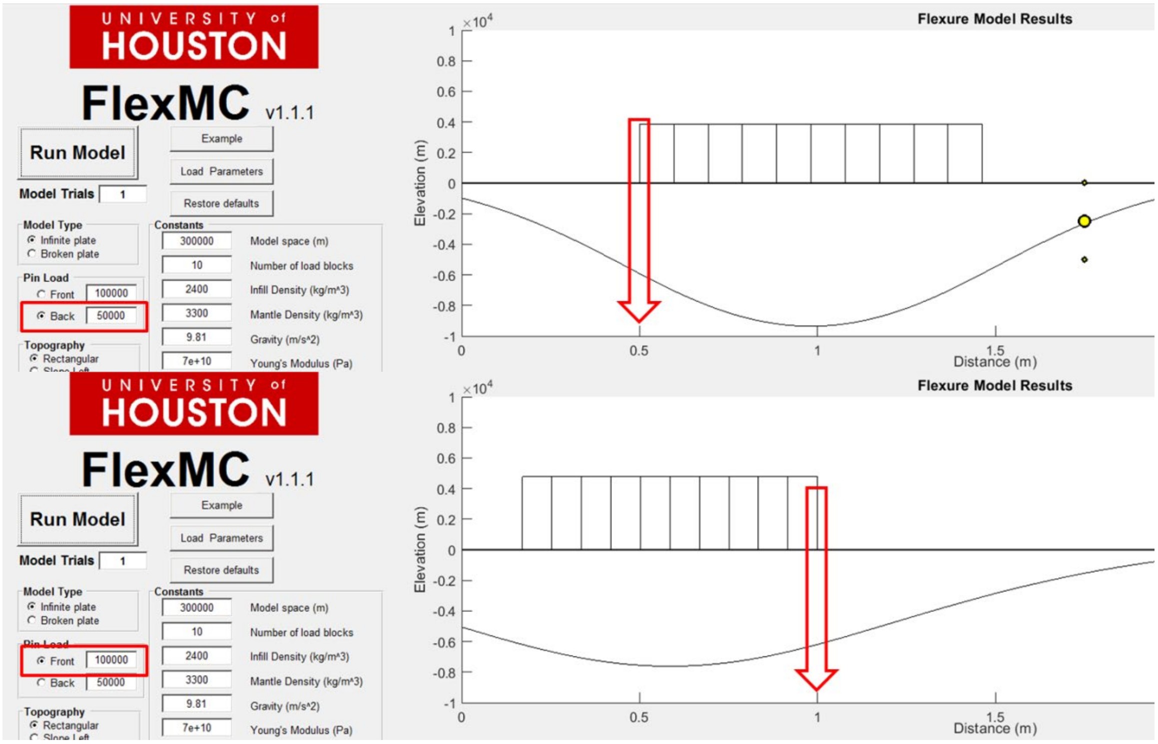

Figure 6. *Examples with the pin at 50,000 m at the back of the load blocks (top) and with the pin at 100,000 m at the front of the load blocks (bottom). In both cases the filter is at 125,000 m from the pin location.*

Topography:

Topography can be rectangular (Figure 6), or sloping left or right (Figure 7).

Note: If a "Front" pin is selected, the slope is the opposite from the default "Back" pin setting.

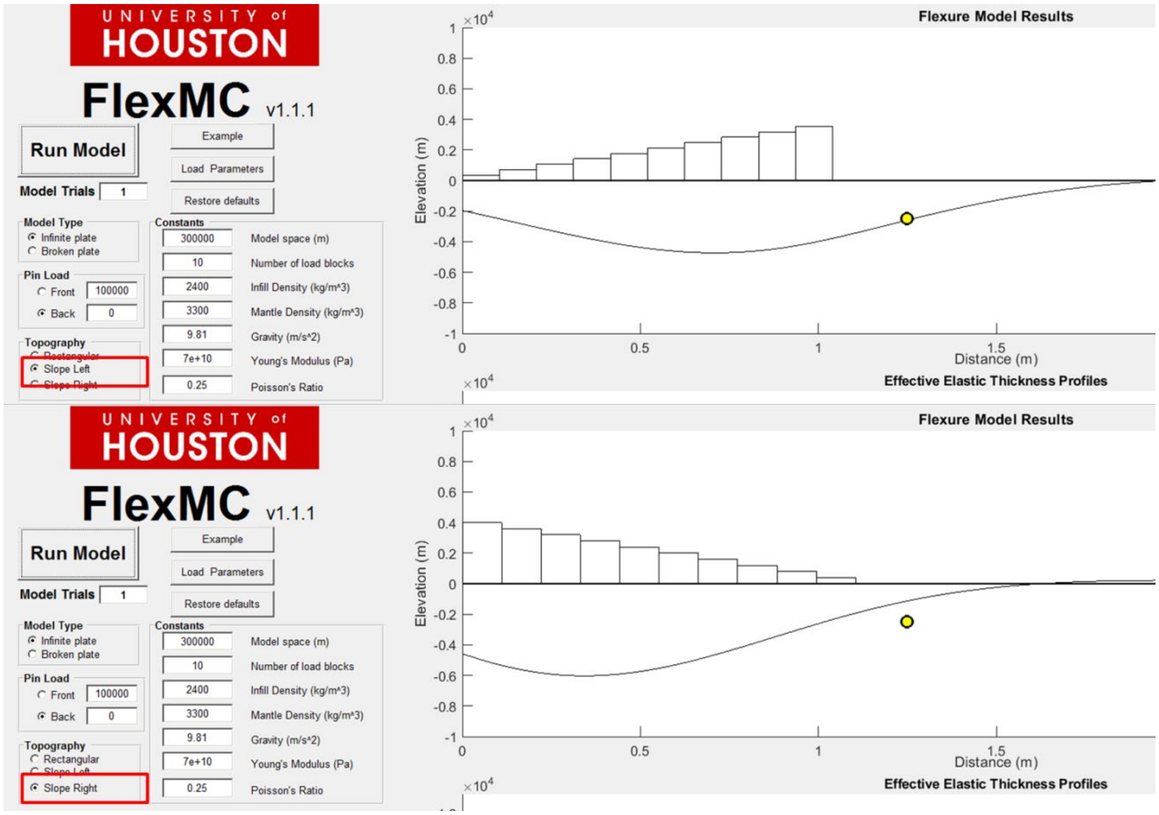

Figure 7. *Loads with a left (top) or right (bottom) topographic slope.*

4. Randomly Generated Load Parameters

All Randomly Generated Load Parameters are selected randomly between the input maximum and minimum values for each Model Trial. The combination of these parameters results in a unique flexural profile which can be compared again known filter points.

Height:

The maximum and minimum load height (in m).

Width:

The maximum and minimum total load width of all load blocks (in m).

Density:

The maximum and minimum density of the imposed load (in kg/m^3).

Effective Elastic Thickness:

The maximum and minimum effective elastic thickness of the bending plate (in m).

Effective Elastic Thickness Gradient:

The user can select an effective elastic thickness that is constant across the model space (x-direction) or one that exponentially increases, linearly increases or decreases, or increases in steps (Figure 8).

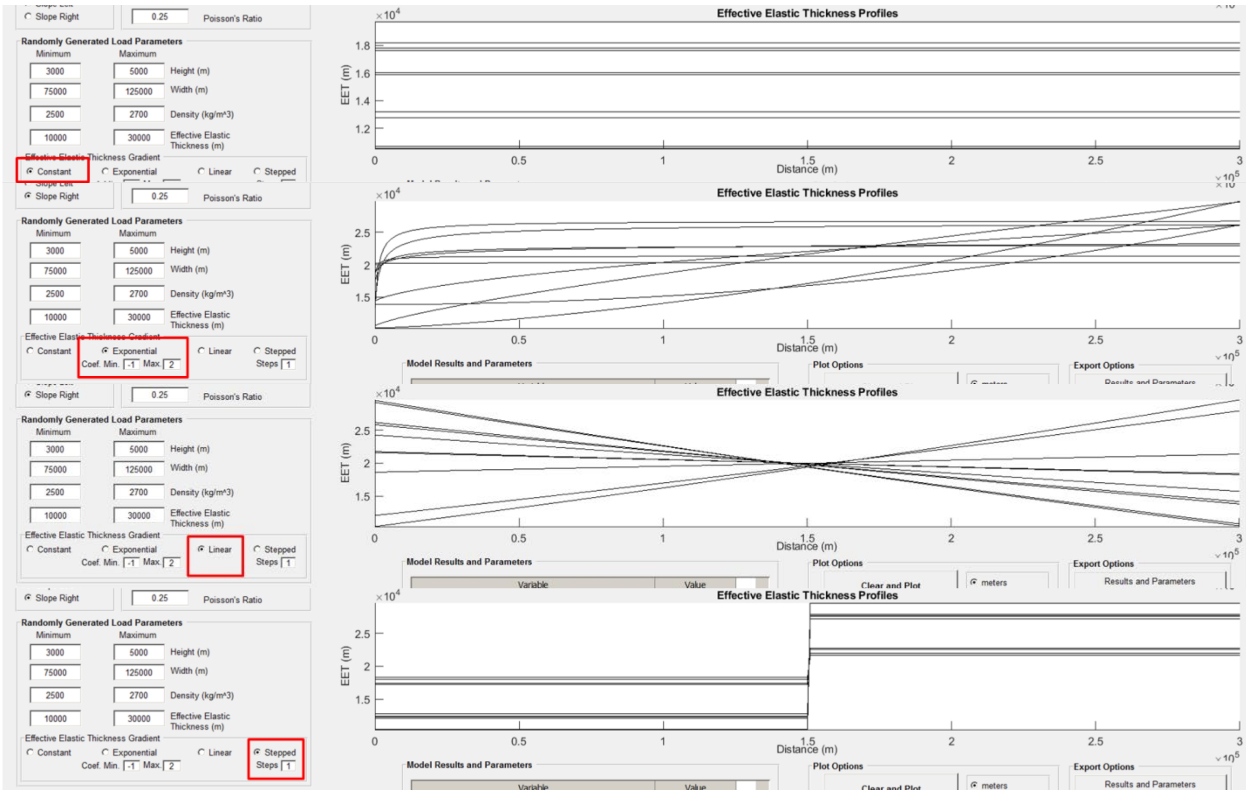

Figure 8. *Effective elastic thickness plot showing constant (top), exponential (second), linear (third), and stepped (bottom) effective elastic thickness profile.*

Constant: The effective elastic thickness profile is constant for all x for each Model Trial.

Exponential: The effective elastic thickness profile increases from the randomly chosen minimum to the randomly chosen maximum EET values as a function of the randomly chosen coefficient (between the selected maximum and minimum coefficient values) for each Model Trial.

Linear: The effective elastic thickness profile linearly increases or decreases between the randomly chosen maximum and minimum EET values for each Model Trial.

Stepped: The effective elastic thickness profile increases in the specified number of steps from the randomly chosen minimum to the randomly chosen maximum for each Model Trial. **Note:** The maximum number of steps allowed is 3.

5. Filters

The randomly generated deflection profiles are compared to the basin geometry based on up to 5 filter locations. Filter locations are locations in the basin where the subsidence for the time interval in question is known. For each of the five filters, the user inputs the subsidence amount (i.e., thickness of the stratigraphic column), the location of the filter (in m right of the pin location), and the uncertainty associated with either the stratigraphic location or thickness (Figures 9 and 10).

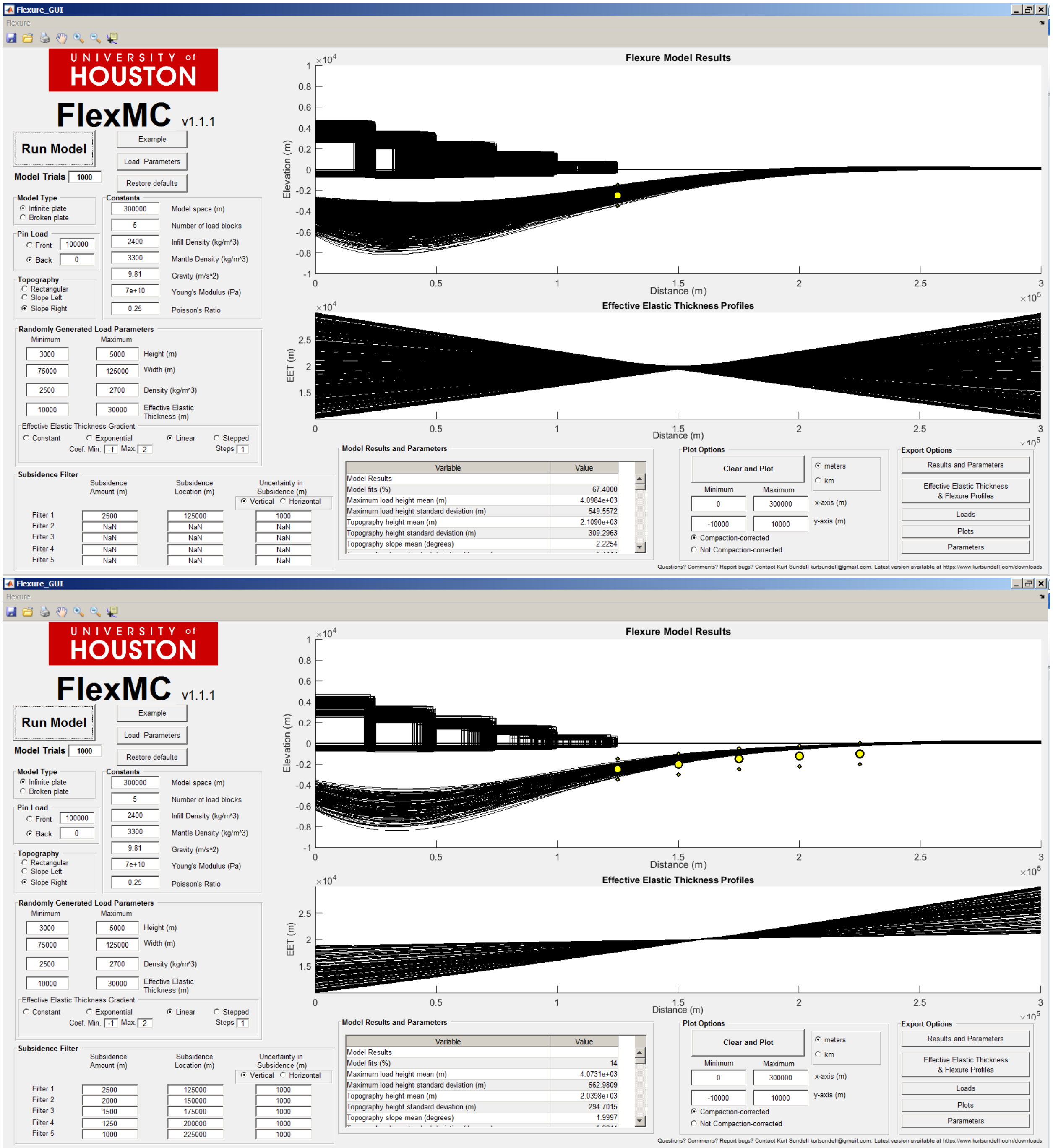

Figure 9. *(Top) A single filter with 1,000 m of vertical uncertainty. (Bottom) Five filters each with 1,000 m of vertical uncertainty.*

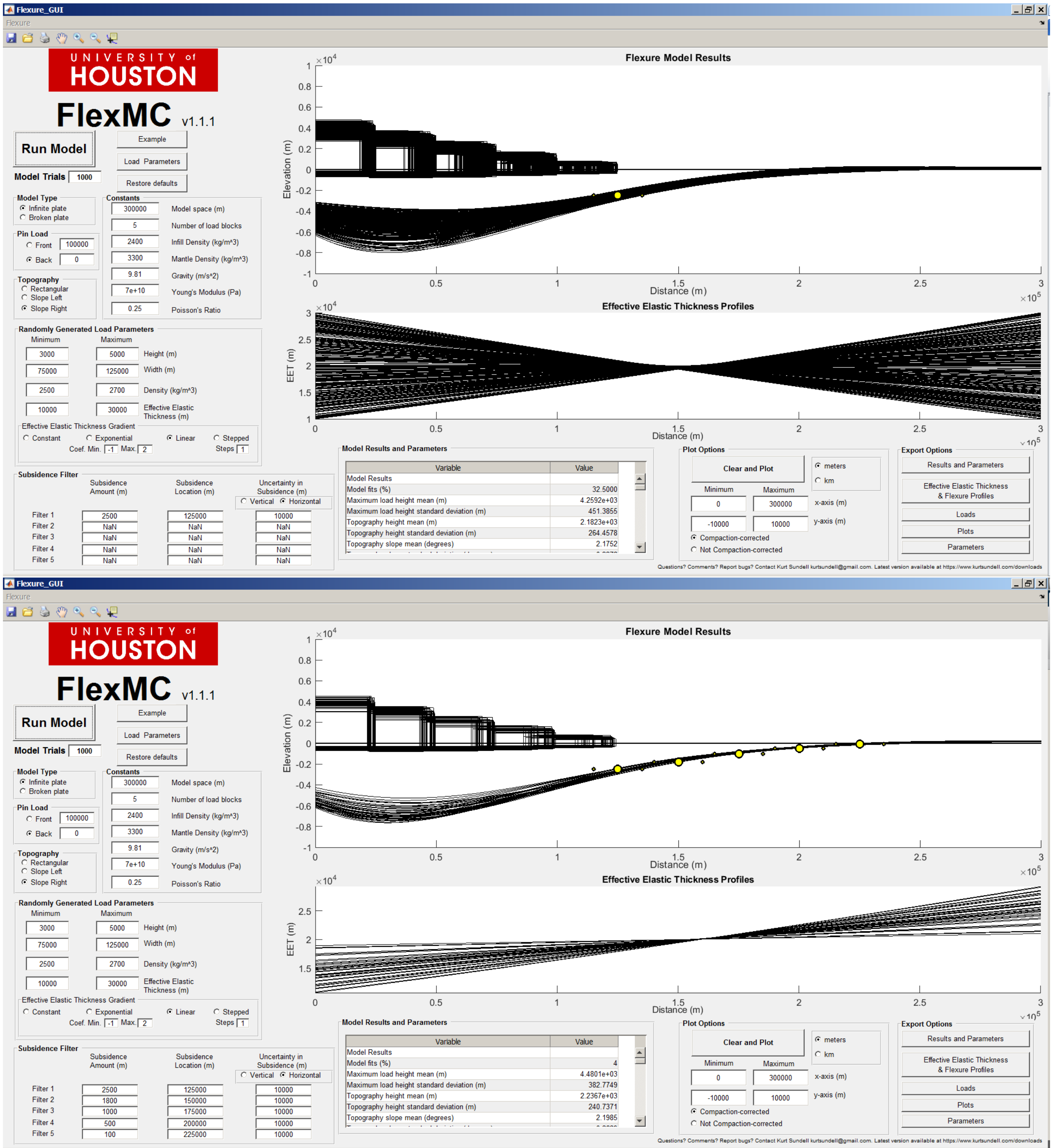

Figure 10. (Top) A single filter with 10,000 m of horizontal uncertainty. (Bottom) Five filters each with 10,000 m of horizontal uncertainty.

6. Plotting Options

The Plotting Options box provides options for changing the maximum and minimum values for the x- and y-axes (Figure 11). X-values in the text boxes are applied to both the flexure and effective elastic thickness plots. Y-values in the text boxes are applied only to the flexure plots.

The figures can be plotted on either meter- or km-scaled axes. However, this does not change the underlying data.

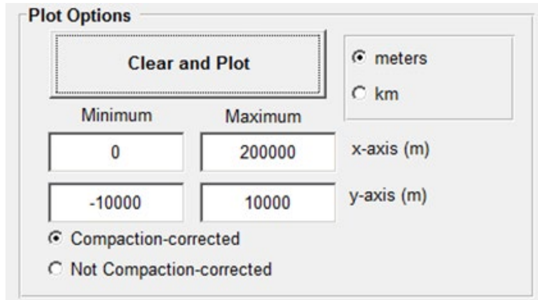

Figure 11. *Plotting options in FlexMC.*

Compaction-corrected vs. Not Compaction-corrected:

Compaction-corrected: In order to most accurately reproduce paleotopography, we accounted for the fact sediment loading adds to the mass of the tectonic load following the method outline by Saylor et al. (2017). They used equation 1 (below, and Figure 12) to calculate the height of the compaction corrected topographic height of the load block (*h'*),

$$h' = \bar{h} - d\left[1 - \left(\frac{\rho_i}{\overline{\rho_c}}\right)\right], \quad \text{(eq. 1)}$$

In this equation $\bar{h}$ is the mean height of the modeled load block, *d* is the subsidence at the center of the load block, and ρ_i and $\overline{\rho_c}$ are the assigned infill density and mean calculated load density, respectively. This approach decreases the area of the basin infill beneath the tectonic load so that its density matches the density of the tectonic load. The resultant decrease in height of the infilling material is subtracted from the height of the tectonic load block to obtain the final topographic elevation. This is equivalent to the more common approach of modeling basin infill as additional load blocks (Jordan, 1981; Yong et al., 2003; Fosdick et al., 2014), but is less computationally expensive.

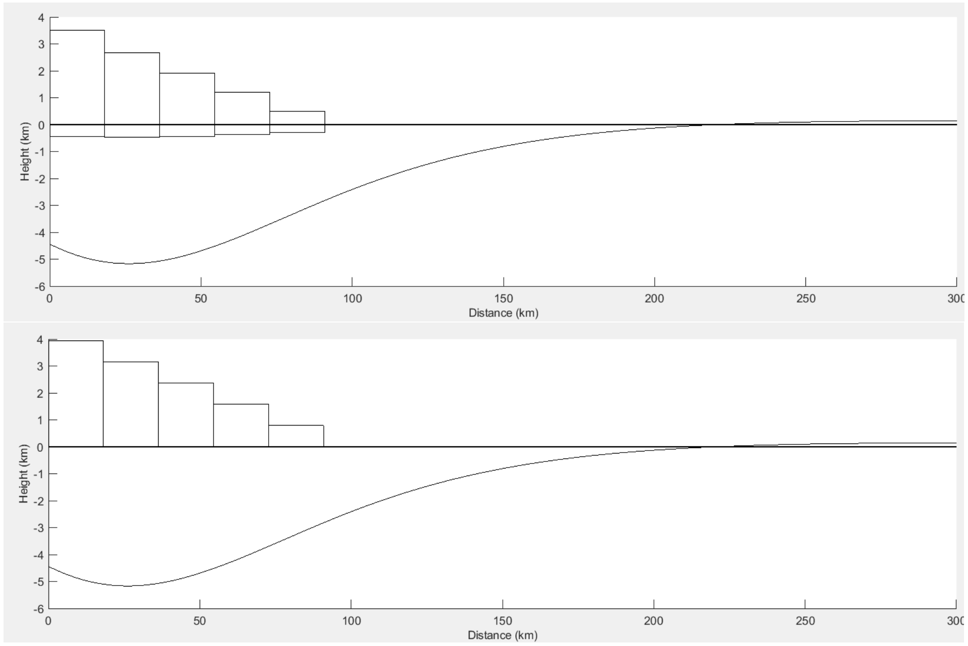

Figure 12. *Compaction-corrected (top) versus Not Compaction-corrected (bottom) topographic heights for the tectonic loads associated with one Model Trial. Note that the Compaction correction has no effect on the geometry of the deflected plate.*

7. Saving and exporting

Results and Parameters: Exports the table visible on the FlexMC main screen as an Excel file.

Effective Elastic Thicknesses & Flexural Profiles: Exports all accepted profiles and their associated x-values as an Excel file.

Loads: Exports all load centers, widths, and heights to an Excel file.

Plots: Creates pop-outs of the figures in the FlexMC main page for individual saving.

Parameters: Saves an excel file with all of the input options. This can be reloaded or used to document the variables of a successful run.

Works Cited

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