

# Simple model of landslide failure surface and displacement

---

Developing a python interface to estimate the SLBL surface and the displacement according to the model, and comparing to field data

# SFA - Setup

- Install python using miniconda
  - Run `install_miniconda.bat`
- Configure a virtual environment installing needed packages
  - Run `env_setup.bat`
- ❖ Start the python interface
  - Run `SFA.bat`

All the process is automated within the bat files, all that is needed is to launch them one by one and wait that the console window disappear before launching the next one. Once the virtual environment is ready, you just need to launch SFA when you need it, no need to modify again the environment.

# Warning:

- The graphs displayed by this interface are powered by matplotlib. The majority of them are displayed with automatic scale. Thus the scale is often different for the axis. With different scales, the displayed angles are actually deformed. Consider manual adjustment in the graph parameters if you need angle accuracy for display purpose. A checkable button next to the graph button allows to set the same scale for each axis if checked.

# Preparing the data

- All points must be sorted according to the x-axis.
- Be wary that python use a dot decimal separator (« 3.1415 » instead of « 3,1415 »).
- The column order in the loaded files is important, please refer to the README file.

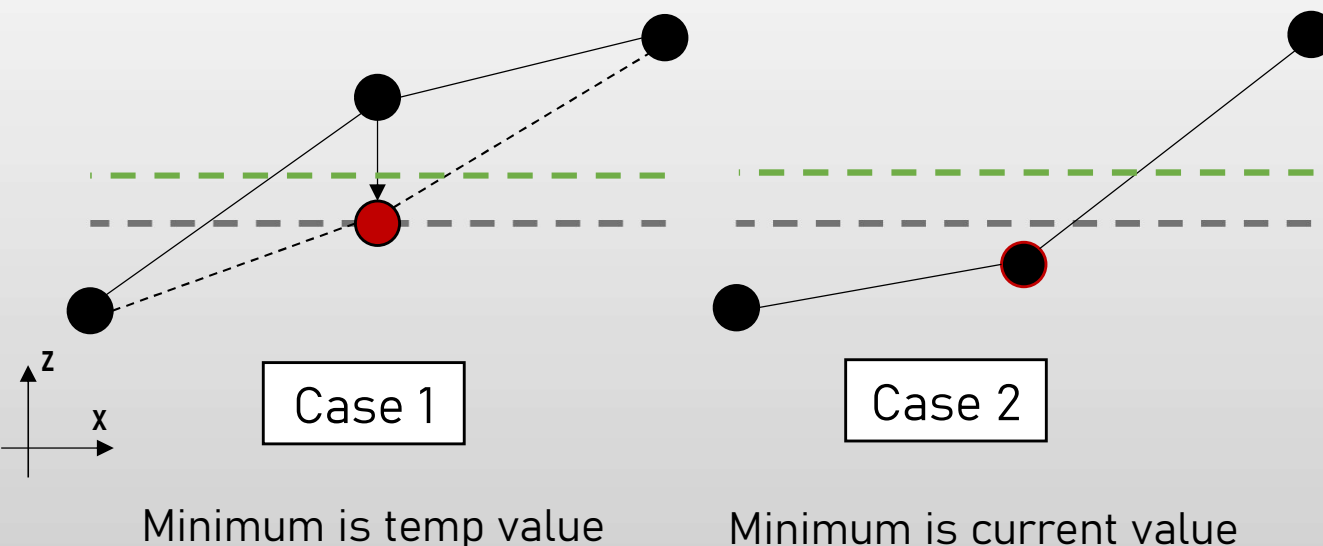
# Modeling the failure surface : SLBL approach

## Overview of the method:

Iterative algorithm « Minimum wise » :

- $slbl_{temp}[i] = \frac{slbl_{-1}[i-1] + slbl_{-1}[i+1]}{2} - C$
- $slbl[i] = \min(slbl_{temp}[i], slbl_{-1}[i])$

C is a tolerance parameter relative to the landslide geometric features



Toward preliminary hazard assessment using DEM topographic analysis and simple mechanic modelling by mean of the sloping local base level, Jaboyedoff et al., 2004

Matrix expression:

$$M \cdot Z = C$$

$$M = \begin{bmatrix} 1 & -0.5 & \dots & 0 \\ -0.5 & 1 & \ddots & \vdots \\ & \vdots & \ddots & 1 \\ & 0 & \dots & -0.5 & 1 \end{bmatrix}$$

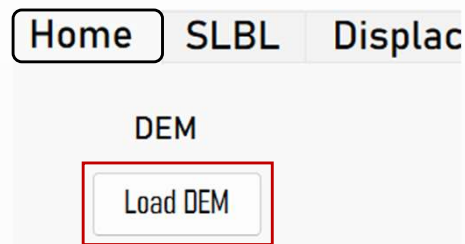
$$Z = \begin{bmatrix} z_1 \\ \vdots \\ z_{n-1} \end{bmatrix}$$

$$C = \begin{bmatrix} z_0 - c \\ -c \\ \vdots \\ -c \\ z_n - c \end{bmatrix}$$

# Modeling the failure surface : SLBL approach

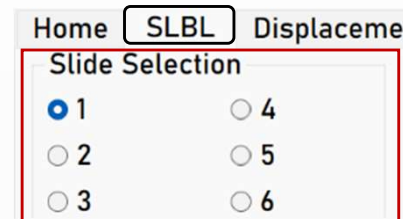
## Implementation in the python interface:

1. Loading the DEM along the profile



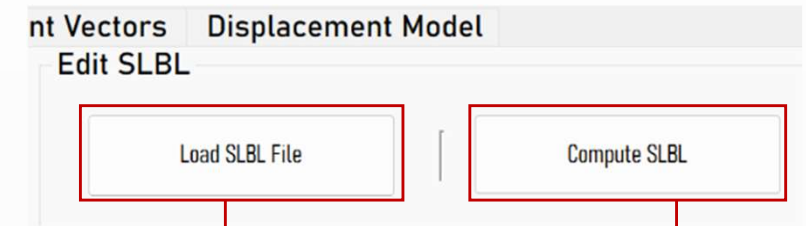
The SLBL data it computed according to the points of the DEM.

2. Selecting the memory slot to edit



Six SLBL can be stored at the same time.

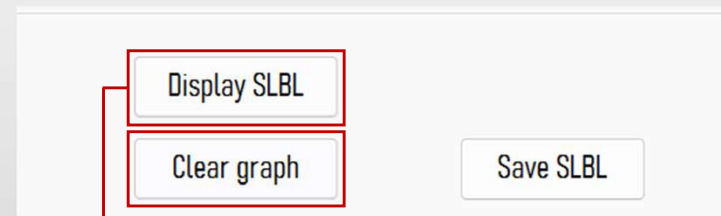
3. SLBL can be loaded from a file or computed



The file formats are specified in the README.md.

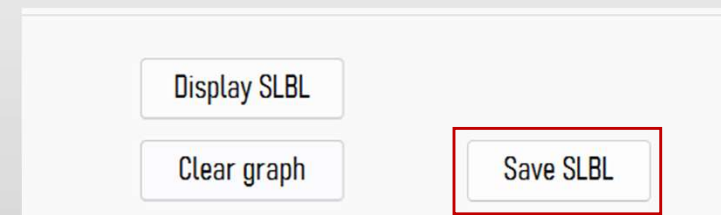
Opens the window for computation.

4. Display the computed SLBL



Display the SLBL of the selected slot along with the DEM.

5. Export the computed SLBL for external use



# Modeling the failure surface : SLBL approach

Compute SLBL with known range within the cross-section:

Form

SLBL

Left limit

100,0m

Right limit

500,0m

Tolerance

2,0000

→ C value

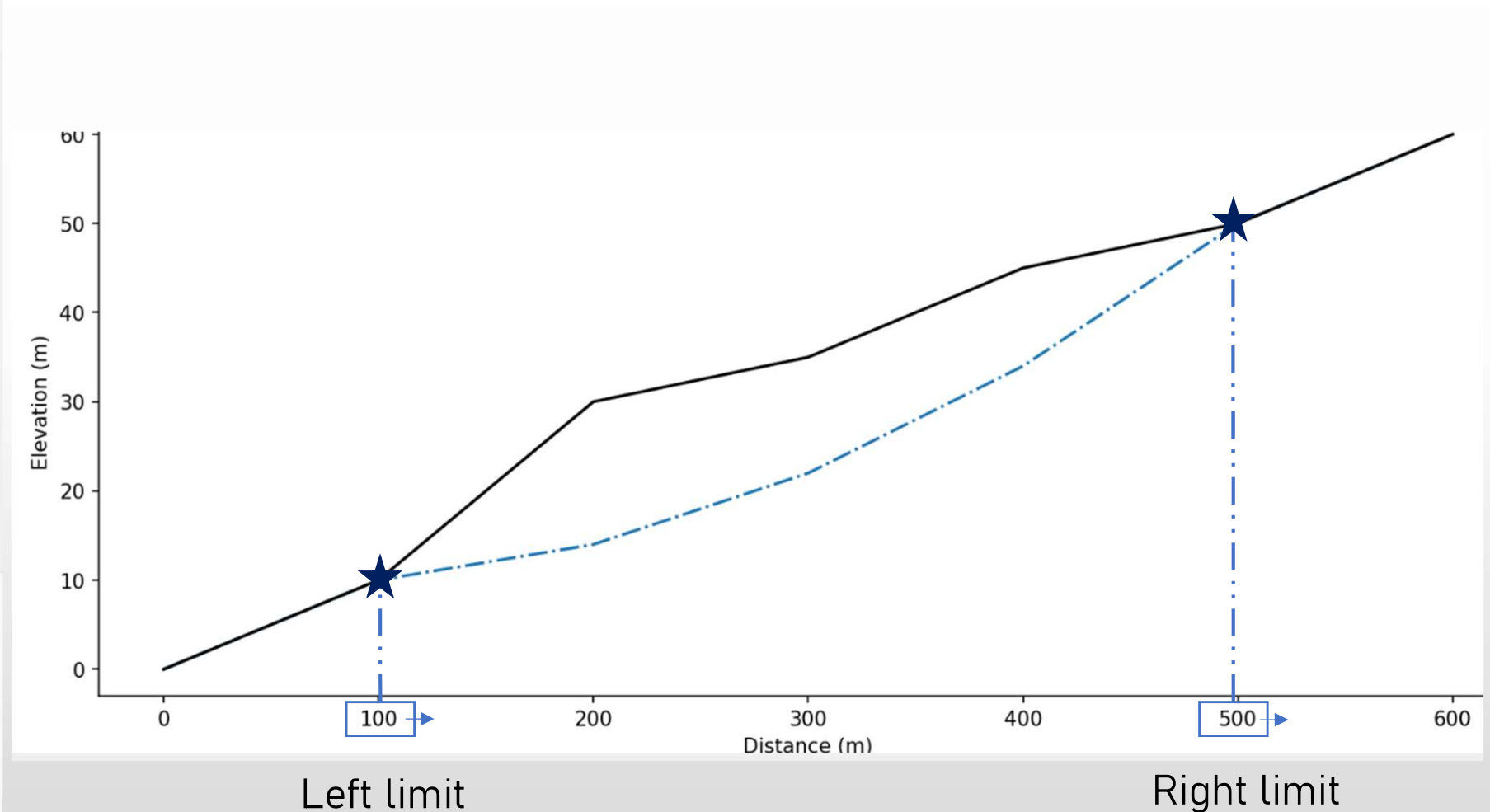
Range

Combine

Sub

Point

Compute



# Modeling the failure surface : SLBL approach

Compute SLBL using two existing features:

Range

Combine

Sub

Point

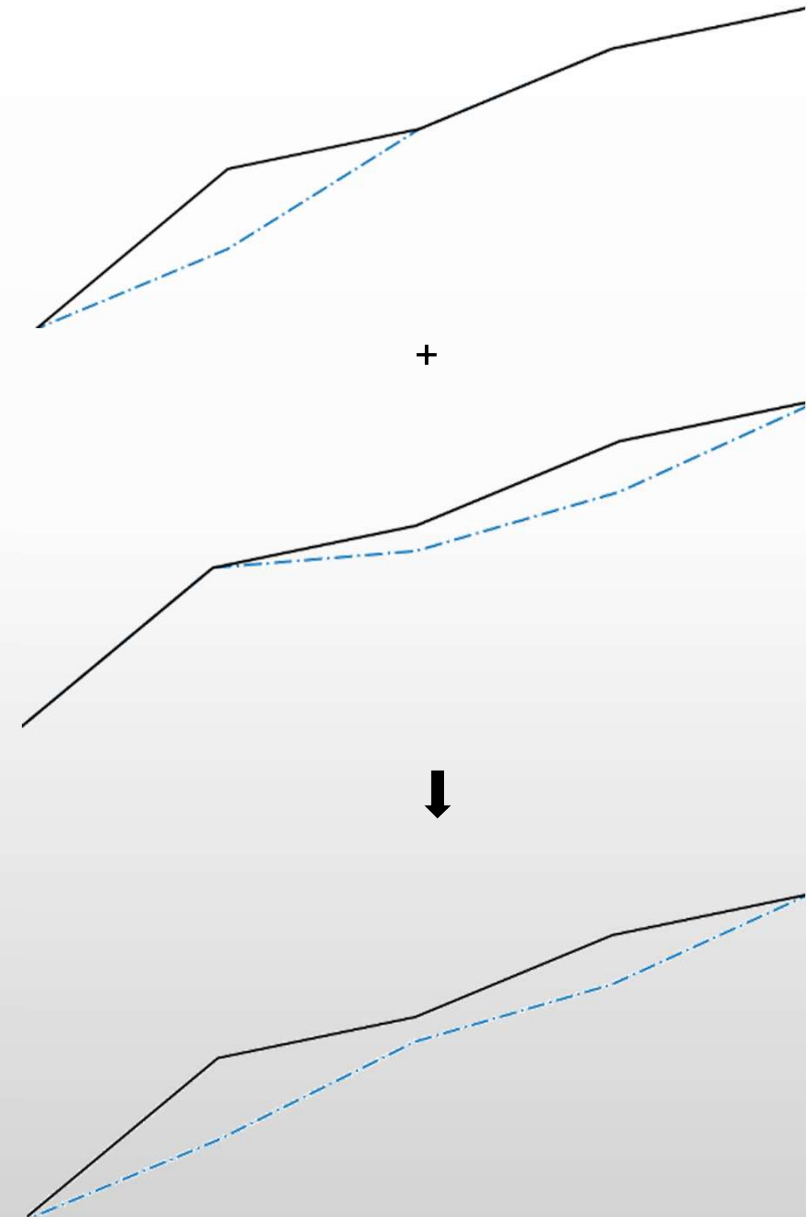
Slot references

SLBLs: 1 2

Compute

Content of slot 1:

Content of slot 2:



Minimum of two features (SLBL)



# Modeling the failure surface : SLBL approach

Compute SLBL using one existing features:

Form

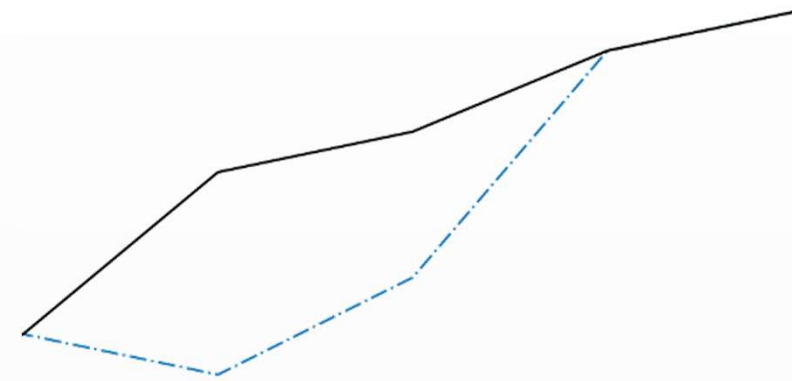
## SLBL

Left limit: 100,0m

Right limit: 500,0m

Tolerance: 2,0000

Computed as range



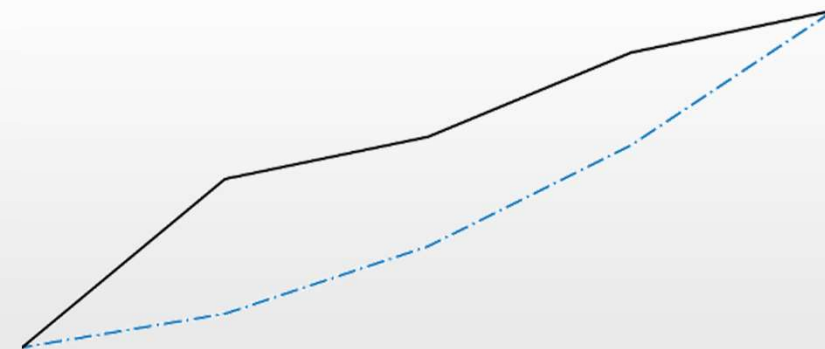
+

Range Combine Sub Point

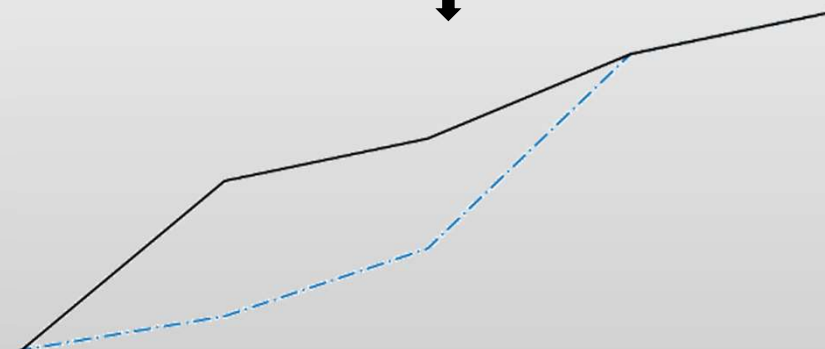
Master SLBL: 1

Compute

Content of master



↓



Maximum of two features (SLBL, faults, ...)

# Modeling the failure surface : SLBL approach

Compute SLBL using two points (inside or outside cross-section):

Form

SLBL

Left limit100,0m

Right limit500,0m

Tolerance2,0000

Range

Combine

Sub

Point

Point left

x: -100m

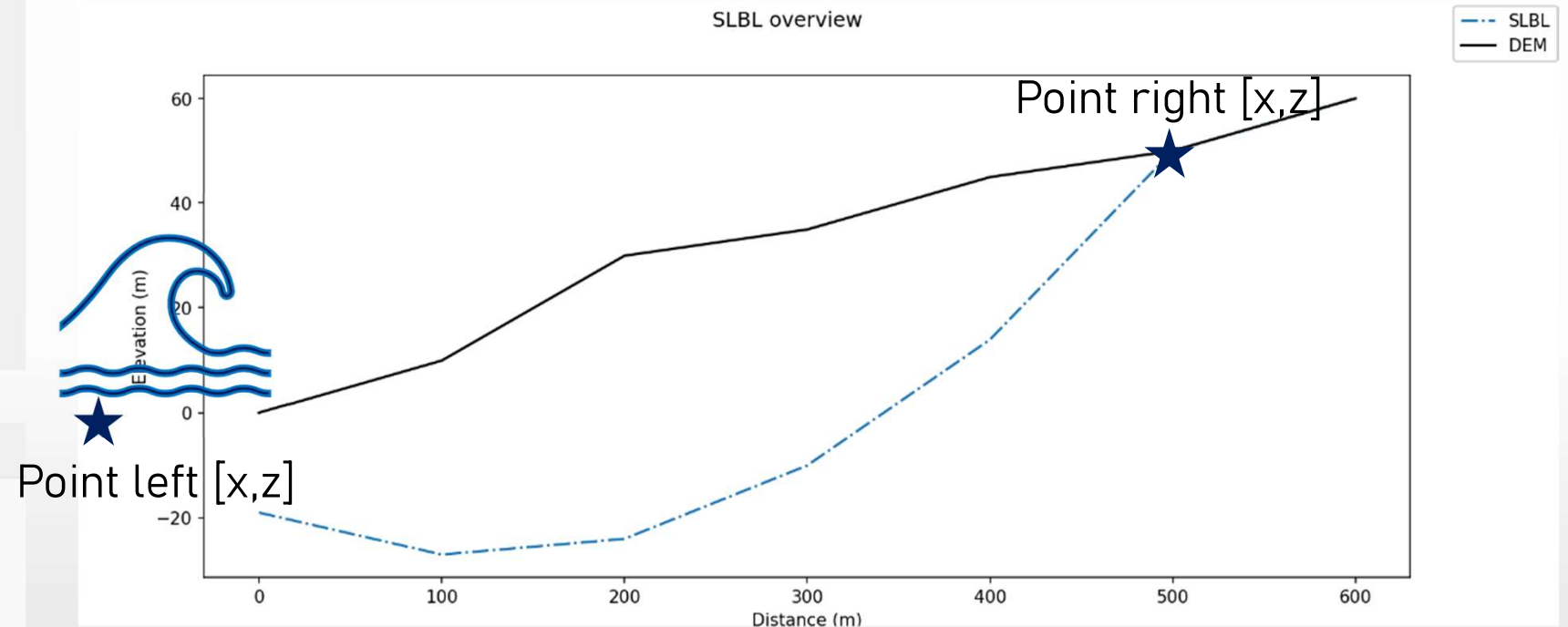
z: 0m

Point right

x: 500m

z: 50m

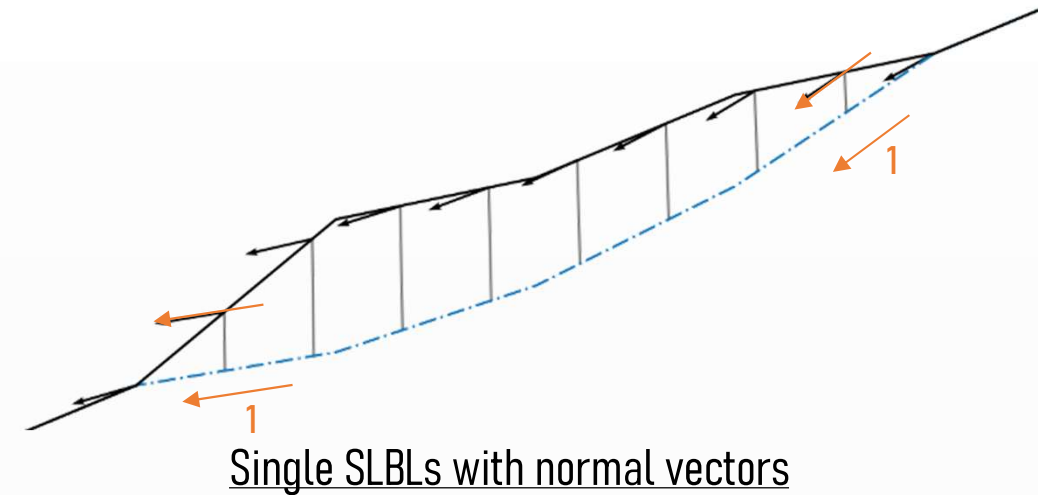
Compute



# Model of displacement

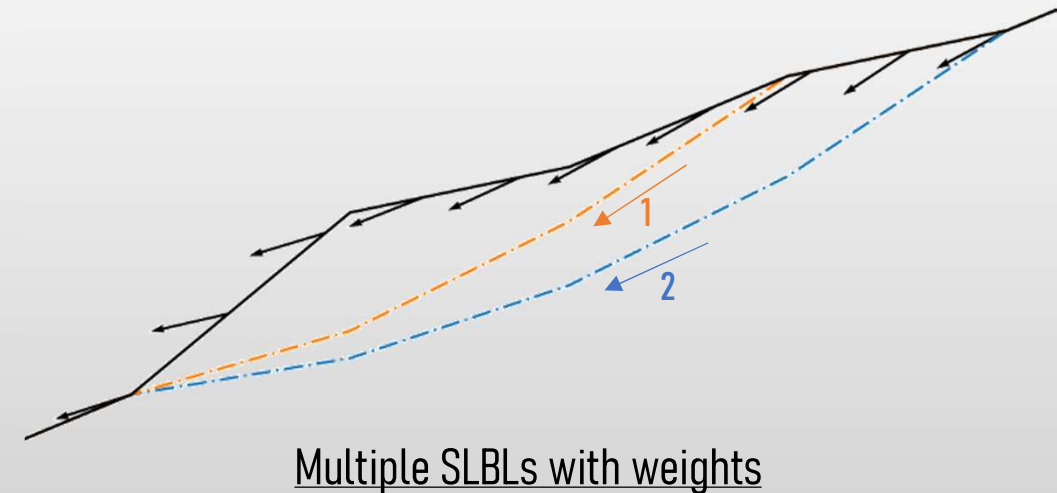
## ❑ Basic displacement:

- Following the failure surface (orientation of the vector)
- Movement is conserved along the section (normalized vectors)
- Movement is the same on one slide of the landslide (perpendicular to the local slope)



## ❑ Multi-layered failure surface:

- Global displacement is the sum of weighted basic displacement for each failure surface

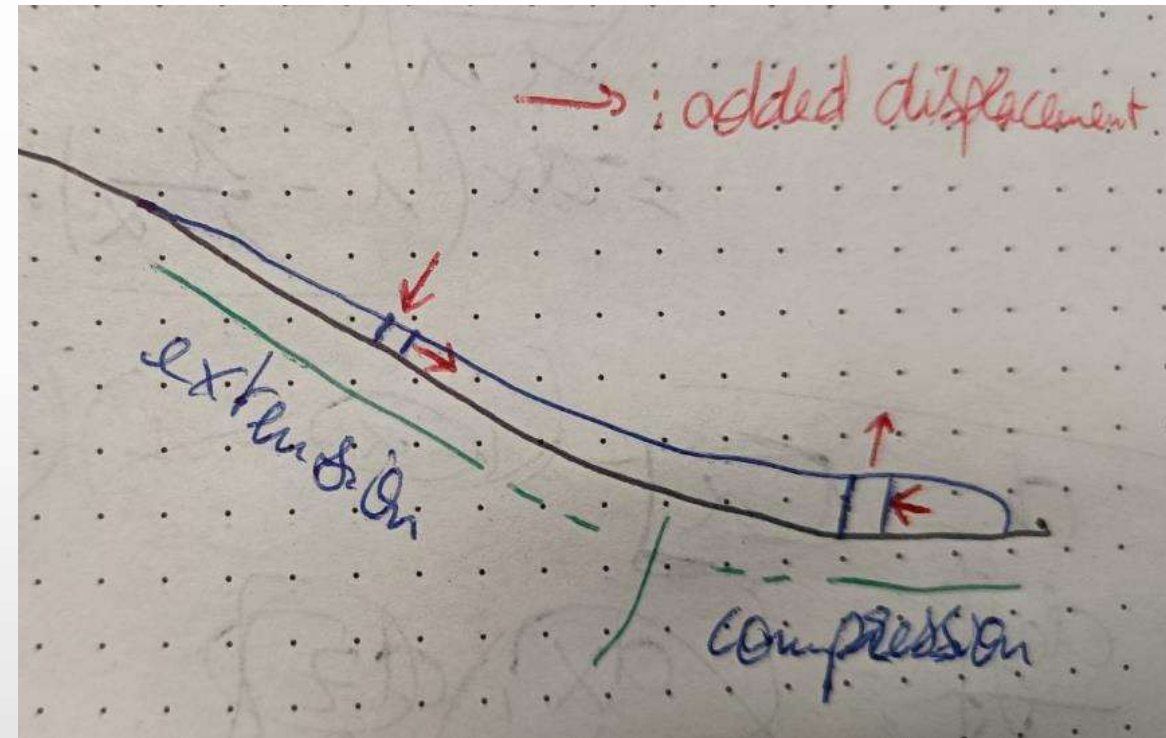


# Model of displacement

NOT  
IMPLEMENTED

## ❑ With material deformation:

- Incompressible but deformable material leads to a loss of thickness in the upper, whereas material is accumulating in the lower part (total volume is conserved)
  - Upper parts : decreasing thickness -> negative vertical displacement and positive horizontal displacement (relatively to the landslide)
  - Lower parts: increasing thickness -> positive vertical displacement and negative horizontal displacement



# Modeling the displacement with one SLBL

Home

SLBL

Displacement Vectors

Displacement Model

Slide Selection

☒ 1

☐ 2

☐ 3

☐ 4

☐ 5

☐ 6

Edit Displacement Vectors

Add linear profile on SLBL

ratio left

1,0

ratio right

1,0

Number of vectors:

10

100,0m

500,0m

min x

max x

Compute displacement vectors

Display Vectors

Clear graph

Load Vectors File

Save Vectors

Select the corresponding SLBL

Set the number of vectors and the range of the model. Must be common for all Slides.

Compute the vectors according to the local slope.

Display the computed vectors.

Export the results.

Displacement vectors overview

Elevation (m)

Distance (m)

SLBL

DEM

Displacement Vectors

Edit Displacement Vector

Add linear profile on SLBL

ratio left

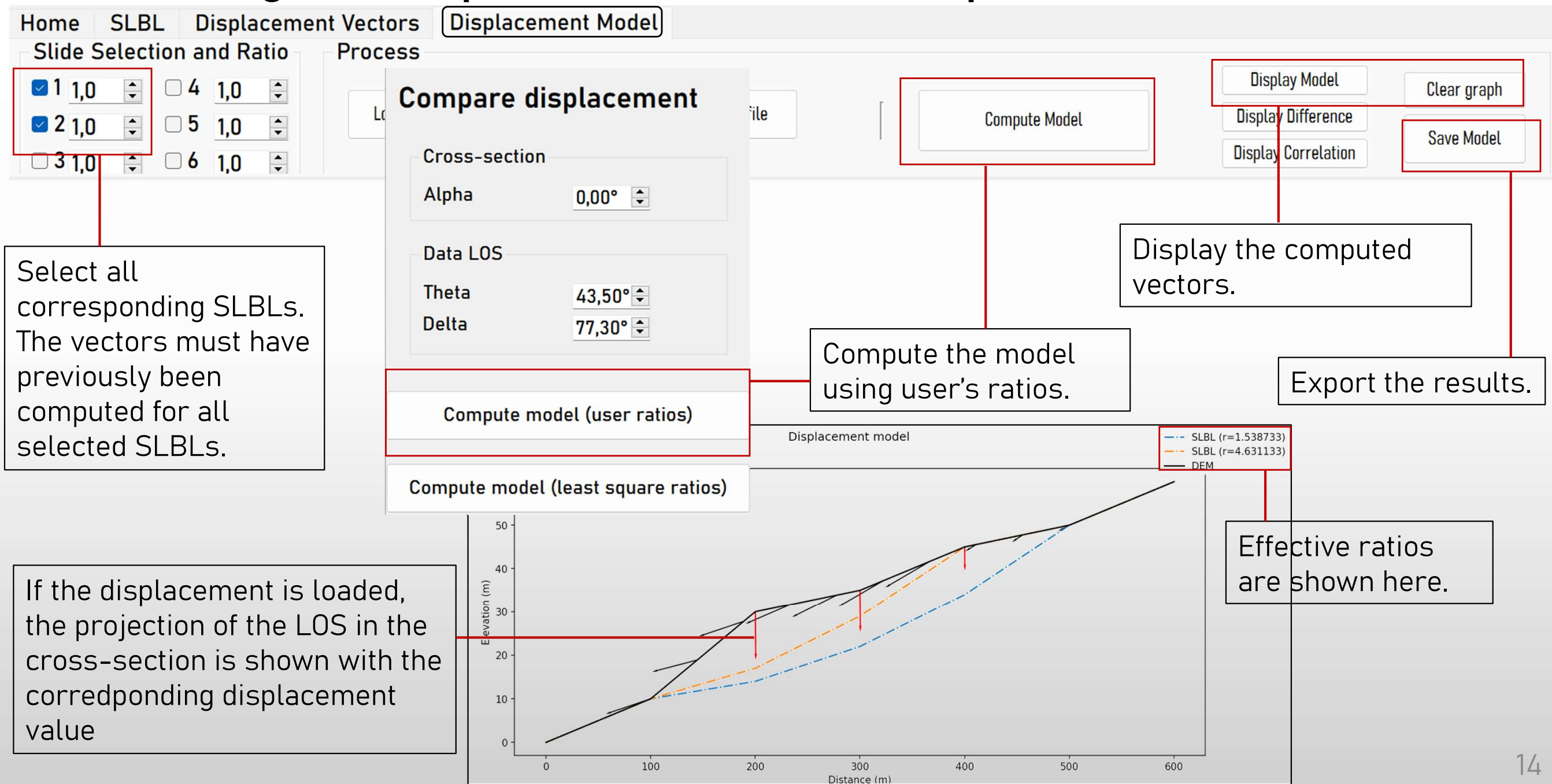
1,0

ratio right

1,0

Weight the displacement along the SLBL using linear profile defined by his two extremum values.

# Modeling the displacement with multiples SLBL



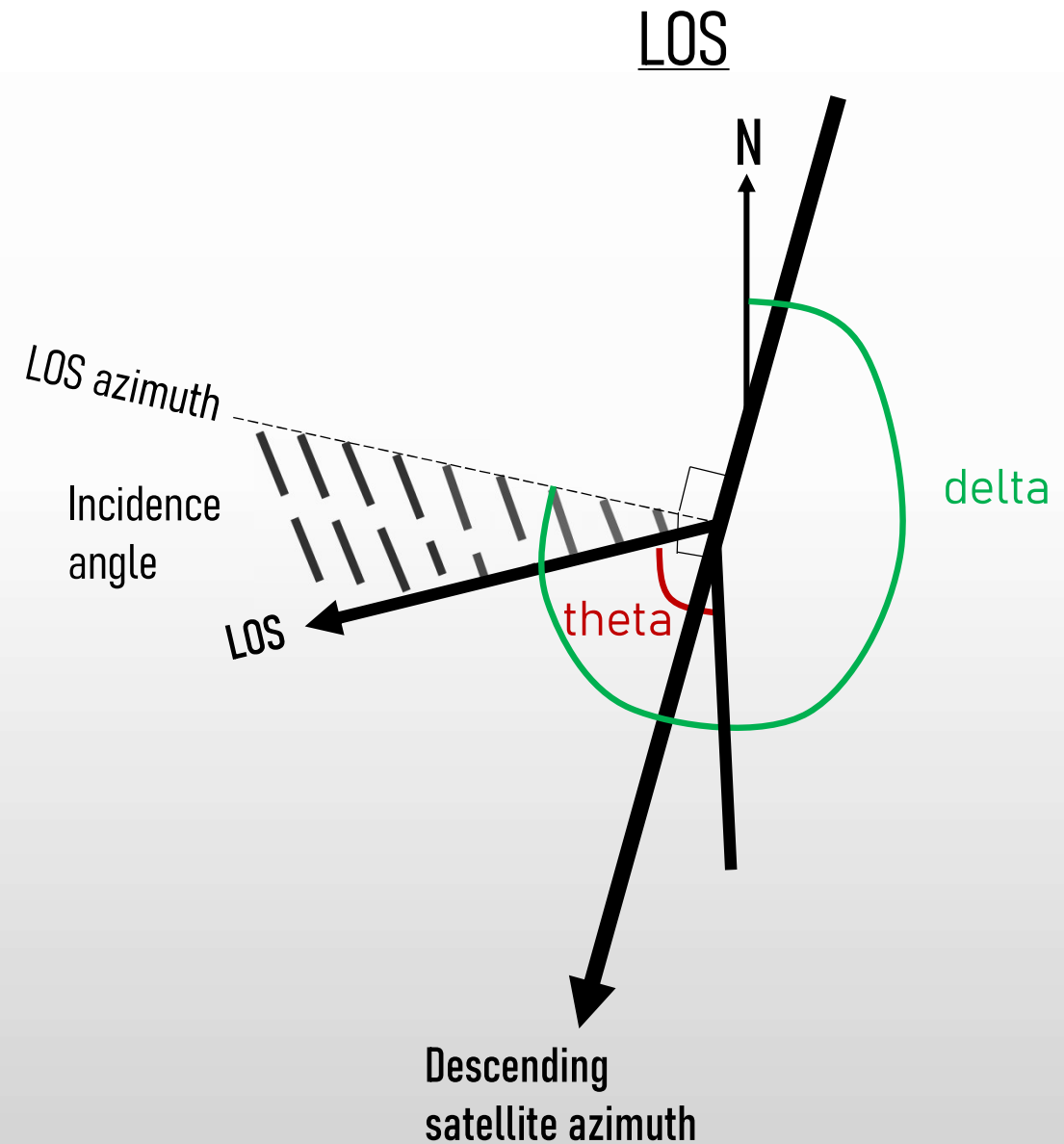
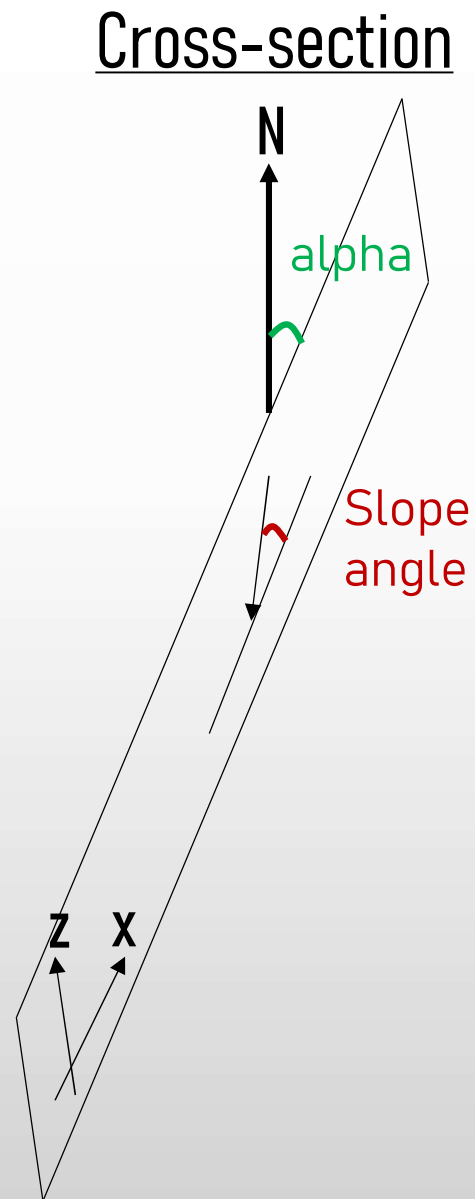
# Recommendation

- If you want to change some parameters and do a new model, consider saving the current model into a project file, closing and opening again the python interface.

Reseting and reusing already used slots and parameters is currently not handled and could ends in unexpected behaviours or errors.



# Comparing the displacement with field data : the geometry





# Ajusting the model to field data

The screenshot shows the 'Displacement Model' software interface. The top navigation bar includes 'Home', 'SLBL', 'Displacement Vectors', and 'Displacement Model'. The 'Slide Selection and Ratio' section on the left has a grid of checkboxes and input fields for SLBLs 1 through 6, all set to 1.0. The 'Process' section contains buttons for 'Load Displacement Data', 'Load Elongation Profile', and 'Compute Model'. On the right, there are buttons for 'Display Model', 'Clear graph', 'Display Difference', 'Display Correlation', and 'Save Model'. Below the 'Compute Model' button is a 'Compare displacement' panel with input fields for 'Alpha' (0,00°), 'Data LOS' (Theta: 43,50°, Delta: 77,30°), and two 'Compute model' buttons: 'Compute model (user ratios)' and 'Compute model (RMSE least square)'. Annotations with red lines point to various elements: the SLBL selection grid, the 'Load Displacement Data' button, the 'Compute Model' button, the 'Alpha' and 'Delta' input fields, the 'Compute model (RMSE least square)' button, and the 'Save Model' button.

Select all corresponding SLBLs. The vectors must have previously been computed for all selected SLBLs.

Load the displacement data from file

Load Elongation Profile

The final model can be weighted via an elongation profile file. It is automatically used when loaded.

Indicate the geometry of the cross-section and the external data. The ratios will be computed via a least-square function.

Display the computed vectors.

Export the results.

Compute model (RMSE least square)

# Ajusting the model to field data

HomeSLBLDisplacement VectorsDisplacement Model

Slide Selection and Ratio

☒ 1 1,0

☐ 4 1,0

☒ 2 1,0

☐ 5 1,0

☐ 3 1,0

☐ 6 1,0

Process

Load Displacement Data

Load Elongation Profile

Compute Model

Display Model

Display Difference

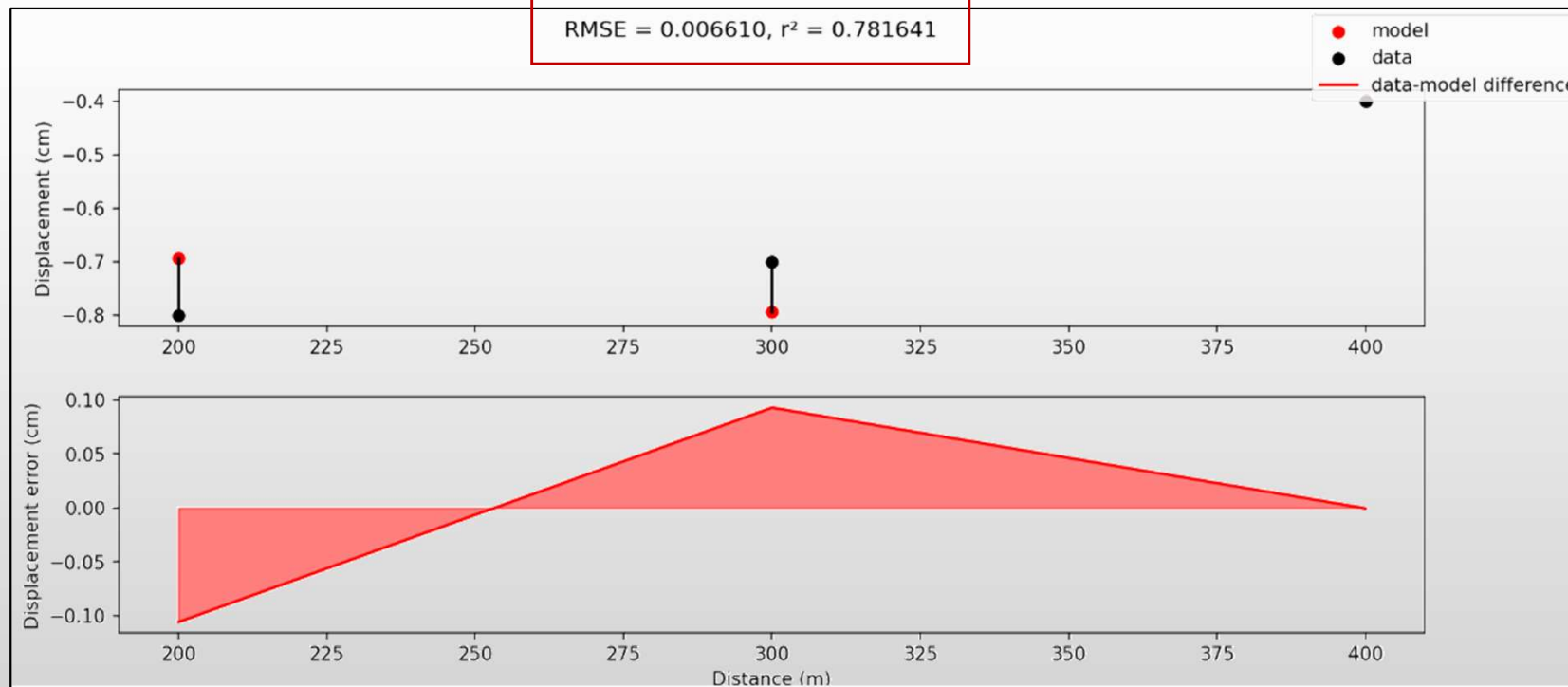
Display Correlation

Clear graph

Save Model

RMSE and  $r^2$  coefficients are automatically computed and displayed.

After computing the model, the difference between the data and the model can be displayed.



Sign convention:

- Positive displacement: Ground moving towards the satellite
- Negative displacement: Ground moving away from the satellite

# Ajusting the model to field data

HomeSLBLDisplacement VectorsDisplacement Model

Slide Selection and Ratio

☒ 1 1,0

☐ 4 1,0

☒ 2 1,0

☐ 5 1,0

☐ 3 1,0

☐ 6 1,0

Process

Load Displacement Data

Compute deformable model

Compute Model

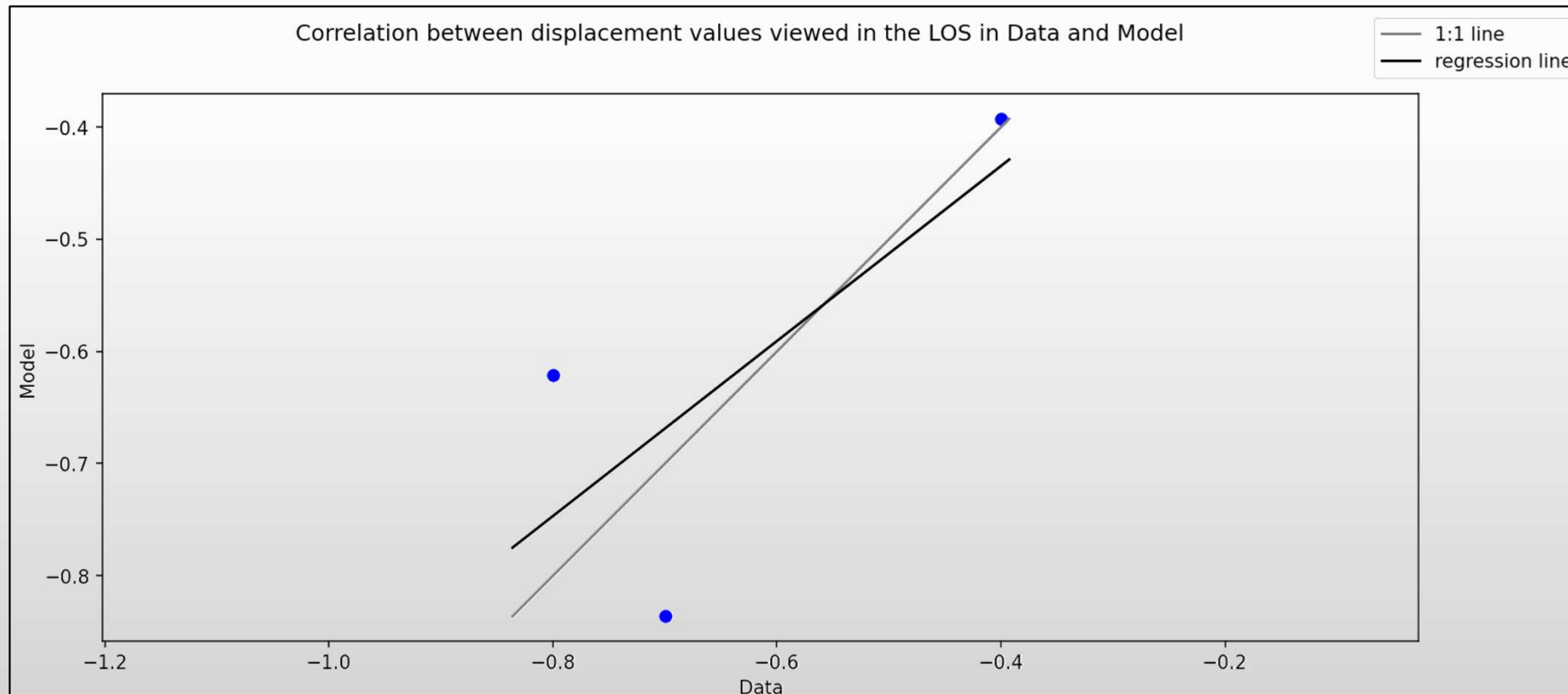
Display Model

Display Difference

Display Correlation

Clear graph

Save Model



After computing the model, the correlation between the data and the model can be displayed.

# Model considering a deformable material at constant volume

Home

SLBL

Displacement Vectors

Displacement Model

Slide Selection and Ratio

☒ 1 1,0

☐ 4 1,0

☒ 2 1,0

☐ 5 1,0

☐ 3 1,0

☐ 6 1,0

Process

Load Displacement Data

Compute deformable model

Compute Model

Display Model

Display Difference

Display Correlation

Clear graph

Save Model

Form

Load from file

Height correction

☒ positive (a+) 1,00
 ☐ negative (a-) -1,00

Generate table

Correct table (custom values)

Neutral point position (m): 281

Volume variation: -2.775557561562

Apply table on model

Save to file

X\_reg

coefficient

	1	2
1	100.0	1.0
2	144.44444444444446	0.7549340171356231
3	188.88888888888889	0.5098680342712466
4	233.33333333333331	0.2648020514068699
5	277.77777777777777	0.01973606854249315
6	322.22222222222223	-0.22532991432188362
7	366.66666666666663	-0.4703958971862601
8	411.11111111111111	-0.7154618800506369
9	455.55555555555554	-0.9605278629150137
10	500.0	-1.2055938457793904

One of the two extremities

The neutral point is calculated considering the vertical displacement of the previous model :

$$\sum \vec{v}_{vertical} \cdot coefficient = 0$$

Displacement is modified as:

$$\vec{v}_{vertical} \pm = \vec{v}_{vertical} \cdot coefficient$$

Can be manually modified

# Project file Exemple

```
1 GLOBAL
2 NAME test_project2
3 DEM_PATH path/example/dem.csv
4
5 SLIDE1
6 METHOD RANGE
7 LEFT_LIM 100
8 RIGHT_LIM 500
9 TOL 2.0
10
11 SLIDE2
12 METHOD RANGE
13 LEFT_LIM 100
14 RIGHT_LIM 400
15 TOL 2.0
16
```

```
17 DISP_VEC
18 N_VEC 10
19 X_MIN 100
20 X_MAX 500
21
22 DISP_MODEL
23 SLIDES 1;2
24 COEFFS 1.538732675989716;4.631133165901916
25 METHOD LEAST_SQUARE
26 DISP_PATH path/example/disp.csv
27 ALPHA 12.0
28 THETA 35.0
29 DELTA 285.0
```