

# Simple model of landslide failure surface and displacement

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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.

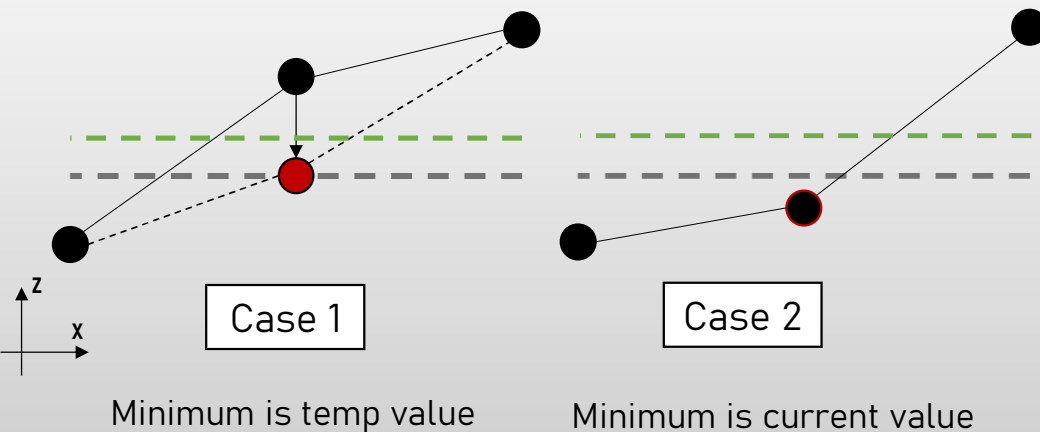
# Modeling the failure surface : SLBL approach

## 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:

$$M \cdot Z = C$$

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

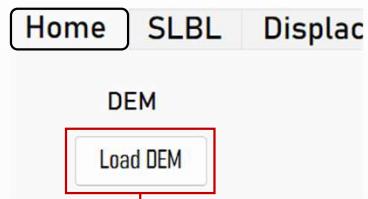
$$Z = \begin{bmatrix} z_1 \\ \vdots \\ z_{n-1} \end{bmatrix}$$

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

# Modeling the failure surface : SLBL approach

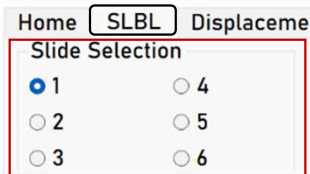
Implementation in the python interface:

1. Loading the DEM along the profile



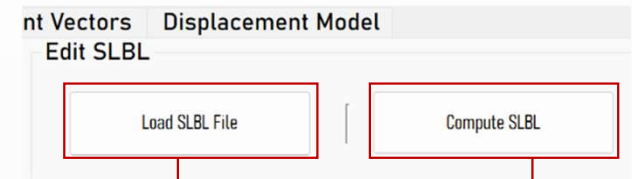
The SLBL data it computed according to the points of the DEM.

2. Selecting the memory slot to edit



Six SLBL can be stored at the same time.

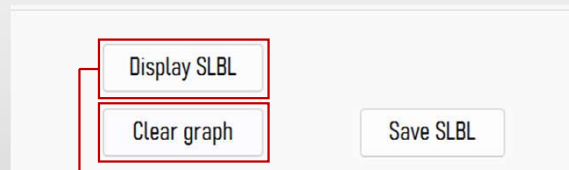
3. SLBL can be loaded from a file or computed



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 limit100,0m

Right limit500,0m

Tolerance2,0000C value

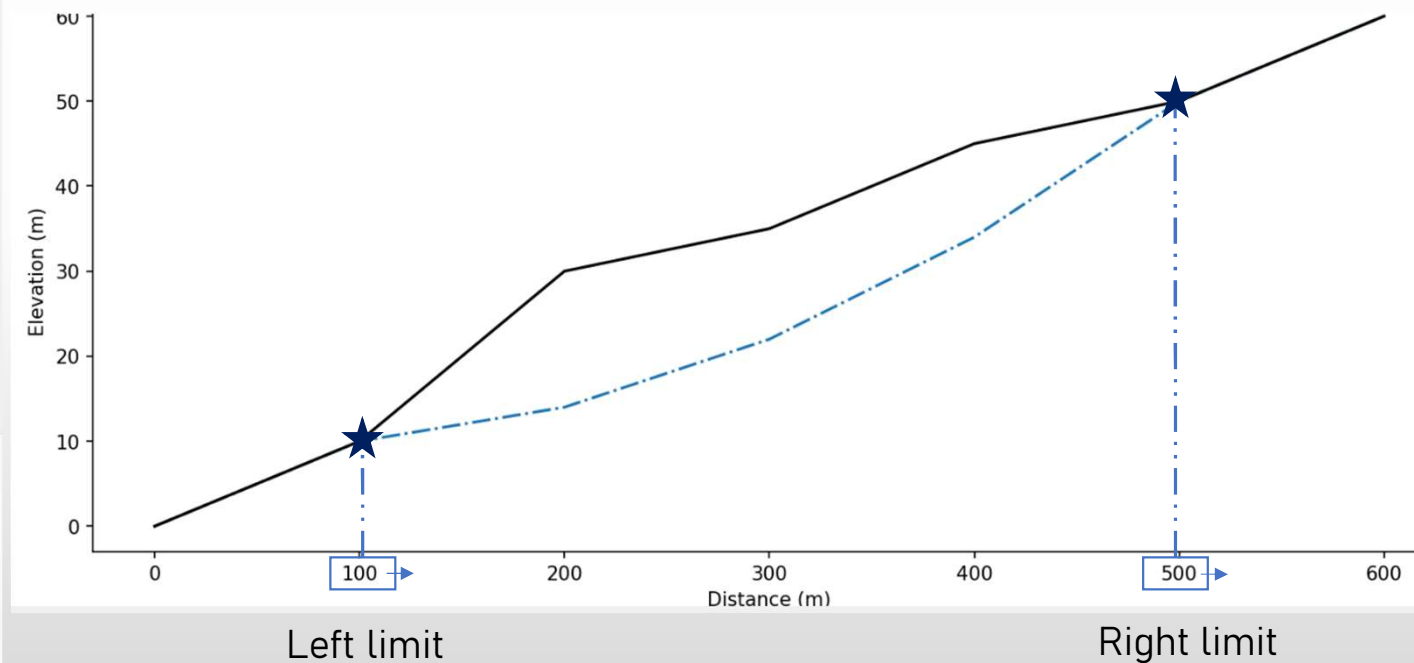
Range

Combine

Sub

Point

Compute



# Modeling the failure surface : SLBL approach

Compute SLBL using two existing features:

Range

Combine

Sub

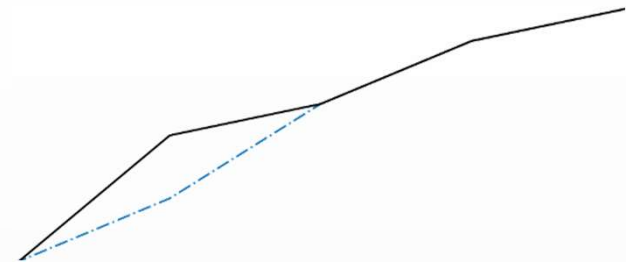
Point

Slot references

SLBLs: 1 2

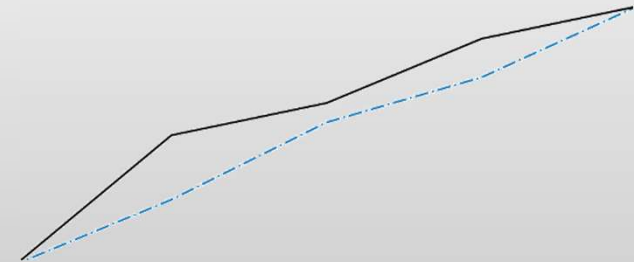
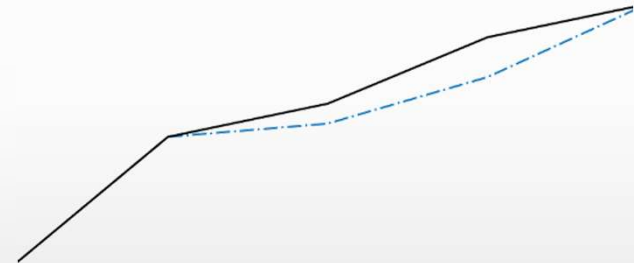
Compute

Content of slot 1:



+

Content of slot 2:

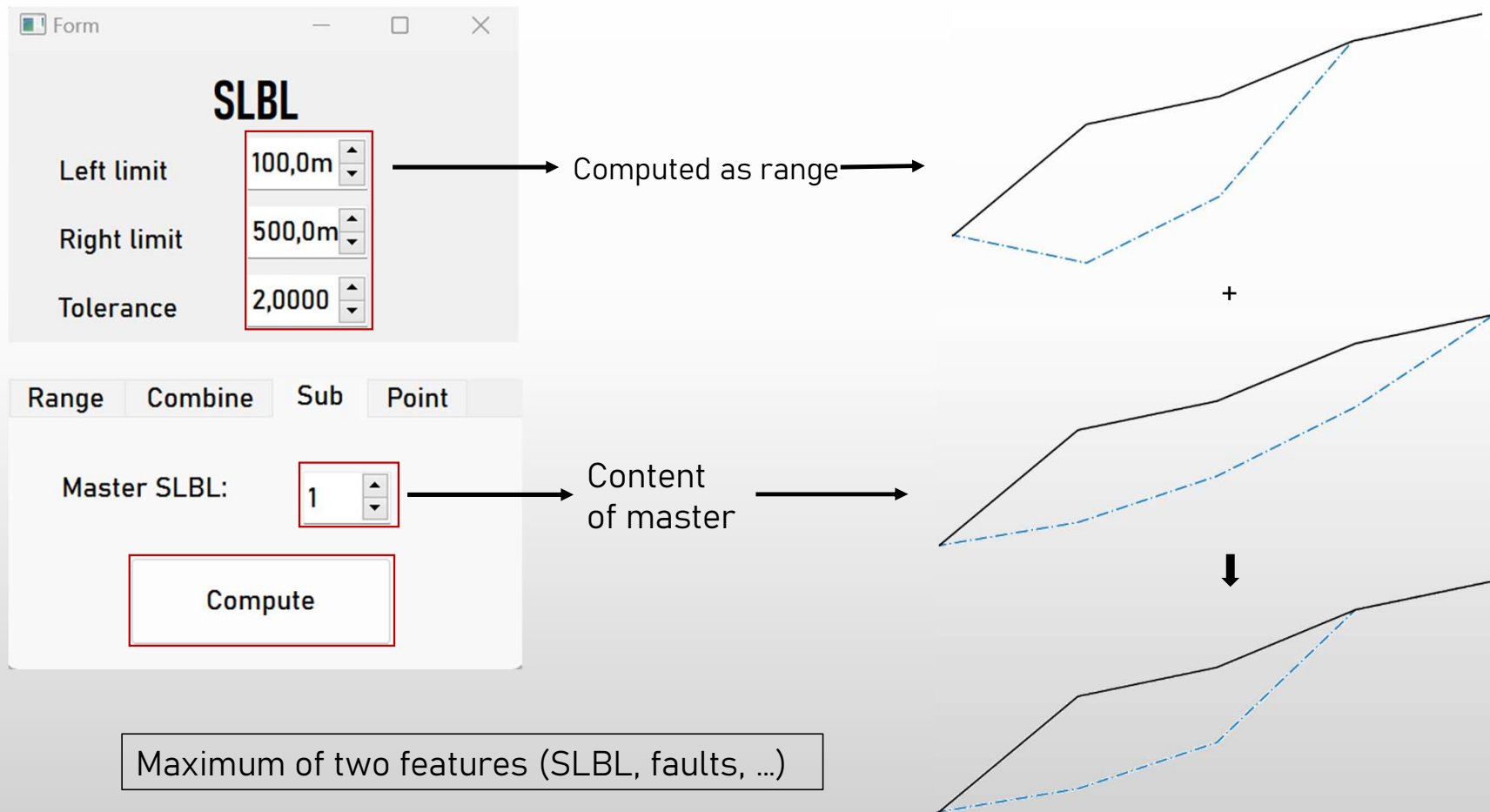


Minimum of two features (SLBL)



# Modeling the failure surface : SLBL approach

Compute SLBL using one existing features:



# 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

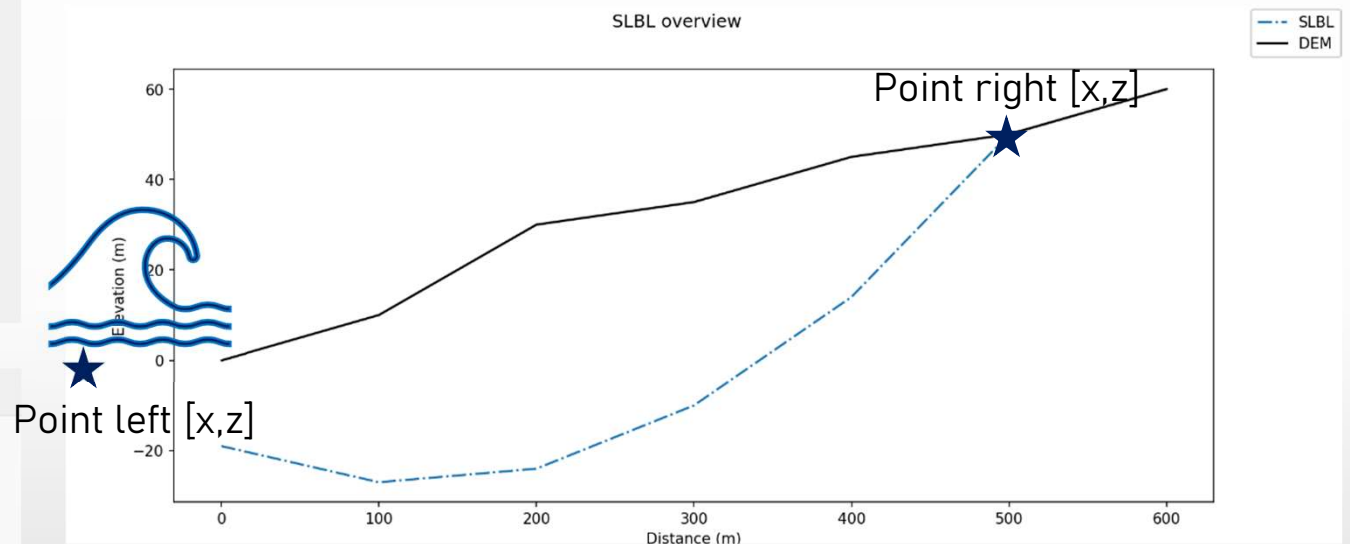
z: 0m

Point right

x: 500m

z: 50m

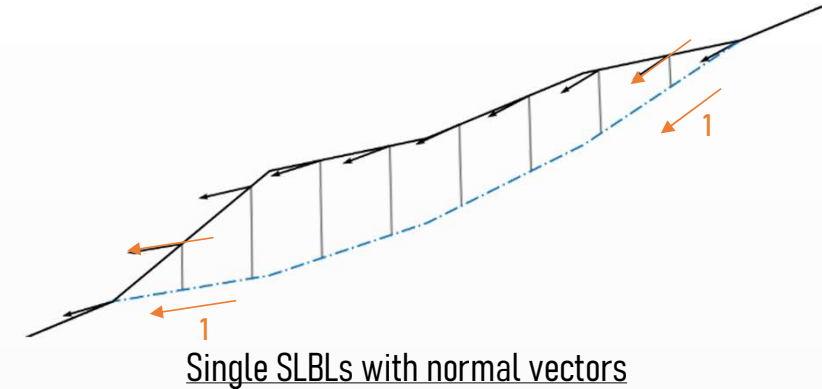
Compute



# Model of displacement

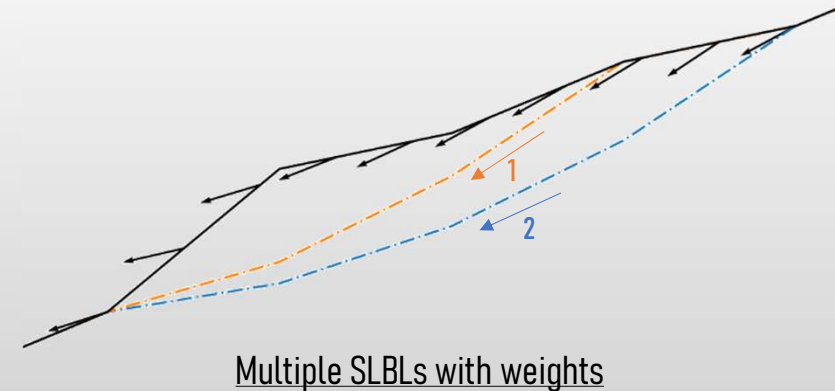
## ❑ Basic displacement:

- 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

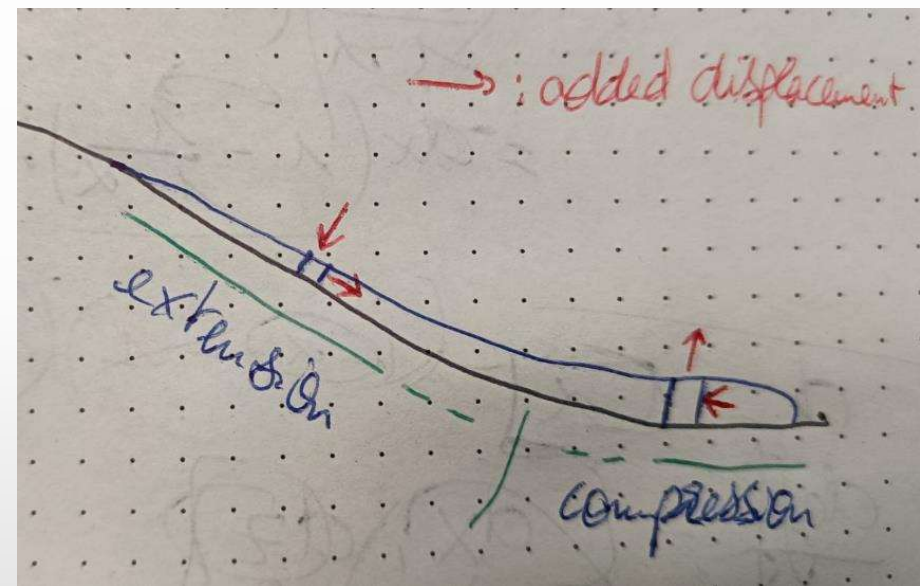


# Model of displacement

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

HomeSLBLDisplacement VectorsDisplacement 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.

Display the computed vectors.

Compute the vectors according to the local slope.

Export the results.

Displacement vectors overview

SLBL

DEM

at Vectors

Displacement

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

Home SLBL Displacement Vectors **Displacement Model**

Slide Selection and Ratio Process

☒ 1 1,0 ☐ 4 1,0 ☐ 5 1,0 ☐ 6 1,0

☒ 2 1,0

☐ 3 1,0

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

**Compare displacement**

Cross-section

Alpha 0,00°

Data LOS

Theta 43,50°

Delta 77,30°

Compute model (user ratios)

Compute model (least square ratios)

Compute Model

Display Model

Display Difference

Display Correlation

Clear graph

Save Model

Display the computed vectors.

Compute the model using user's ratios.

Export the results.

Displacement model

SLBL ( $r=1.538733$ )

SLBL ( $r=4.631133$ )

DEM

Elevation (m)

Distance (m)

Effective ratios are shown here.

If the displacement is loaded, the projection of the LOS in the cross-section is shown with the corresponding displacement value

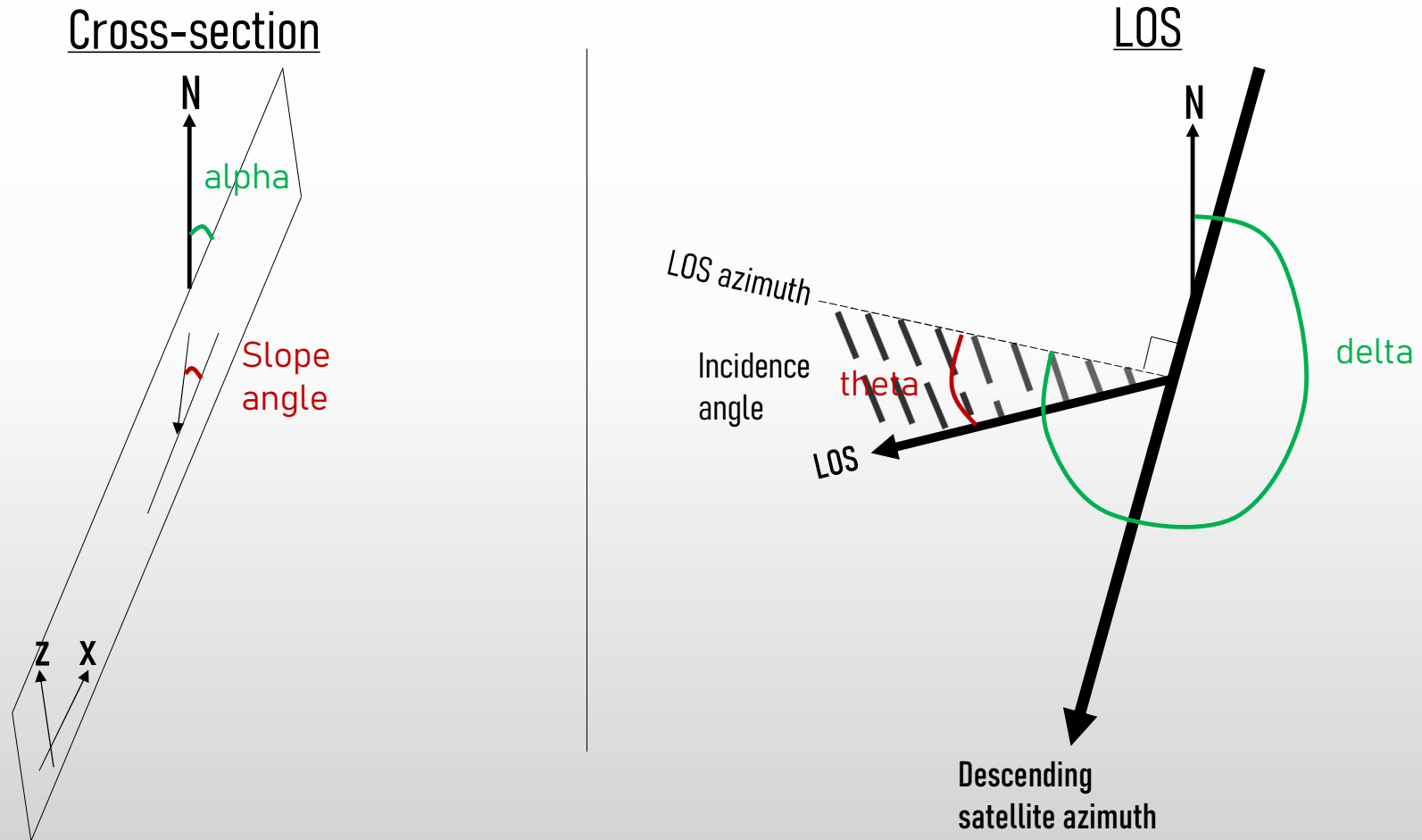
The screenshot shows the 'Displacement Model' software interface. At the top, there are tabs: 'Home', 'SLBL', 'Displacement Vectors', and 'Displacement Model' (which is active). Below the tabs, there are two main sections: 'Slide Selection and Ratio' and 'Process'. In 'Slide Selection and Ratio', there are six checkboxes with associated numbers and ratios: 1 1,0, 2 1,0, 3 1,0, 4 1,0, 5 1,0, and 6 1,0. Checkboxes 1 and 2 are checked. A red box highlights these two. A callout points to them, stating 'Select all corresponding SLBLs. The vectors must have previously been computed for all selected SLBLs.' In the 'Process' section, there are two buttons: 'Compute Model (user ratios)' and 'Compute model (least square ratios)'. A red box highlights the 'Compute Model (user ratios)' button, with a callout stating 'Compute the model using user's ratios.' To the right of these buttons, there are three more buttons: 'Display Model', 'Display Difference', and 'Display Correlation'. A red box highlights the 'Display Model' button, with a callout stating 'Display the computed vectors.' To the right of these buttons, there are two more buttons: 'Clear graph' and 'Save Model'. A red box highlights the 'Save Model' button, with a callout stating 'Export the results.' Below the buttons, there is a graph titled 'Displacement model'. The graph shows 'Elevation (m)' on the y-axis (0 to 50) and 'Distance (m)' on the x-axis (0 to 600). There are three data series: a blue dashed line for 'SLBL (r=1.538733)', an orange dashed line for 'SLBL (r=4.631133)', and a solid black line for 'DEM'. A red box highlights the legend, with a callout stating 'Effective ratios are shown here.' A red horizontal line is drawn across the graph at an elevation of approximately 25 meters. A callout points to this line, stating 'If the displacement is loaded, the projection of the LOS in the cross-section is shown with the corresponding displacement value'.

# Recommandation

- 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 'Displacement Model' tab is active, showing a 'Process' section with buttons for 'Load Displacement Data', 'Load Elongation Profile', and 'Compute Model'. A 'Slide Selection and Ratio' section on the left allows selecting SLBLs (1-6) with checkboxes and ratio input fields (all set to 1.0). A 'Compare displacement' section in the center has input fields for 'Alpha' (0,00°), 'Theta' (43,50°), and 'Delta' (77,30°), along with buttons for 'Compute model (user ratios)' and 'Compute model (RMSE least square)'. On the right, a 'Display' section includes buttons for 'Display Model', 'Display Difference', 'Display Correlation', 'Clear graph', and 'Save Model'. Red boxes and lines highlight specific features, each with an explanatory text box.

**Slide Selection and Ratio**

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

**Process**

Load Displacement Data

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.

**Compare displacement**

Cross-section

Alpha

0,00°

Data LOS

Theta

43,50°

Delta

77,30°

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

Compute model (user ratios)

Compute model (RMSE least square)

**Display**

Display Model

Display Difference

Display Correlation

Clear graph

Save Model

Display the computed vectors.

Export the results.

# Ajusting the model to field data

Home SLBL Displacement Vectors **Displacement Model**

Slide Selection and Ratio

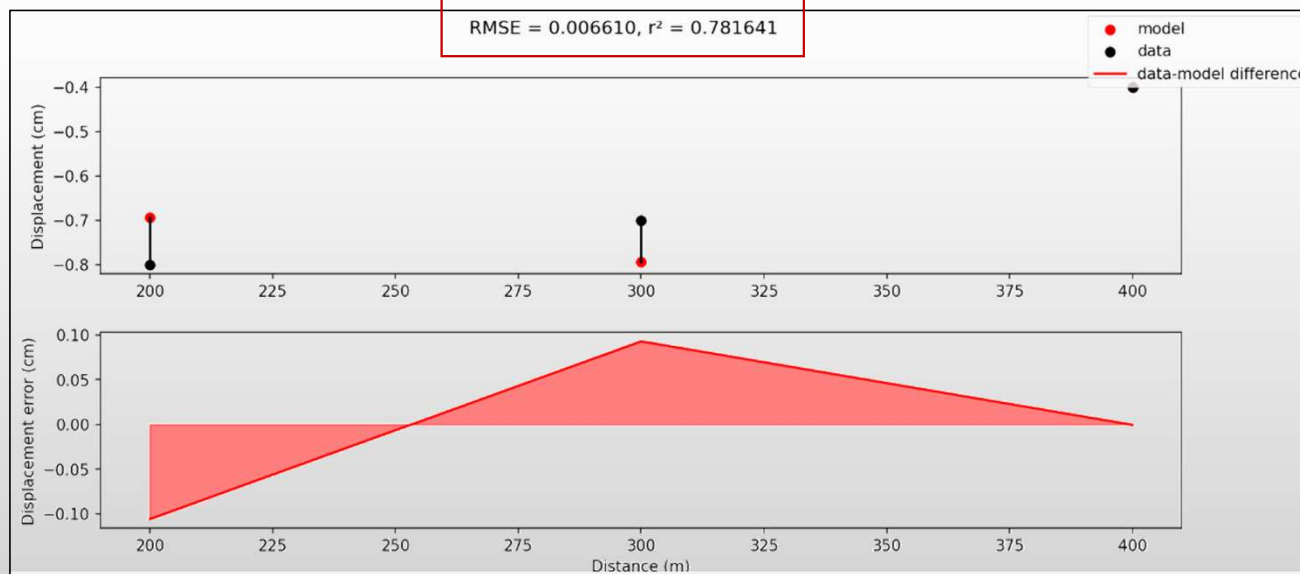
|                                       |     |                            |     |
|---------------------------------------|-----|----------------------------|-----|
| <input checked="" type="checkbox"/> 1 | 1,0 | <input type="checkbox"/> 4 | 1,0 |
| <input checked="" type="checkbox"/> 2 | 1,0 | <input type="checkbox"/> 5 | 1,0 |
| <input type="checkbox"/> 3            | 1,0 | <input type="checkbox"/> 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

[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

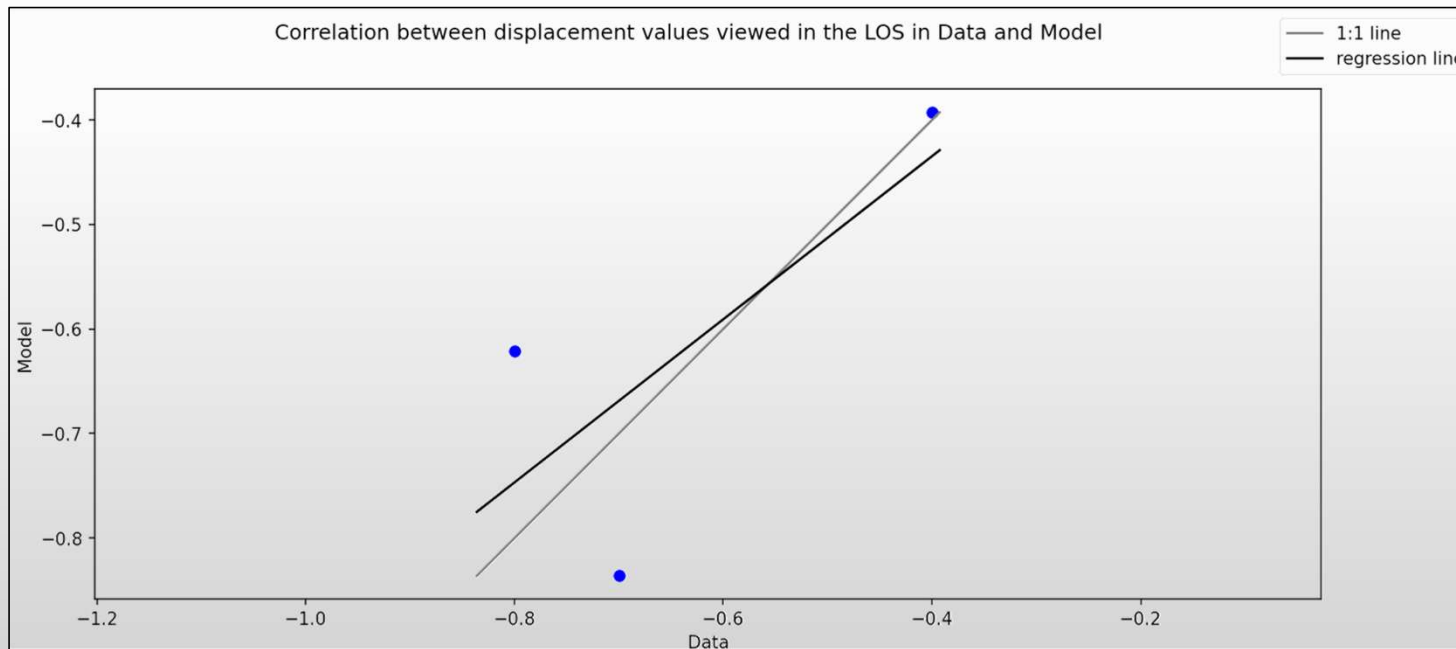
Display Model

Display Difference

Display Correlation

Clear graph

Save Model



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

Process

Load Displacement Data Compute deformable model Compute Model Display Model Display Difference Display Correlation Clear graph Save Model

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:

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

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  |

Can be manually modified

# Project file Example

```
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
```