“Unravel”
An ImageJ Macro to aid conversion of interface roughness to planar roughness

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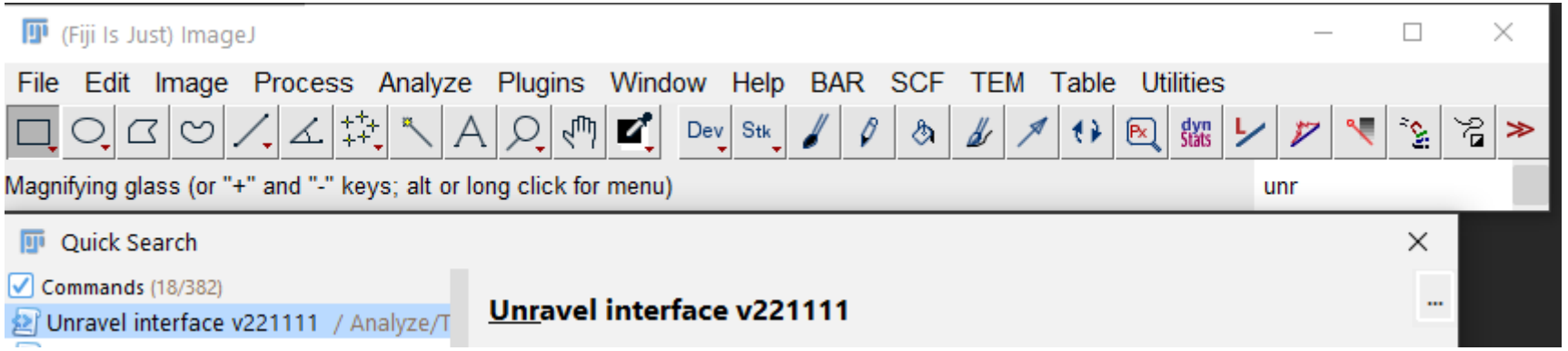
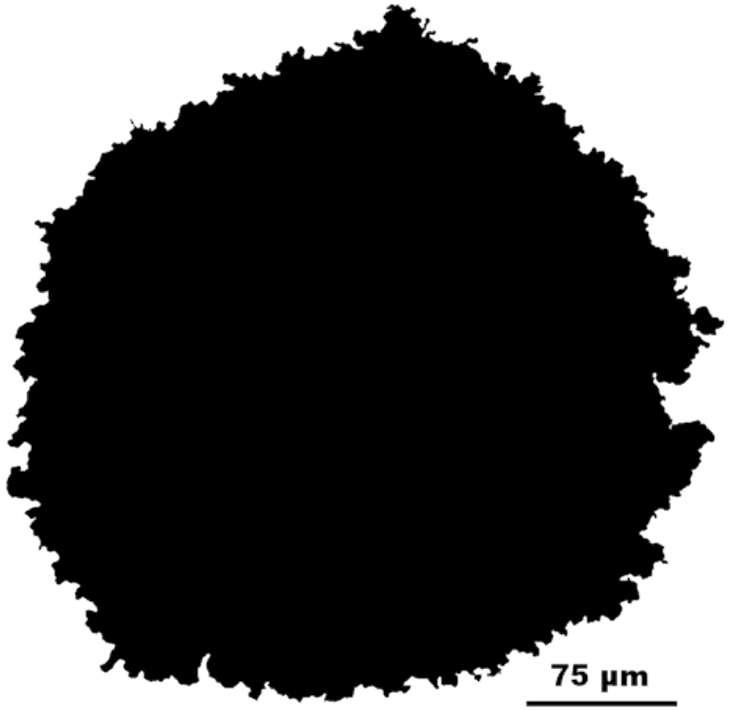
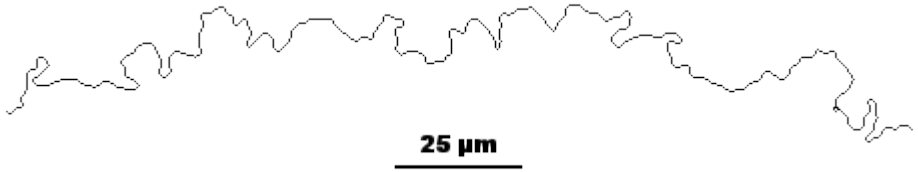


Issue: How do you obtain roughness from a cross-section of an interface?



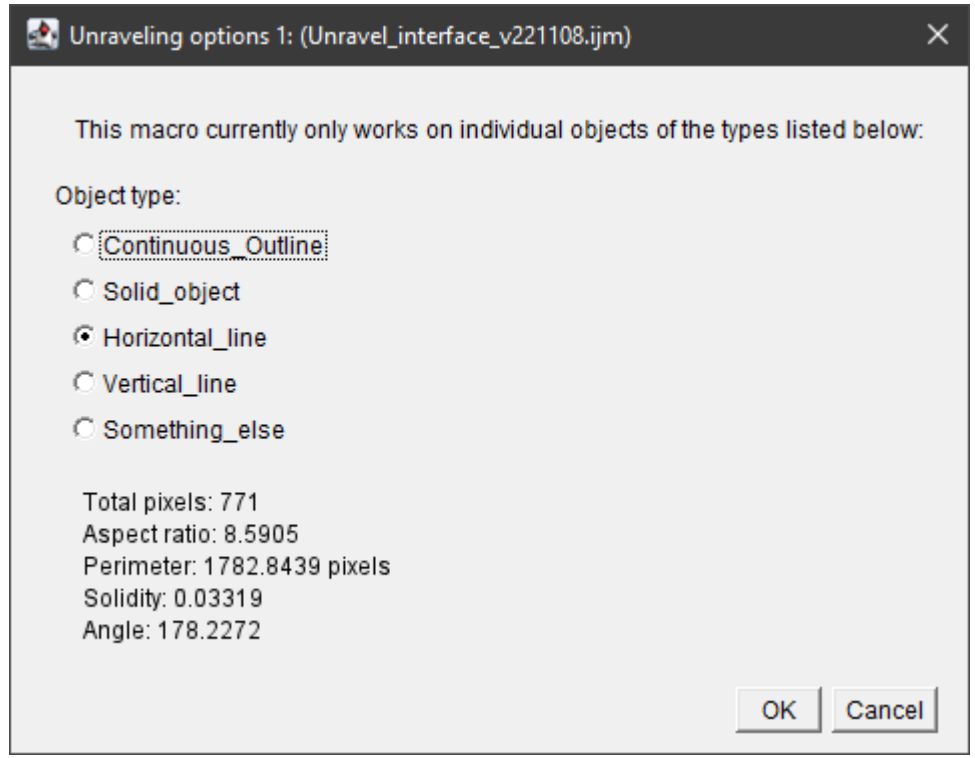
- Image above is a filament cross-section with a rough interface
  - How can the surface roughness be measured?



- Image above is an interface
  - Can the interfacial roughness be measured?

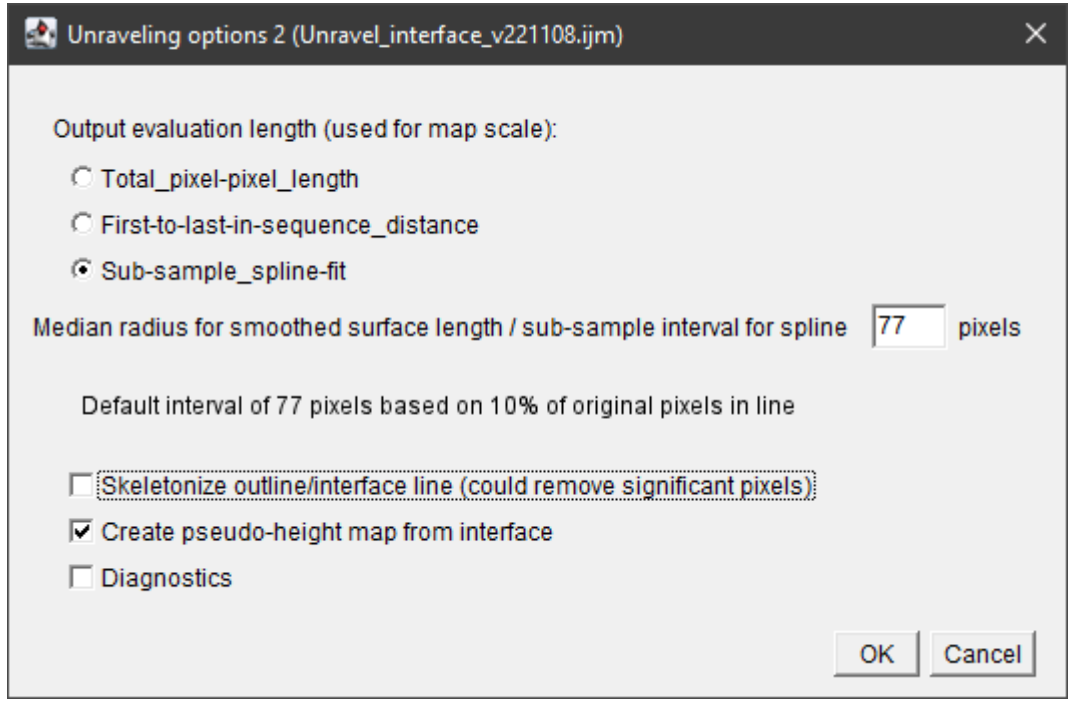
Menu 1: Choose object type

- Current version works on continuous outlines or solid objects
- The macro guesses the object type from measured parameters
  - In this case a horizontal line



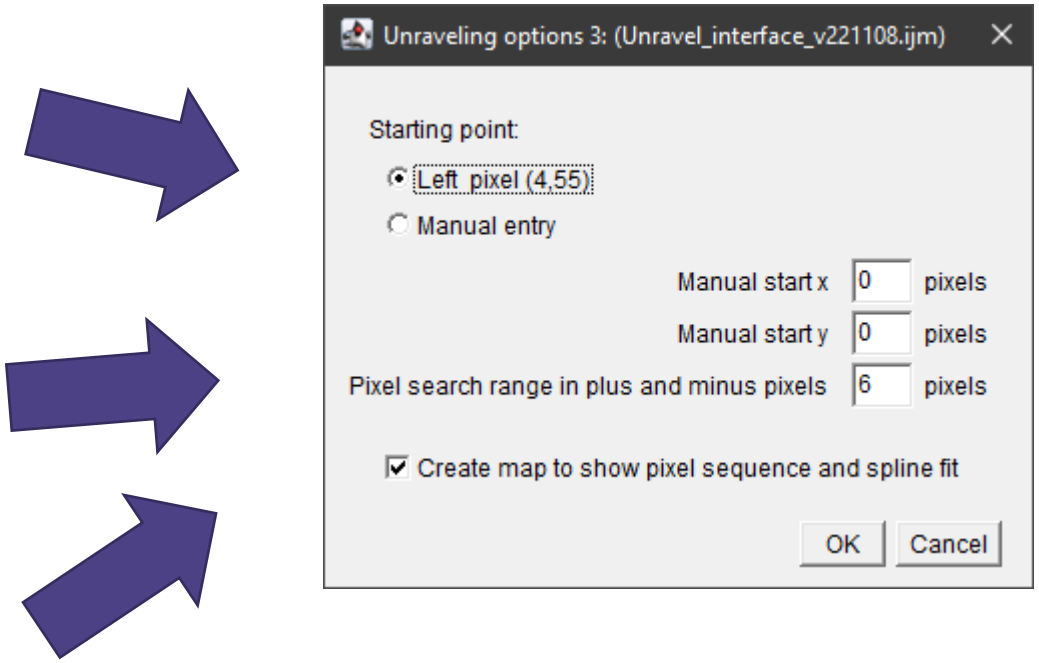
Menu 2 (line): Sample length and basic options

- 3 options for providing measuring the total evaluation length are provided:
  - This evaluation length will be embedded in the exported map
- The outline can be skeletonized to minimum pixel width but at the risk of losing significant pixels. Fewer skeletonized pixels will be missed from the unraveled sequence, so it is the default setting.
- A pseudo height map can be exported that can be used in 3rd party topographic software like Gwyddion



Menu 3 (line): Unravelling options

- The starting point of the unravelling can be selected
- The search range for the next pixel can be adjusted
- A map can be created to show the pixel sequence order and the spline fit



“Heights” from horizontal or vertical lines

- For horizontal or vertical lines, “heights” are simply obtained from the *y* coordinates or *x* coordinates respectively
  - For horizontal lines the *y* coordinate is subtracted from the maximum *y* so that increasing “height” is upwards

Results

File Edit Font Results

	Seq_coord_x	Seq_coord_y	Seq_dist(px)	Seq_dist(µm)	Height(px)	Height_norm(px)	Height_norm(µm)	Height_norm^2(µm^2)	Fourier_Ht
1	4	65	0.000000000	0.000000000	33	13	5.038761701	25.389119484	16.099252701
2	4	64	1.000000000	0.387597054	34	14	5.426358755	29.445369342	11.786406517
3	3	64	2.000000000	0.775194108	34	14	5.426358755	29.445369342	1.603672147
4	5	64	4.000000000	1.550388216	34	14	5.426358755	29.445369342	1.291527987
5	6	64	5.000000000	1.937985270	34	14	5.426358755	29.445369342	0.290924072

Log

File Edit Font

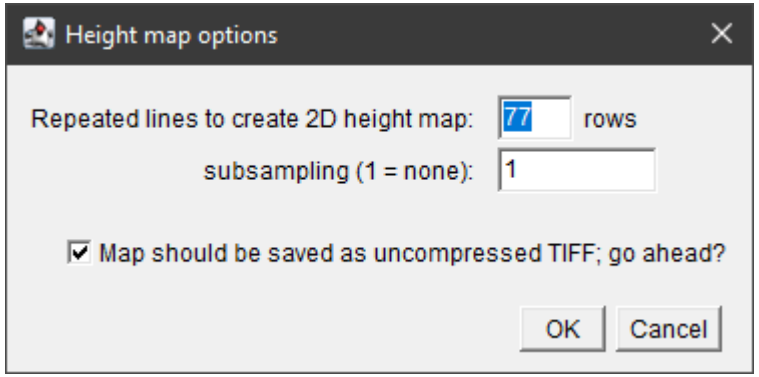
```
For 158B_67a_acBleach_(red)-skel_lzw.tif:
Sub-sample spline-fit = 182.6171 µm

_____
158B_67a_acBleach_(red)-skel height statistics:
min = 0 µm
max = 26.3566 µm
range = 26.3566 µm
mean = 16.4094 µm
std Dev = 6.3754 µm
Ra(full length) = 16.4094 µm
Rq(full length) = 17.6029 µm

_____
```

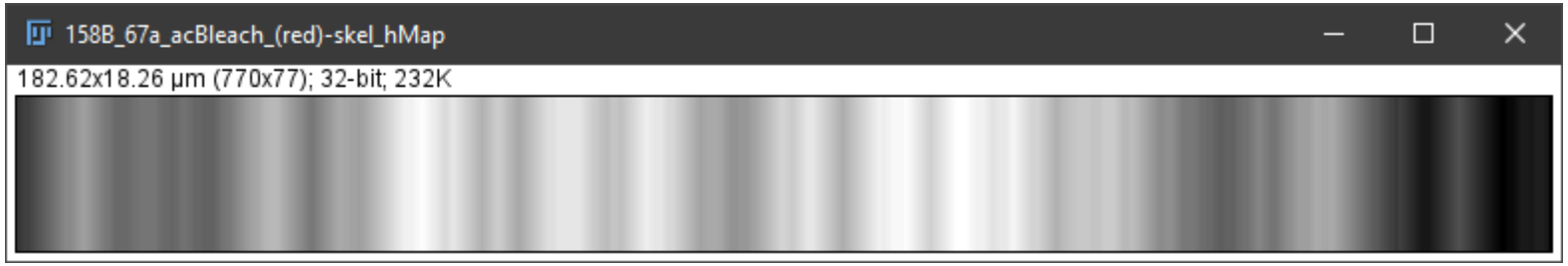
Note:
The Fourier sequence is calculated for the entire sequence (column is for convenience).

Ra and Rq are not adjusted for true sampling lengths

Pseudo height map from horizontal or vertical lines

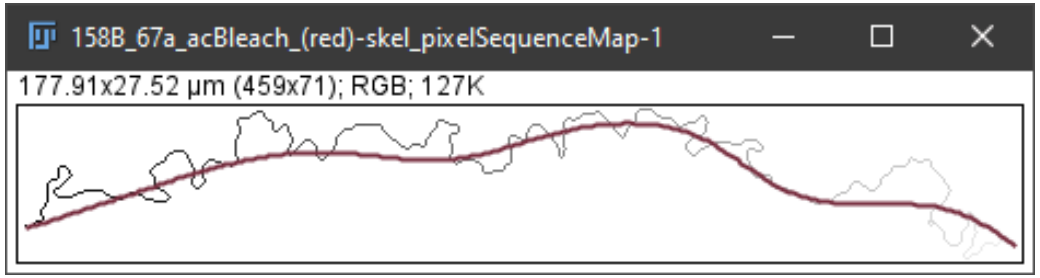
- The 2D line data can be stretched vertically to create a 32-bit pseudo height map that can be imported into 3rd party topological analysis software
  - Unit-scaled “Heights” are directly stored in the 32-bit data
  - The measured evaluation length is embedded in the horizontal scale





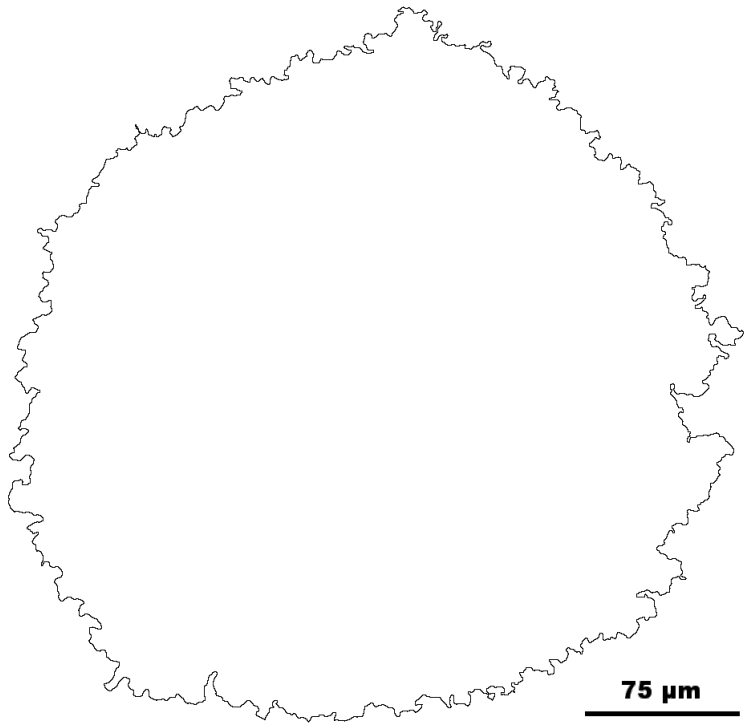
Additional output

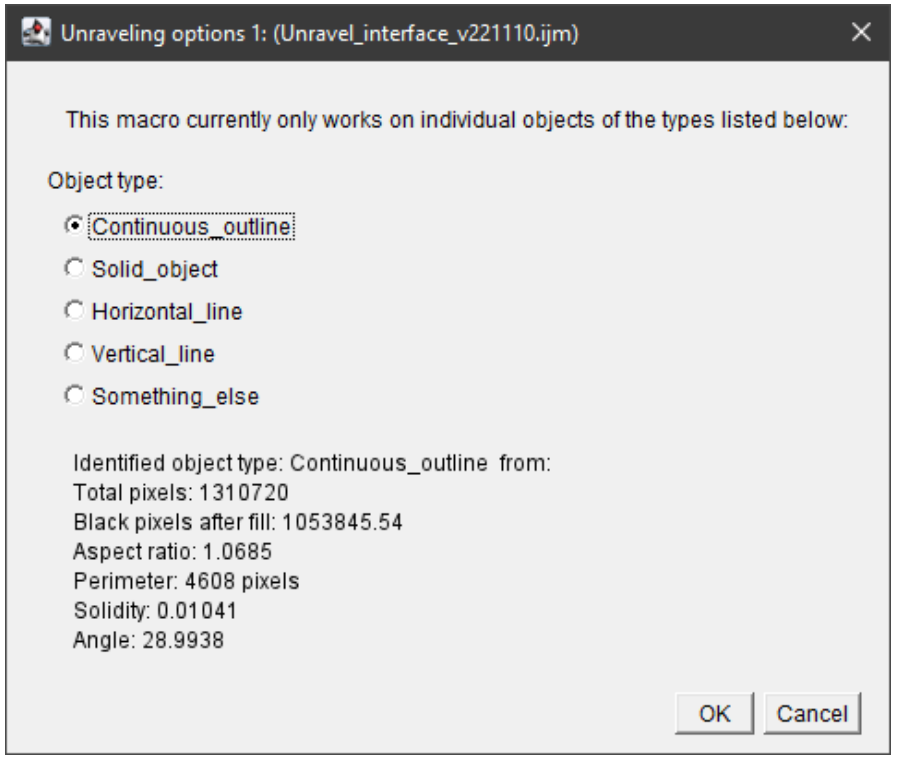
- If the sequence map option is chosen the spline fit is drawn over the map as an overlay.



Menu 1: Choose object type – outline continuous

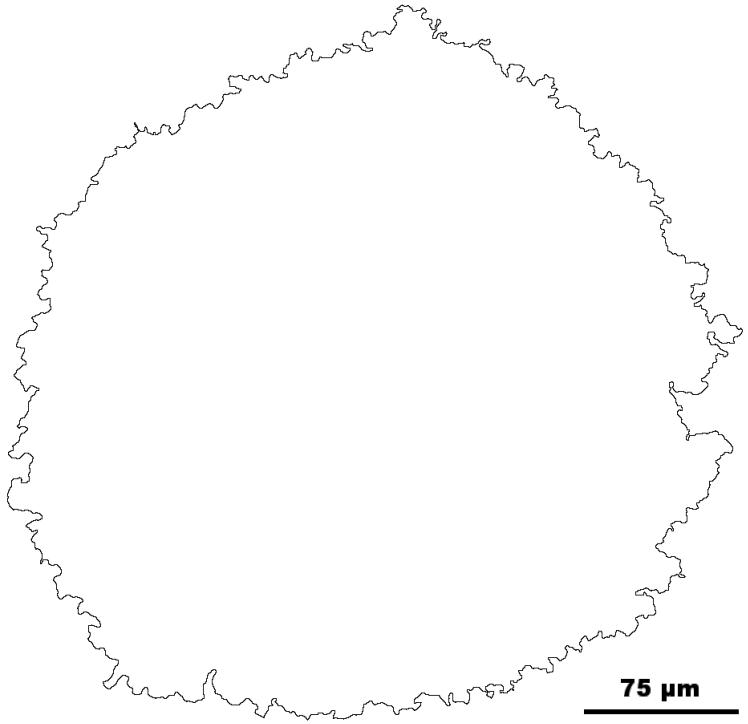
- This example: A continuous outline around an object

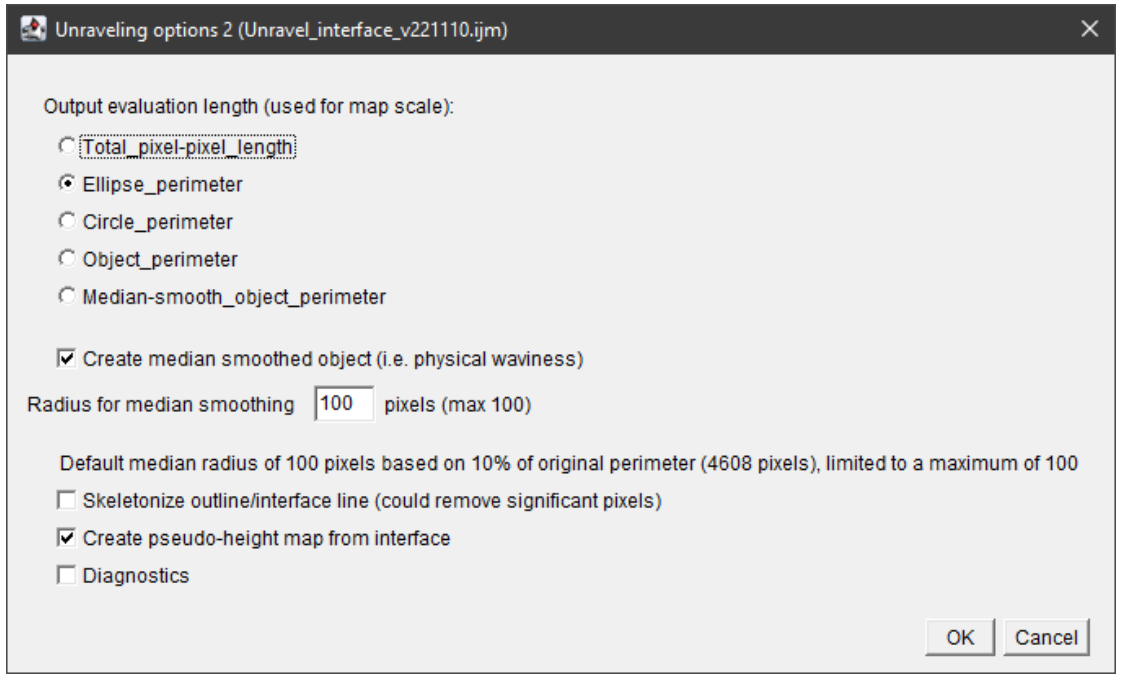




Menu 2 (continuous): Sample length and basic options

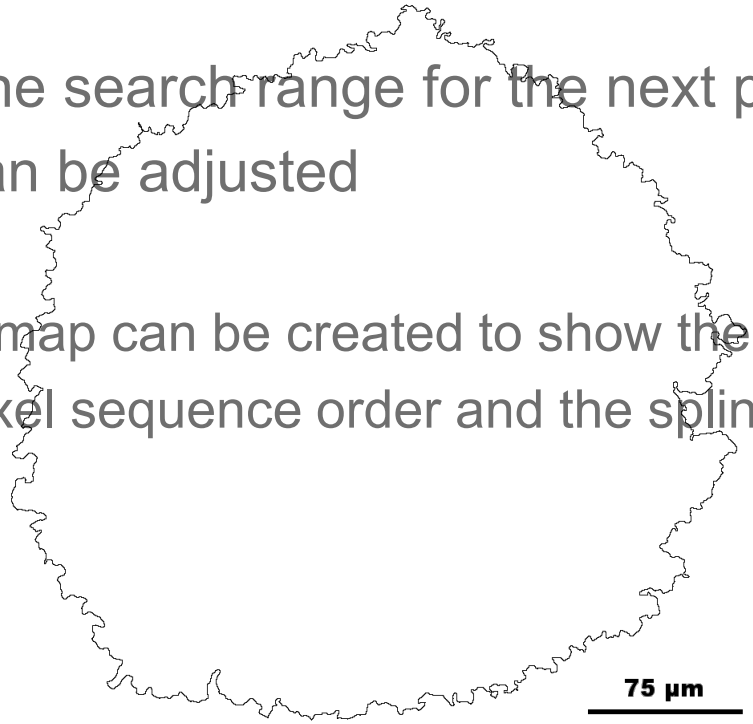
- 5 options for providing measuring the total evaluation length are provided:
  - This evaluation length will be embedded in the exported map

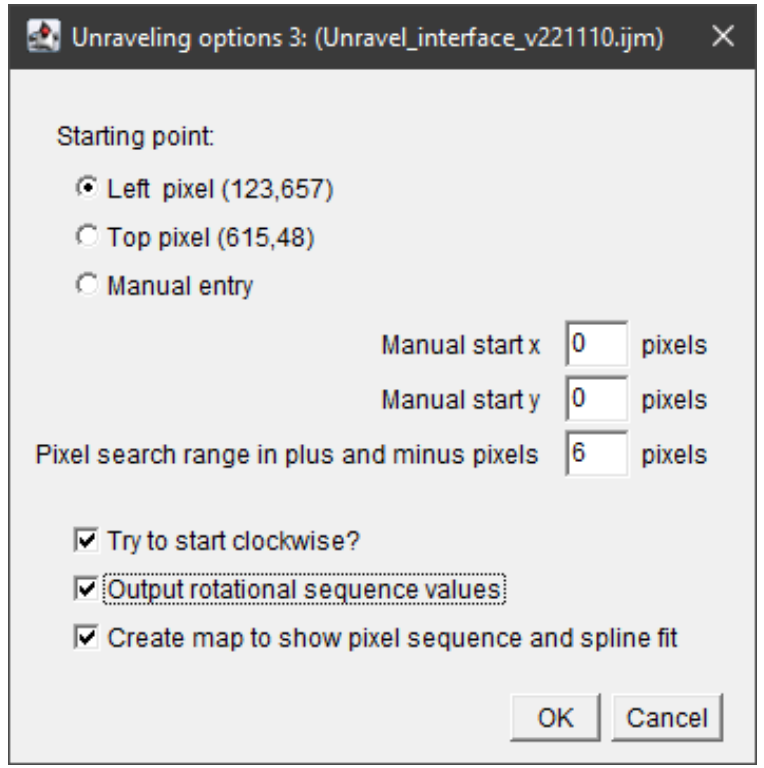




Menu 3 (continuous): Unravelling options

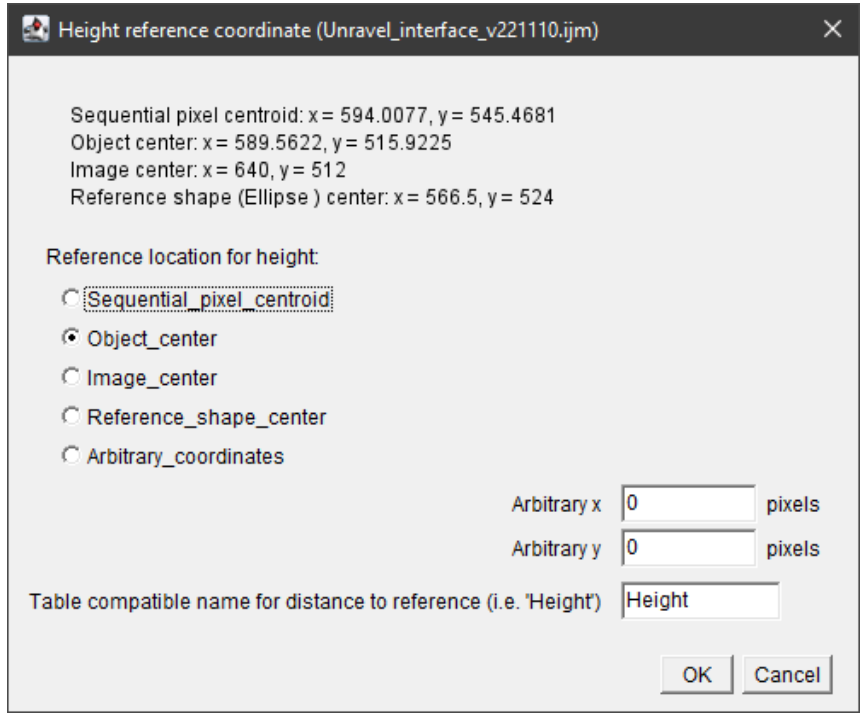
- The starting point of the unravelling can be selected
- The search range for the next pixel can be adjusted
- A map can be created to show the pixel sequence order and the spline fit





“Height” reference menu (continuous

- For continuous objects, distances (“heights”) are calculated to a single reference point (default is the measured object center)



- The minimum distance value is subtracted to output the normalized values

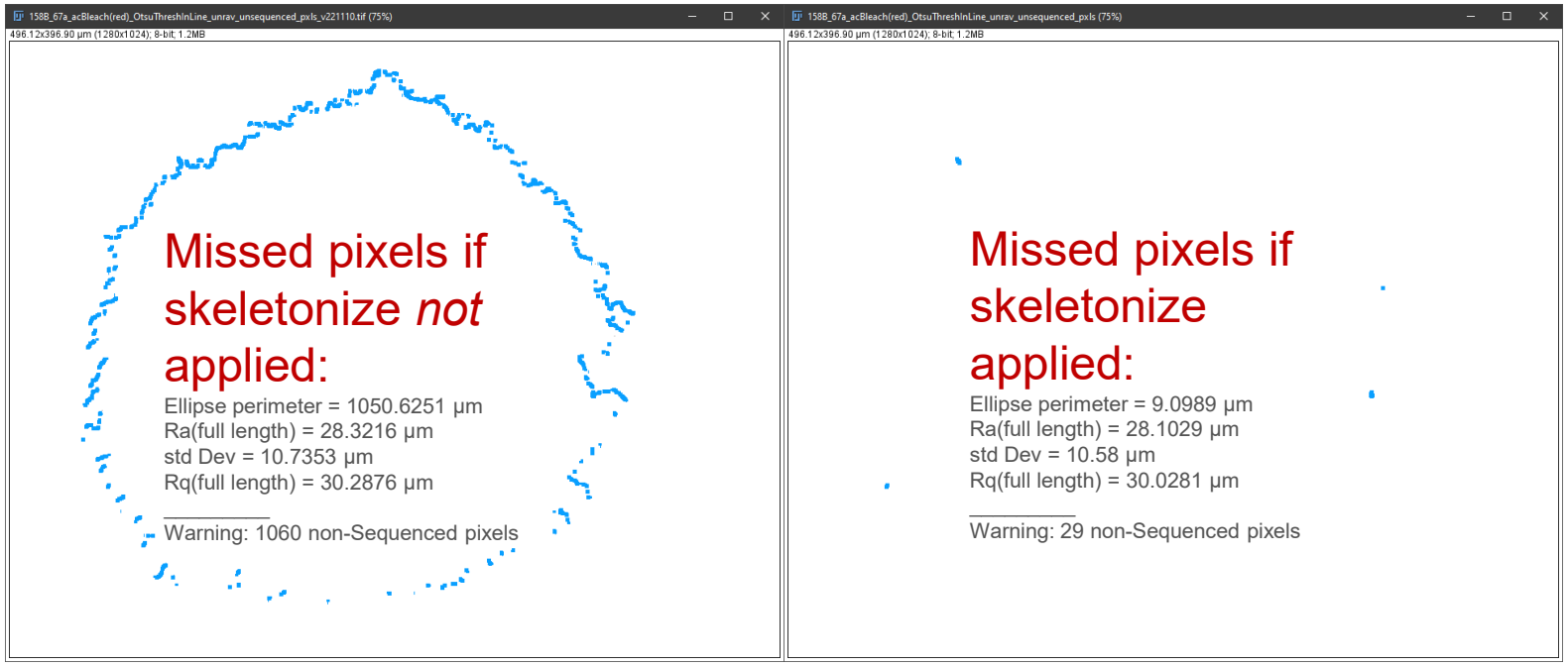
Results

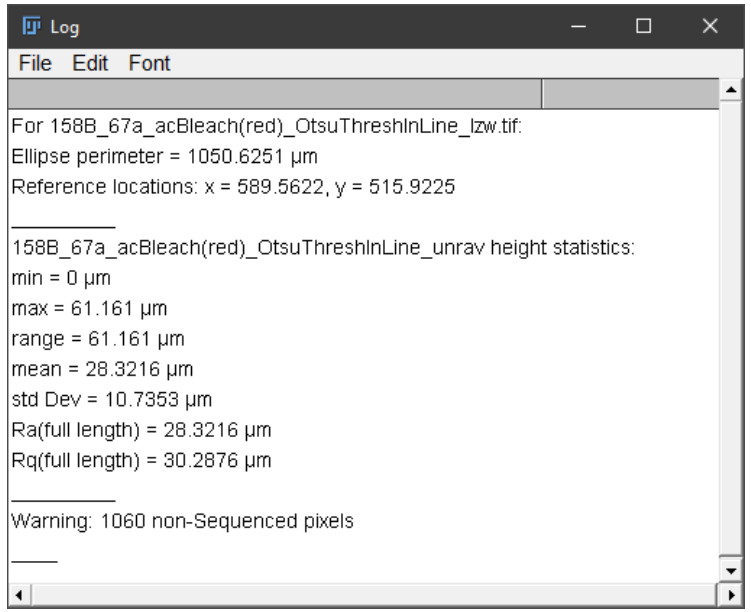
File Edit Font Results

	Seq_coord_x	Seq_coord_y	Seq_dist(px)	Seq_dist(μm)	Height(px)	Height_norm(px)	Height_norm(μm)	Height_norm^2(μm^2)	Angle (radians)	Angle Offset (radians)	Angle Offset (degrees)	Fourier_amps
1	123	657	0.000000000	0.000000000	487.424964538	129.981082914	50.380303430	2538.174973736	0.185072240	0.000000000	0.000000000	28.321575165
2	123	656	8.544003745	3.311631905	487.136470741	129.692589116	50.268484043	2526.920487976	0.185347950	0.000275710	0.015797016	11.625046730
3	123	655	9.544003745	3.699229102	486.849860014	129.405978390	50.157394529	2515.764225915	0.185624473	0.000552233	0.031640627	13.900227547
4	123	654	10.544003745	4.086826299	486.565135687	129.121254063	50.047036178	2504.705830165	0.185901813	0.000829573	0.047531037	3.644485712
5	124	653	11.958217308	4.634971512	485.322935813	127.879054188	49.565562988	2456.745034297	0.187658482	0.002586242	0.148180744	6.416252613

Additional output

- A basic summary is sent to the log window
- Note: The Fourier amplitudes are calculated for the entire sequence (column is for convenience).
- Ra and Rq are not adjusted for true sampling lengths

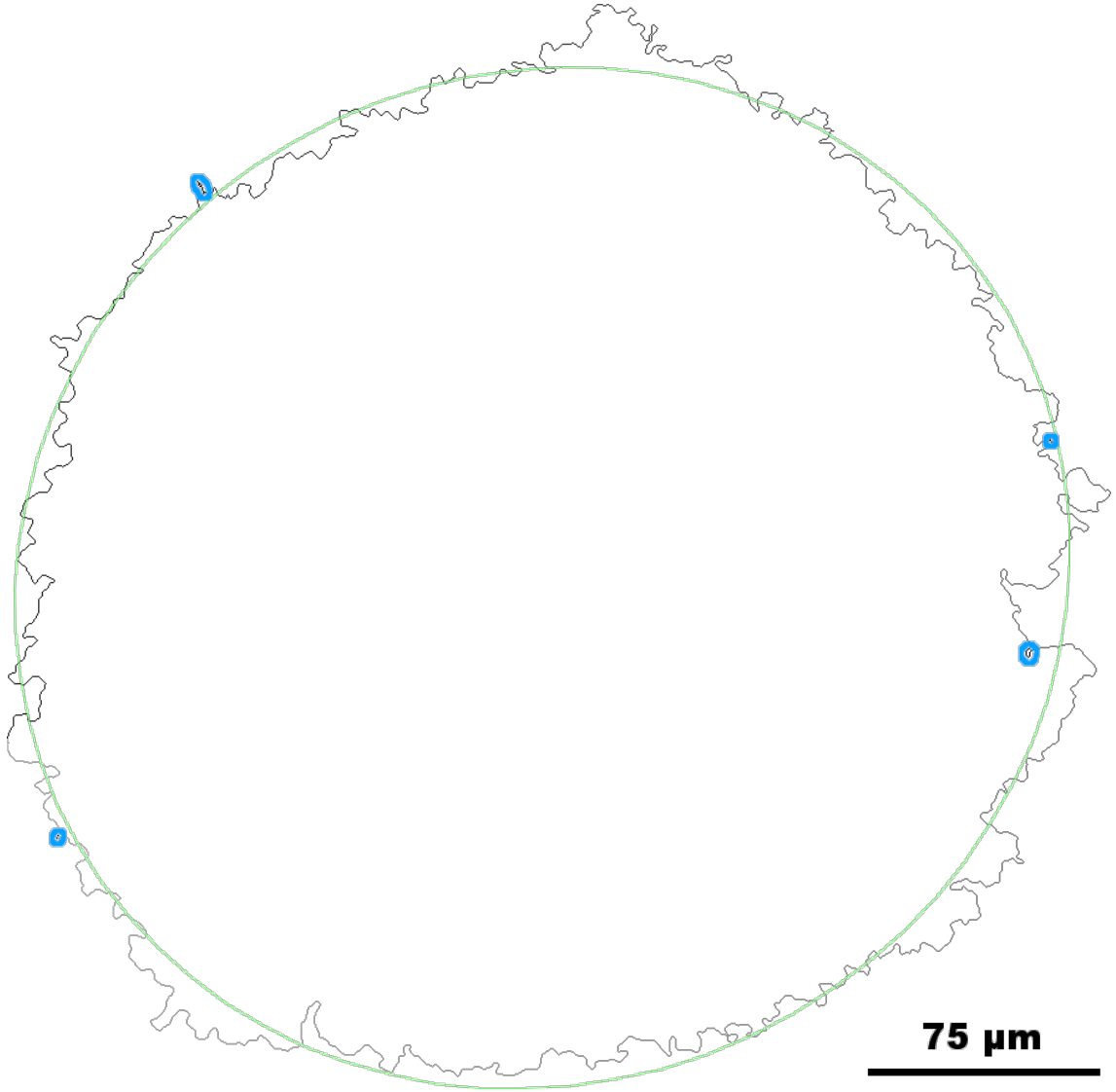




Note: If not all pixels are captured in the sequence the missing count as reported and an image (left) is created with the missing pixels highlighted.
The pixel capture is not uniform because the search matrix looks for the first-nearest pixel with the search sequence the same for all searches
Some improvement might be useful here
The higher the image resolution for the interface, the less likelihood of error from this issue

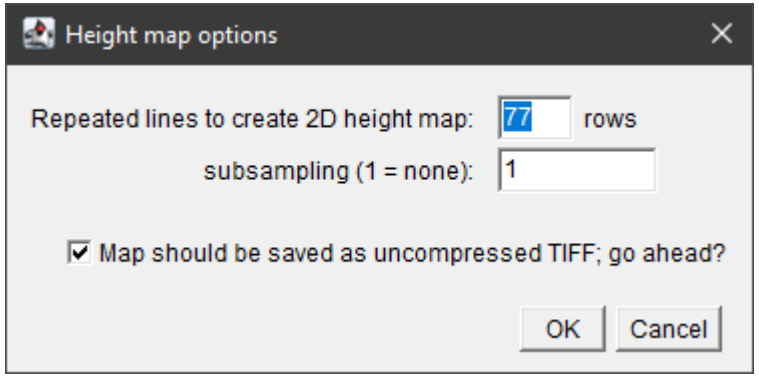
Summary Image

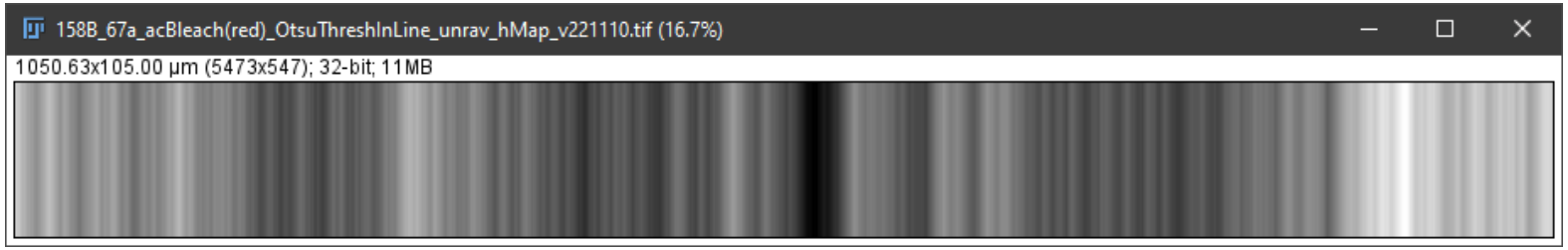
- A summary image is created showing:
  - Direction of sequence (dark-to-light)
  - Fit used for evaluation length (green)
  - Any missed pixels from the sequence (surrounded by blue highlight)



Pseudo height map from horizontal or vertical lines

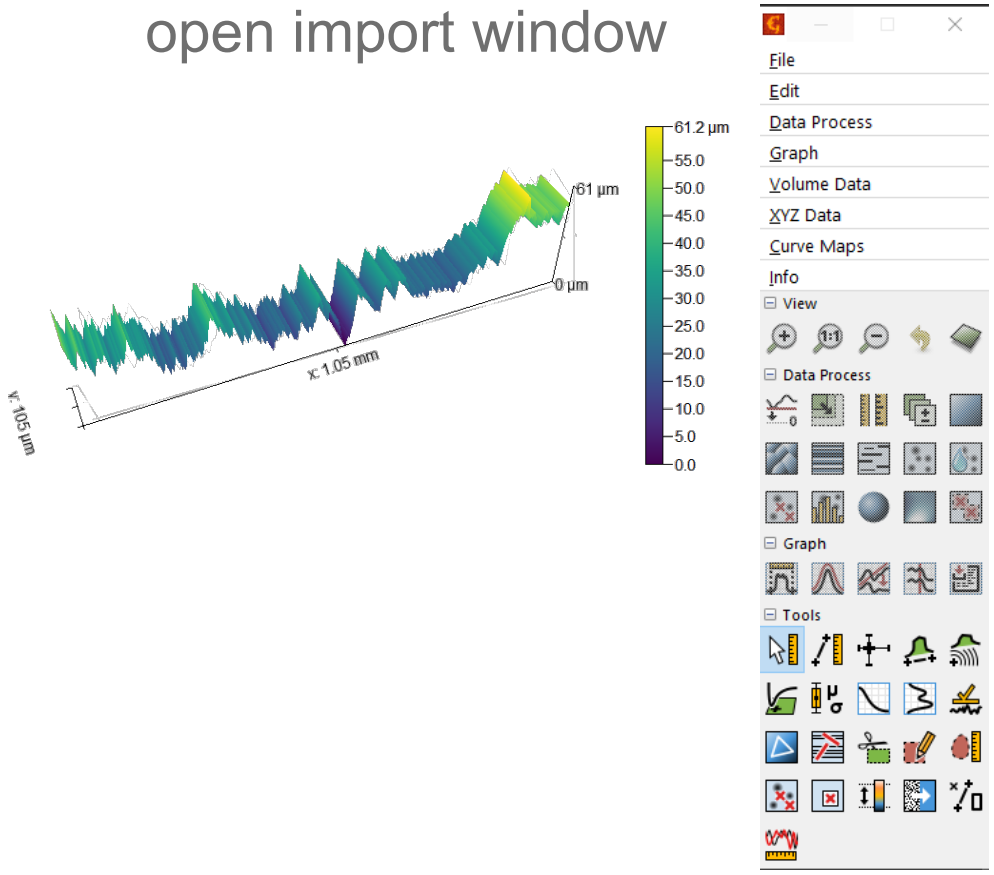
- The 2D line data can be stretched vertically to create a 32-bit pseudo height map that can be imported into 3rd party topological analysis software.
  - Unit-scaled “Heights” are directly stored in the 32-bit data
  - The measured sample length is embedded in the horizontal scale

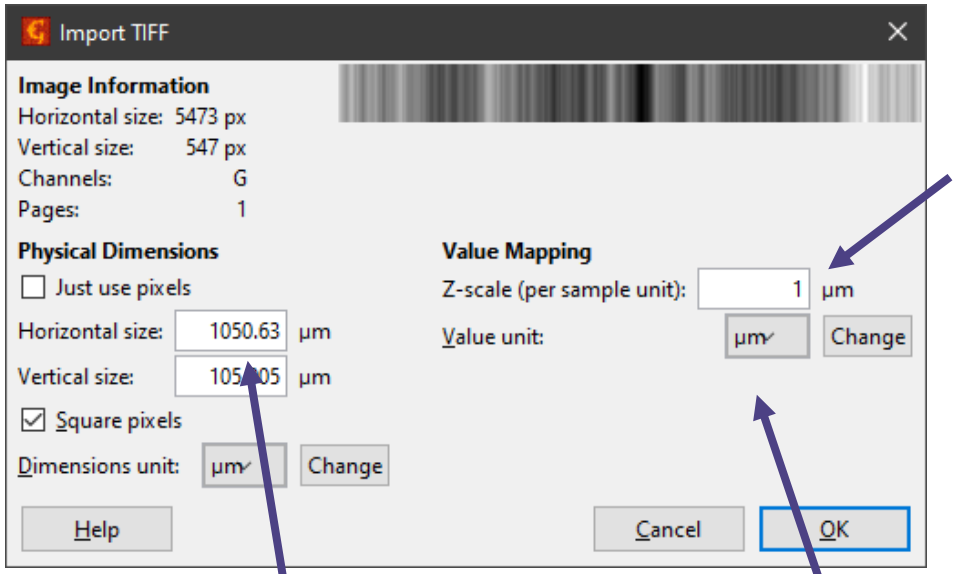




Gwyddion Import (http://gwyddion.net/)

- Drop TIFF format hMap file onto Gwyddion toolbar to open import window



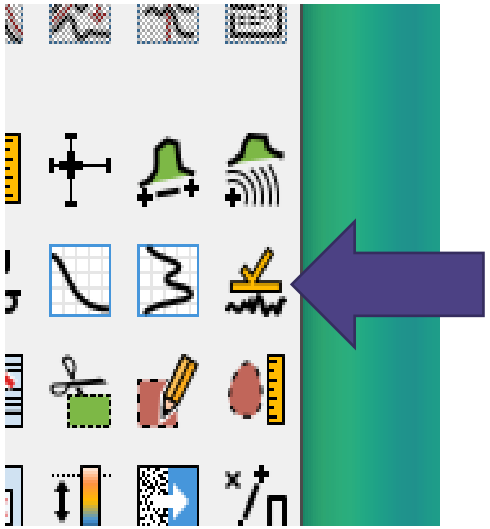


Leave as "1" to directly import 32-bit height data from the TIFF file

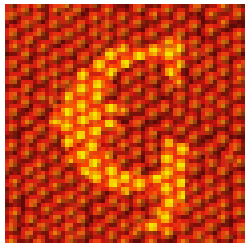
The last width is remembered so it is important to correct this to the current value. Should this value be the circle/ellipse perimeter or the smoothed surface?

These are the units used for the 32-bit TIFF file

Import into Gwyddion to correct curvature and measure roughness parameters



Roughness values can be calculated by clicking on this icon on the Gwyddion toolbar



- After clicking on icon draw a horizontal line across the map (use shift key to enforce horizontal)