Demo: APS Estimation & Multi-temporal analysis with Sarproz

Sarproz processing tutorial series

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APS Estimation & Multi-temporal Analysis

In this tutorial, a demo is shown for estimating the atmospheric phase screen (APS) and doing InSAR time series analysis.

Downloading Sample Data

- ~~ftp://johndoe:psinsar12138@128.46.174.159/data/LA_small.tar.gz~~ SEE BELOW
  - File size: 532MB

THE LINK ABOVE IS NO LONGER WORKING

PLEASE USE THE FOLLOWING ONE

https://my.pcloud.com/publink/show?code=XZjDnU7ZBjVOXMsDFc542fUWO0vBdLaq1TaV

Part 1:
Preparation

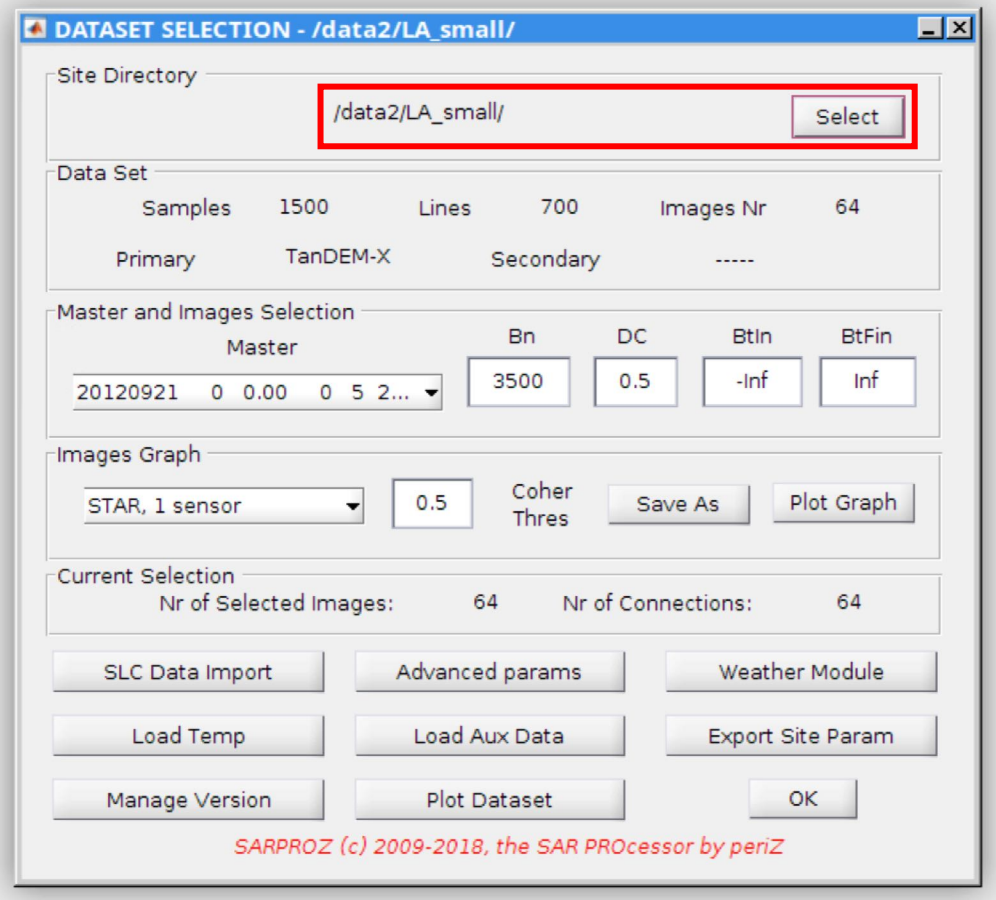
Step 0: start Sarproz

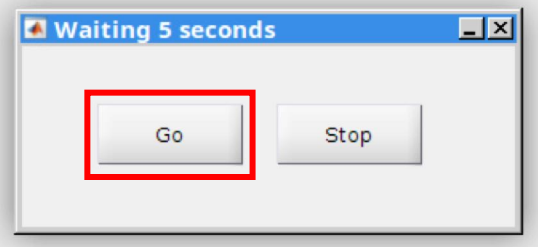
This is the main interface of Sarproz. We import our data by clicking “select dataset”, and then all the process are done in “site processing” module. You can also click “dataset description” to learn descriptions about your site.

Step 1-1: unpack and load data

Unpack the `LA_small.tar.gz` to your local folder with any extraction tool. You should have a "`LA_small`" folder after extraction.

Click "select dataset" in the main interface to open the module. Click "select" in "site directory" frame and select the "`LA_small`" folder. When the data is loaded, you should be able to see some basic information, such as samples, lines, number of images, sensors, etc.

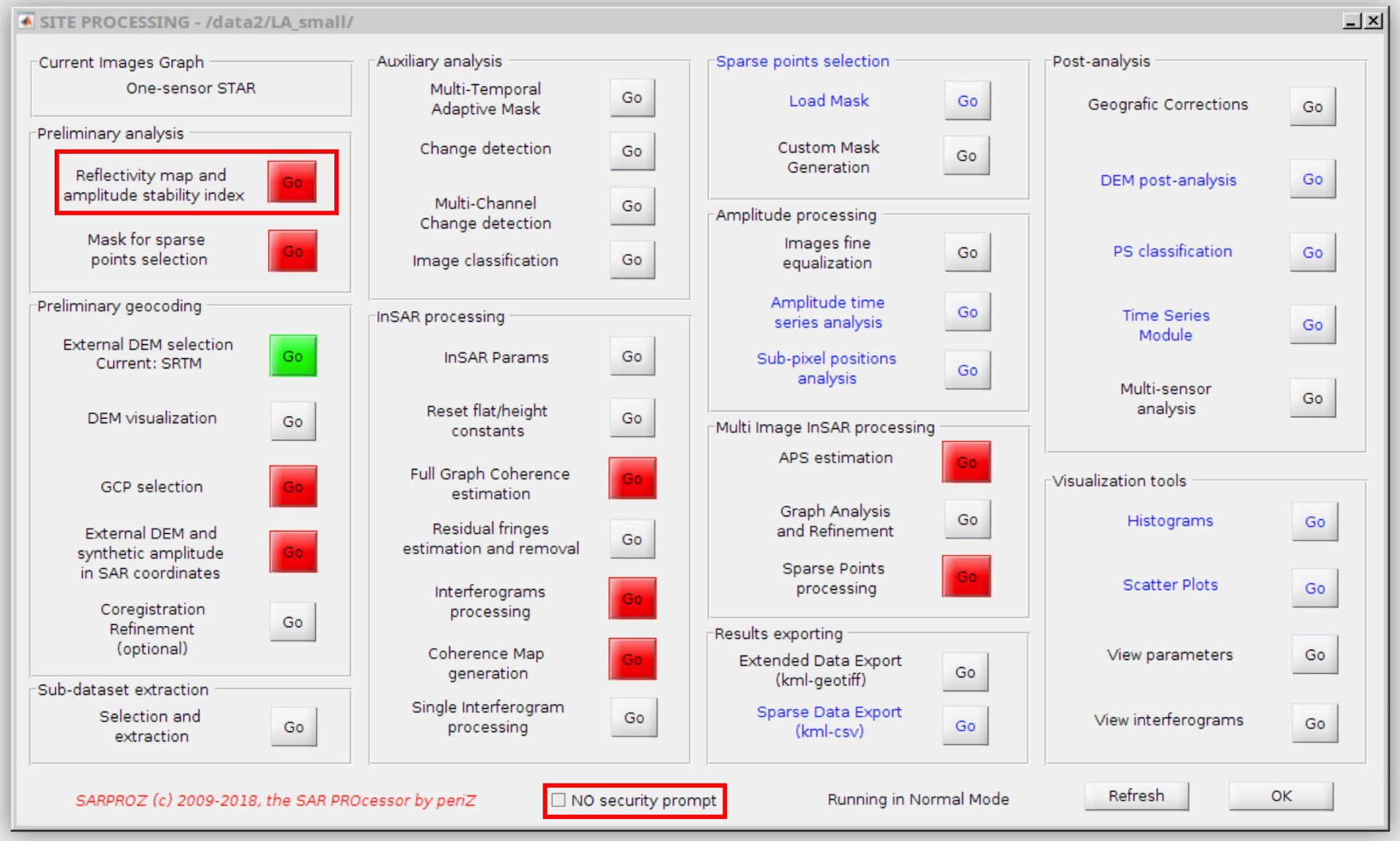


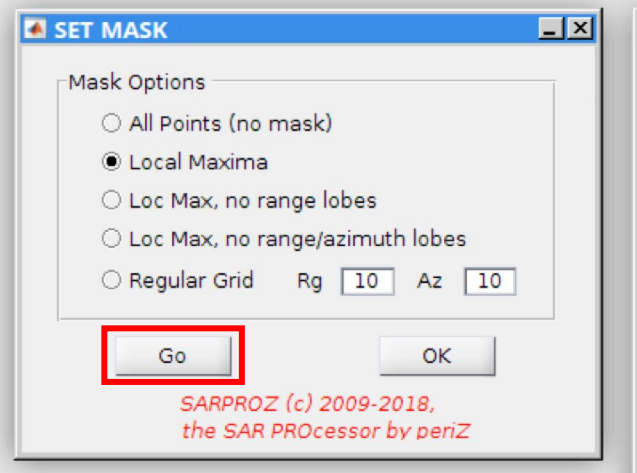


Step 1-2: reflectivity map

Open the "site processing" module. Click "Reflectivity map and amplitude stability index". A prompt window "waiting 5 seconds…" will pop up for confirmation. Click "go" to confirm. When finished, the red button will turn green.

If you want to skip the prompt window, check the "No security prompt".





Step 1-3: mask

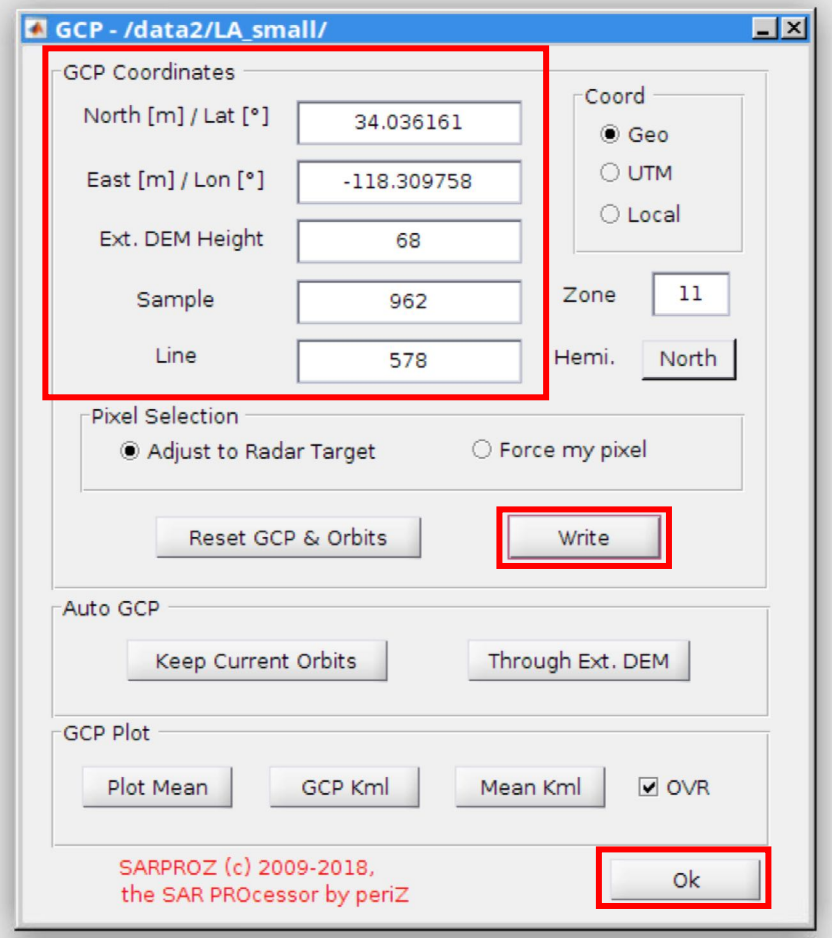
Click “mask for sparse points selection”. In the “set mask” window, click “go” with the default option. When finished, click “ok” to close the window.

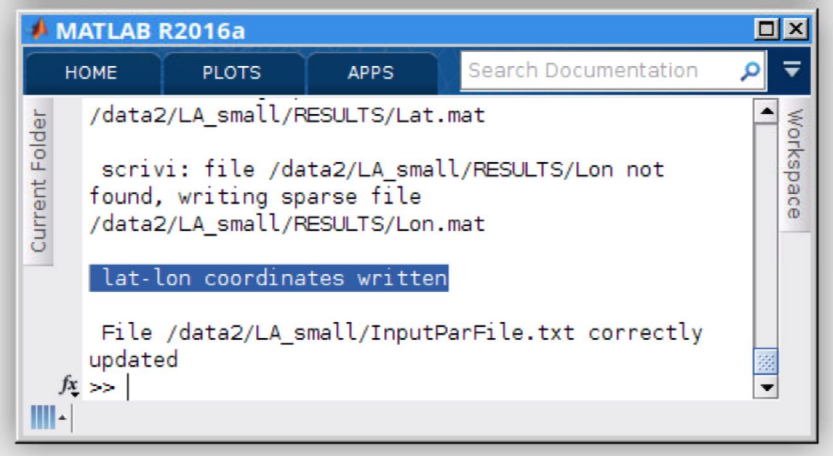
Check here and here to see more details about these processing steps.

Step 1-4: ground control point

Click and open "GCP selection" module. Put down the latitude/longitude and sample/line coordinate as shown in this slide. Click "write" to set the ground control point (GCP). When finished, you should see the message, "`lat-lon coordinates written`" in the command window. Then click "ok" to close the module.

For a more detailed description about how to select a GCP, please refer to this tutorial.





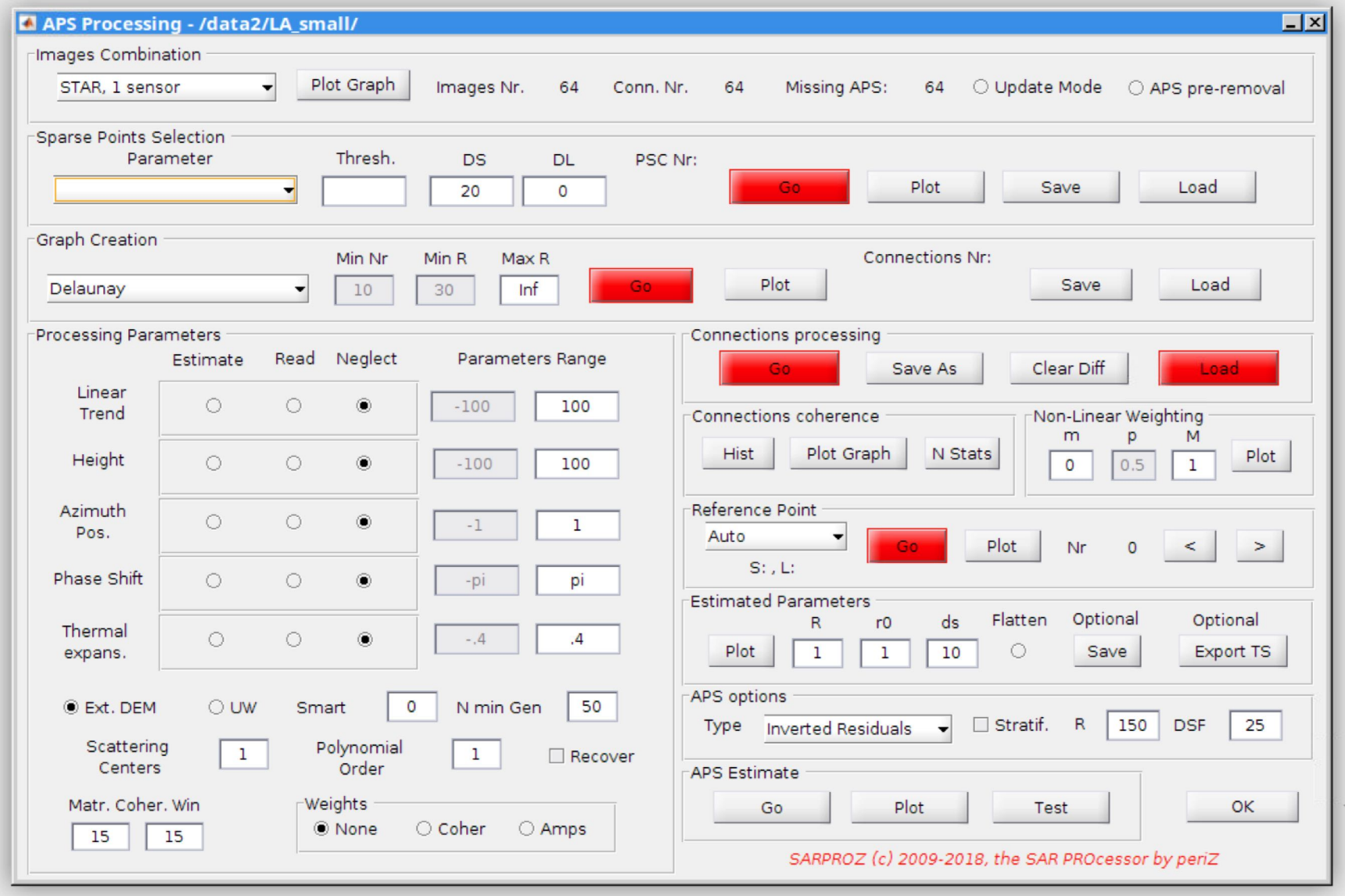
Step 1-5: External DEM

Click “external DEM and synthetic amplitude in SAR coordinates”. When finished the button will turn green. We are now finished with pre processing step and can start the APS estimation.

Part 2:
APS Estimation

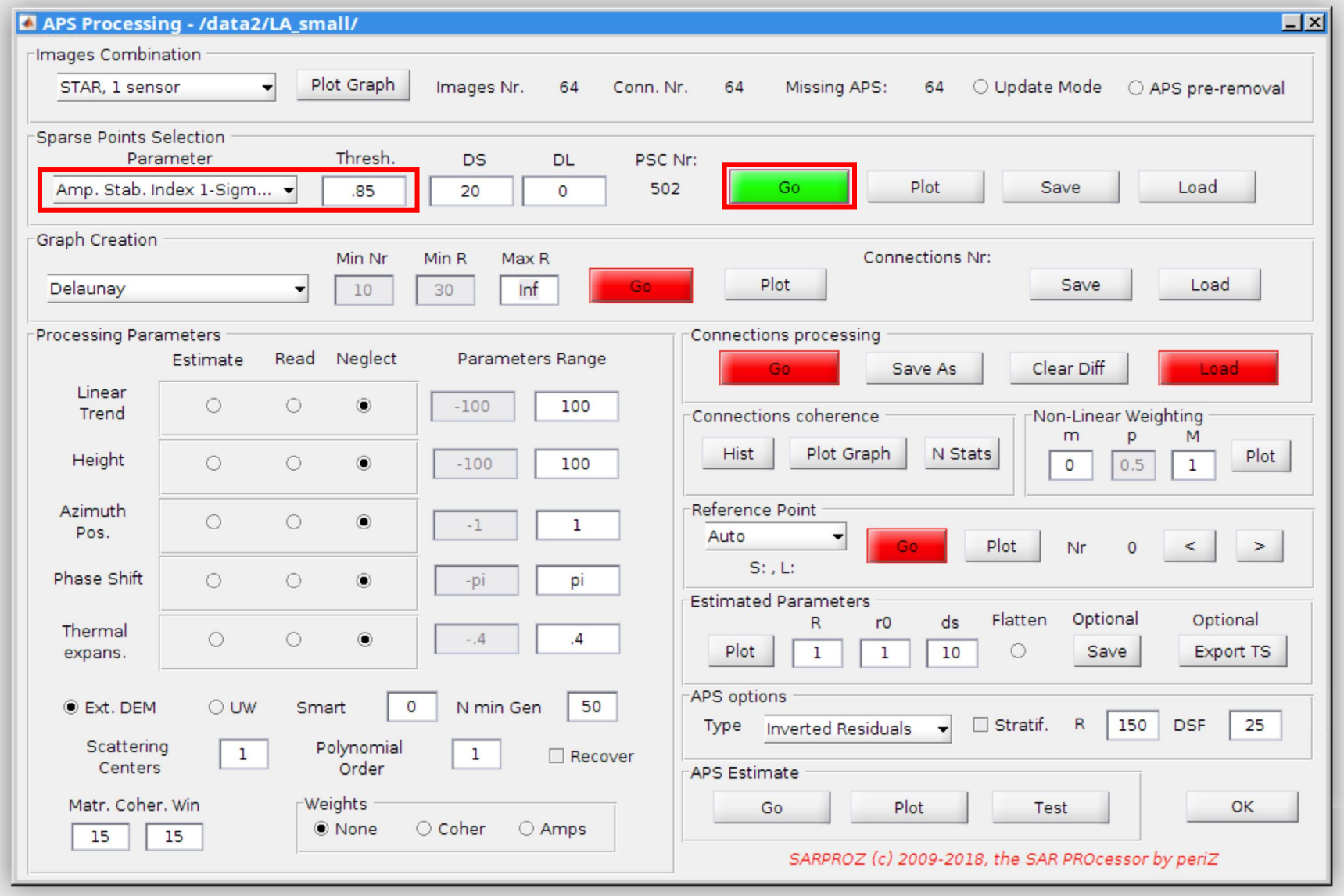
Step 2-1: open APS module

Click “APS estimation” from “site processing” panel.



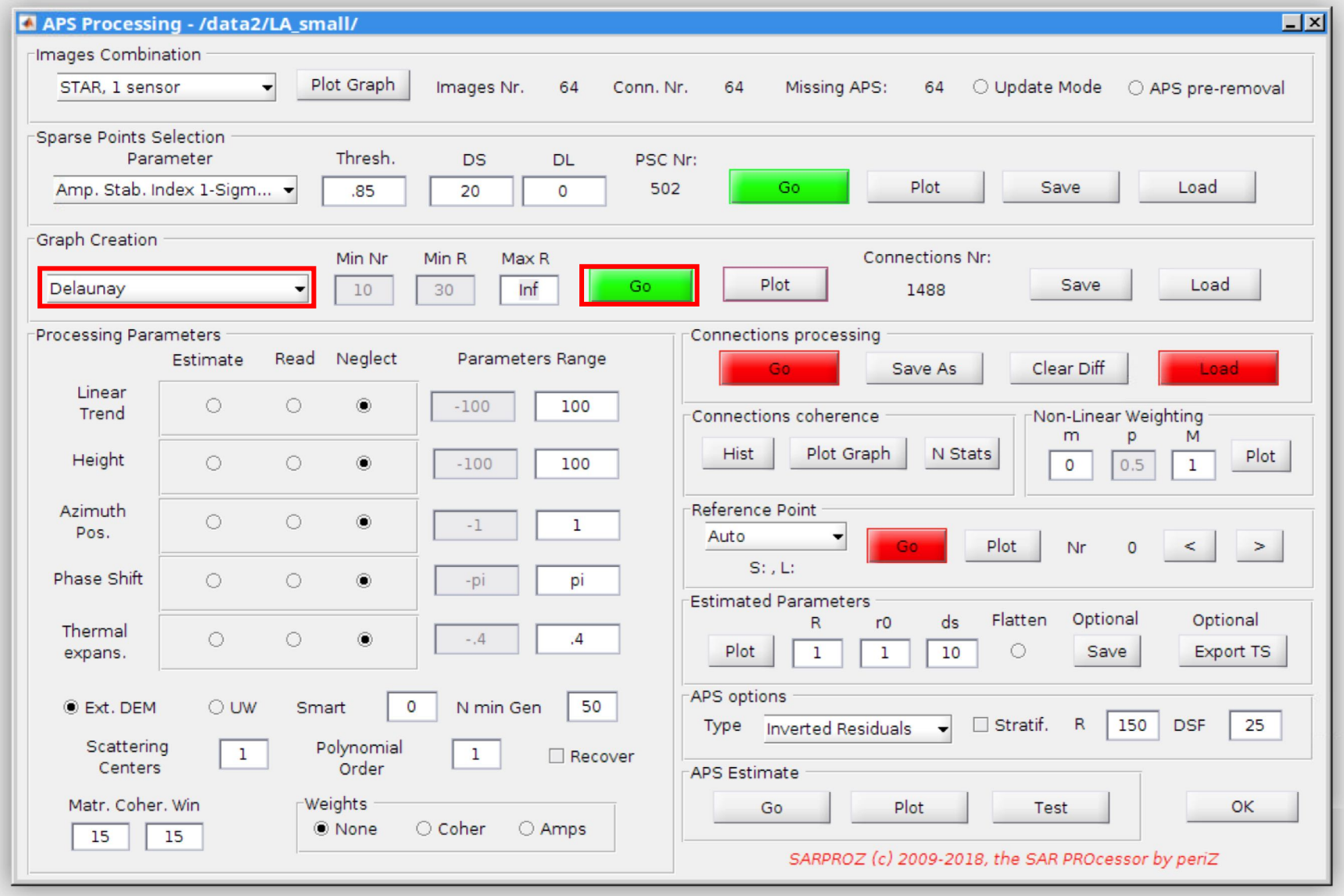
Step 2-2: select points

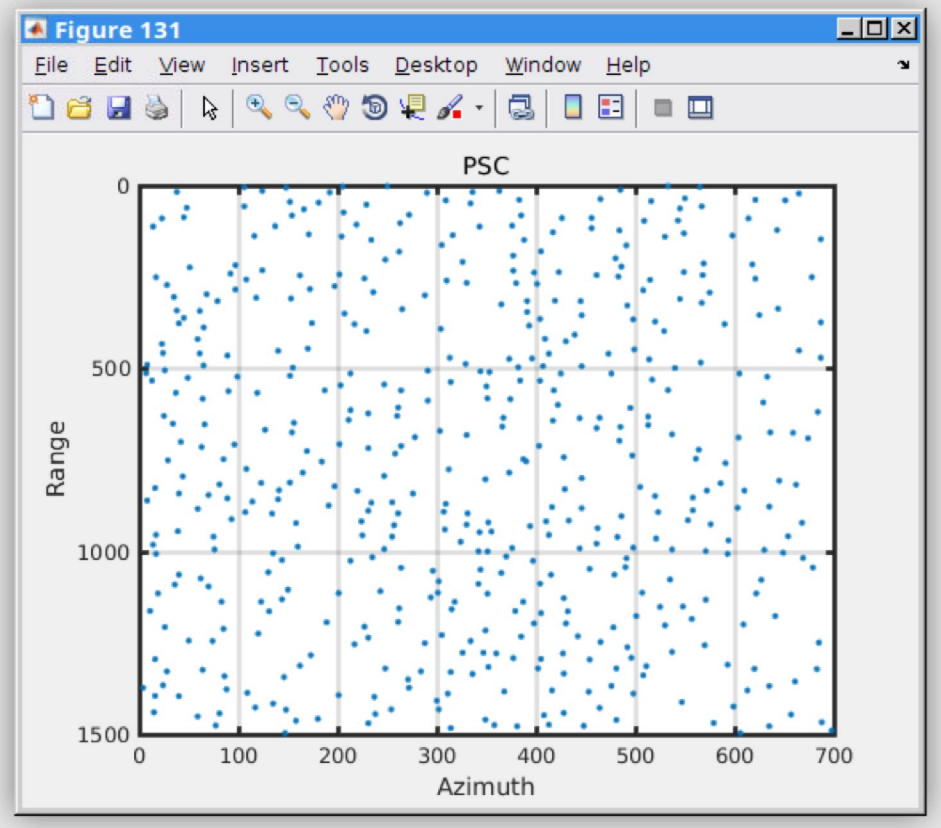
Sparse point selection. Choose "amplitude stability index (Amp. Stab. Index 1-sigma/mu)" from the "parameter" dropdown menu. Put down "0.85" as the selection threshold. Keep the default down-sample (DS) and down-line (DL) value. DL is zero means it is using the same DS value of 20. Click "go" to select points. You can also plot, save and later load your selected points.



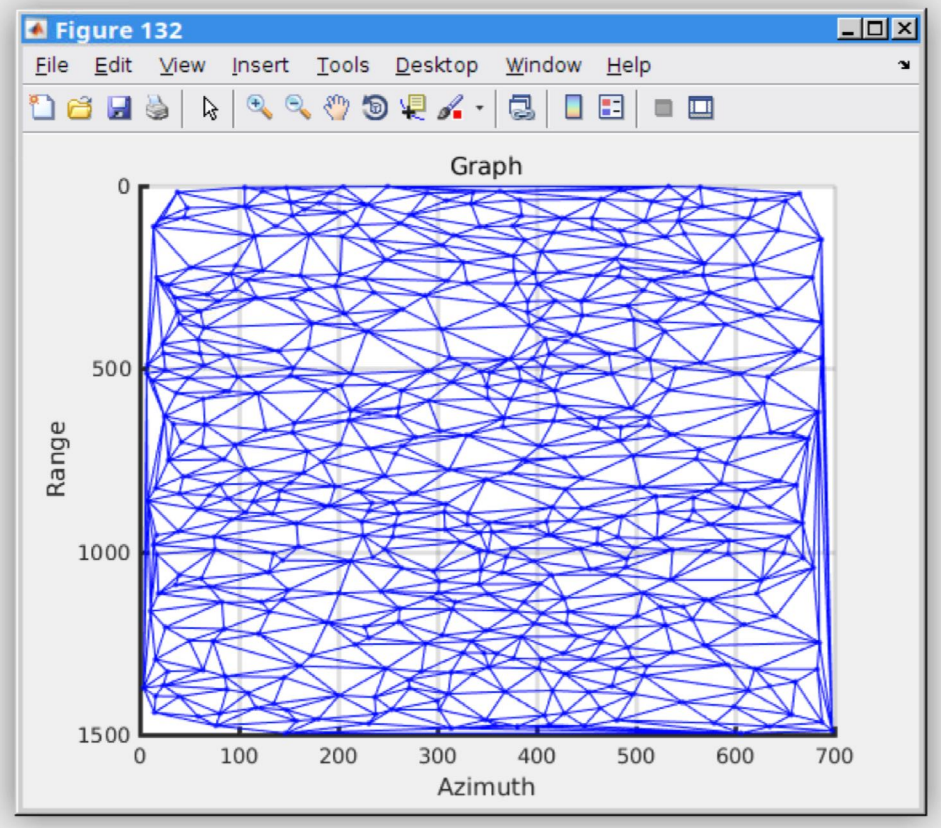
Step 2-3: create graph

Create connection graph. Use the default Delaunay graph. Click “go” to generate the graph. You can also plot, save and later load your graph.





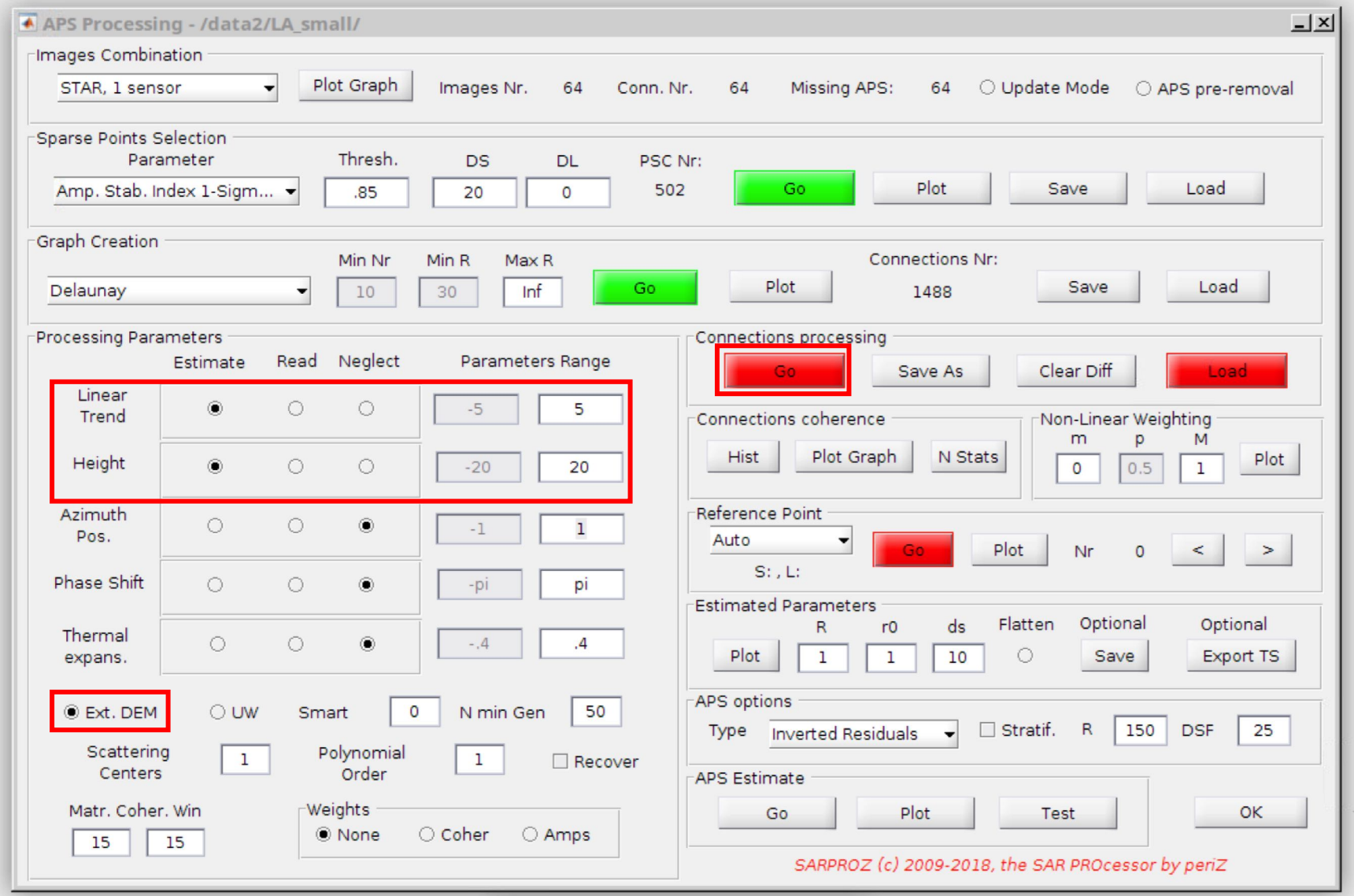
The plot of sparse point selection



The plot of Delaunay graph connection

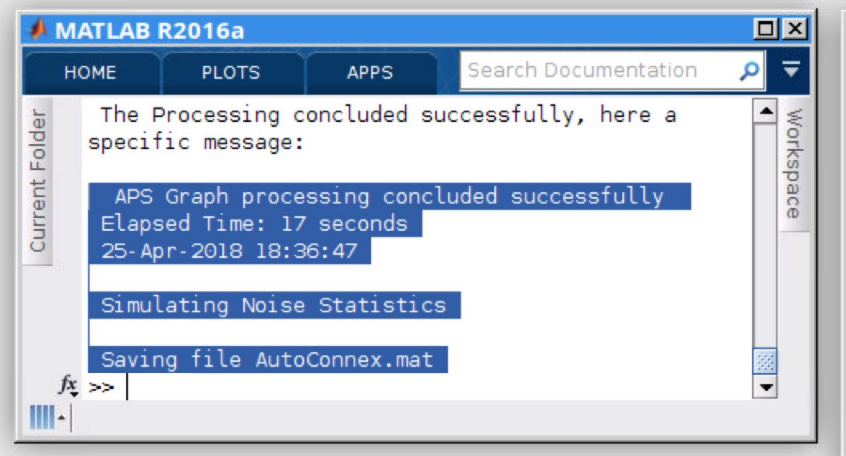
Step 2-4: estimate parameters

Put down ranges value for estimated parameters. Here we estimate linear trend and height and neglect other parameters. Put down "5" (millimeters/year) for linear trend and "20" (meters) for height. Make sure the external DEM is selected. Keep other options as in their default settings. Click "go" in "connections processing" to estimate the parameters in your connected graph.



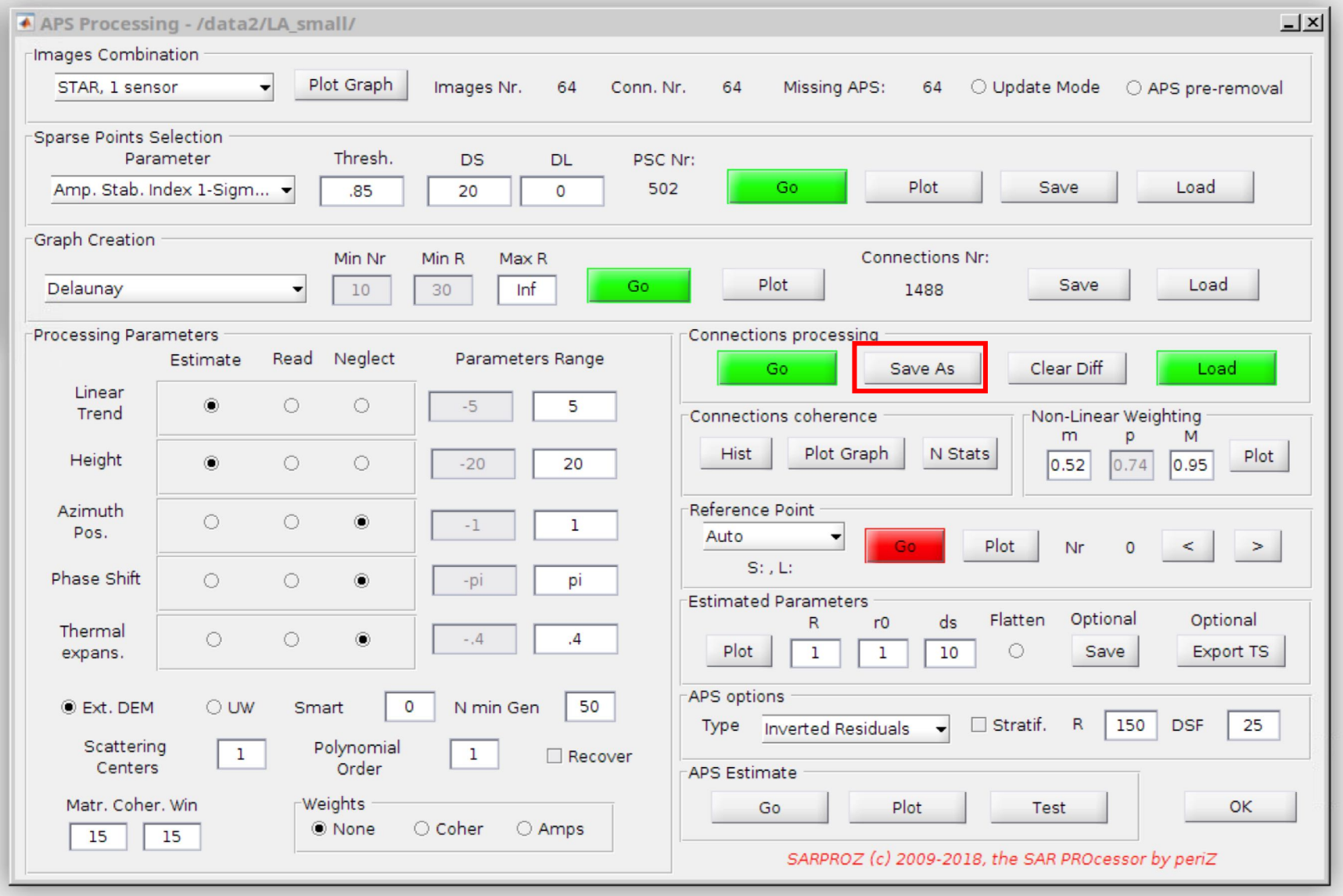
How to select the range for estimation?

- Later, in step 2-10, check the histogram of connection velocity and connection residual height. The histogram gives an idea of the velocity/residual height value distribution.
- If the numbers you put down in the first place are too large/too small, they would be reflected to the histogram. You can adjust your numbers accordingly and process again.



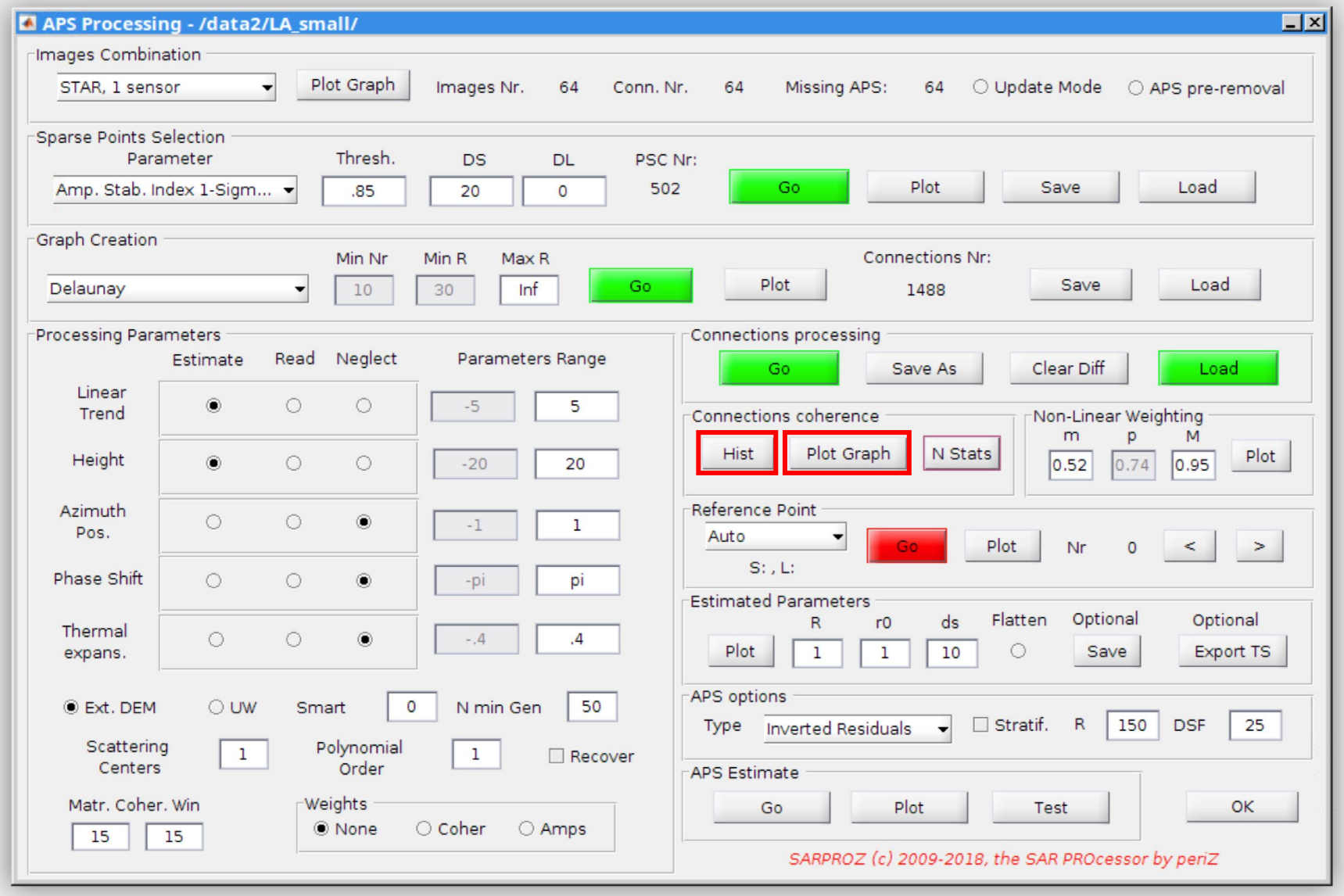
Step 2-5: connections process

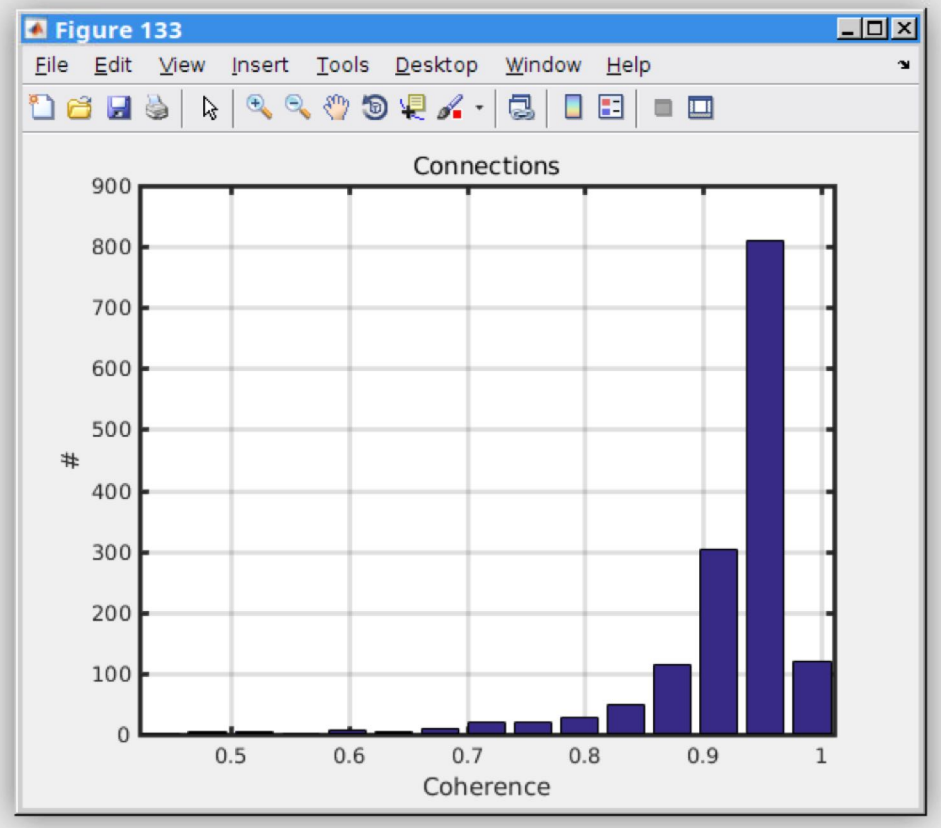
A message "`APS graph processing concluded successfully`" will appear in command window when the process finishes. The result is automatically saved as "`AutoConnex.mat`". You can also click "save as" to save it with your own filename. Later you can load your processed result with the "load" button in "connections processing" frame.



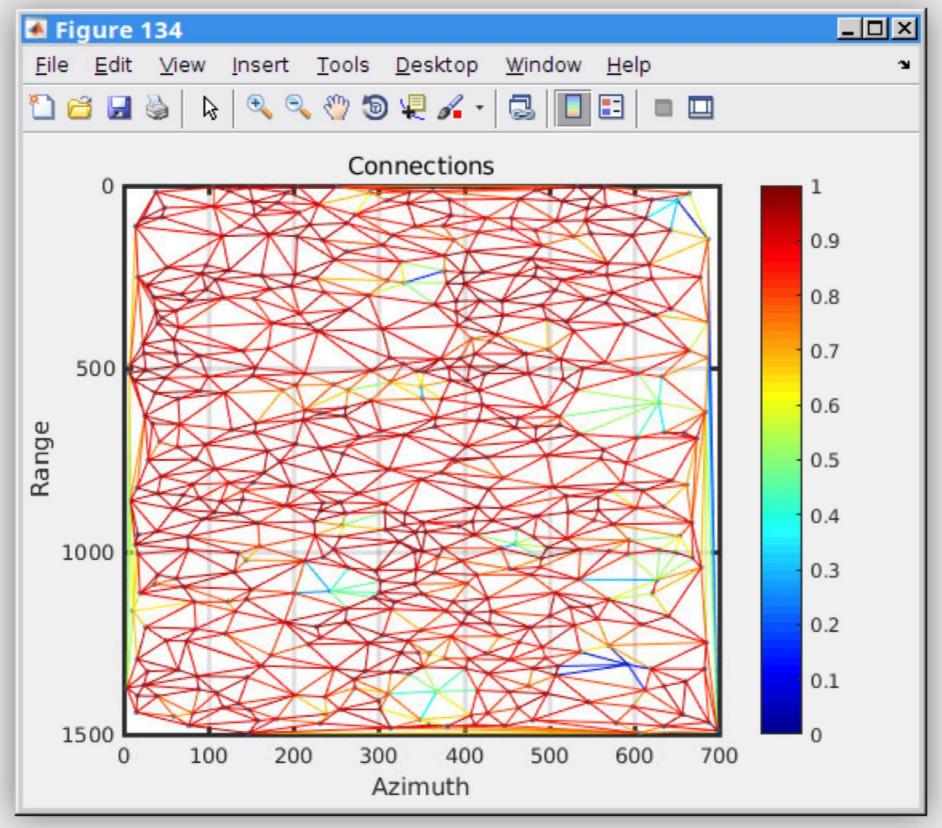
Step 2-6: connection coherence

It is important to check the connections coherence via the "hist" (histogram) and "plot graph" button. The histogram gives a statistical overview of coherence. The graph is useful for checking if there are isolated areas (with very low coherence to the rest of points). It is desired to be able to find a path to every points in the graph with high connection coherence value.

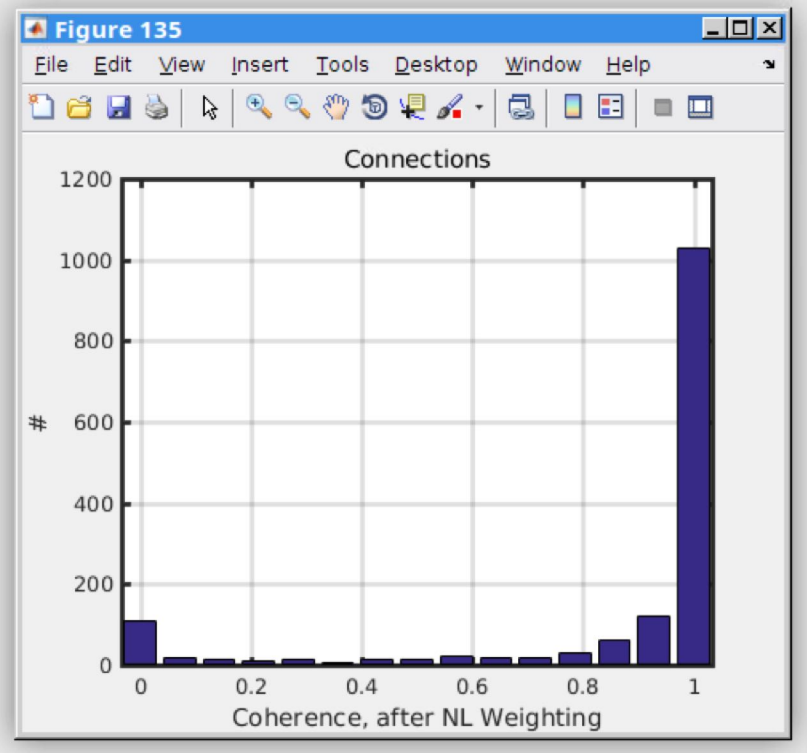




The histogram of graph connection coherence

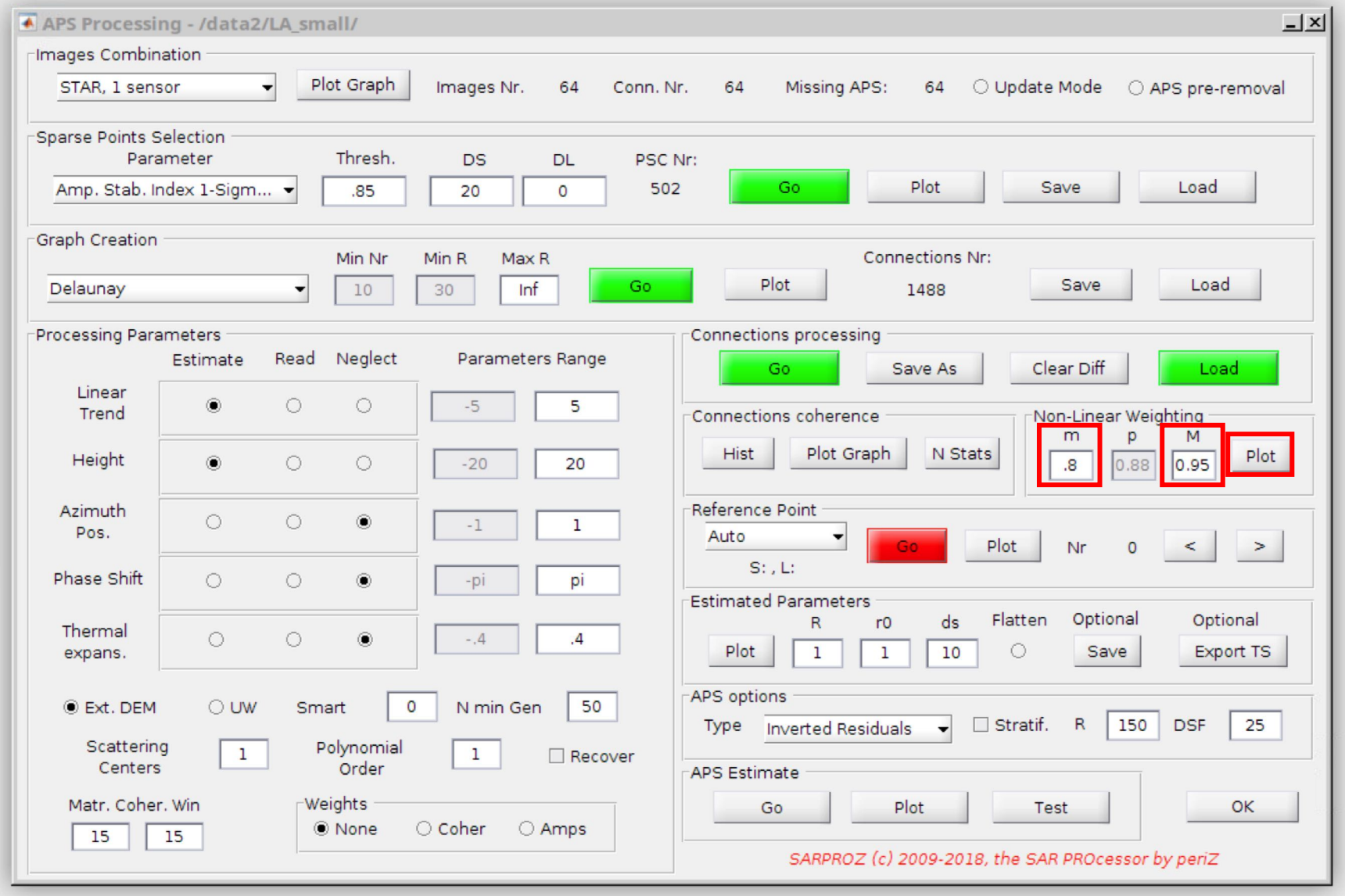


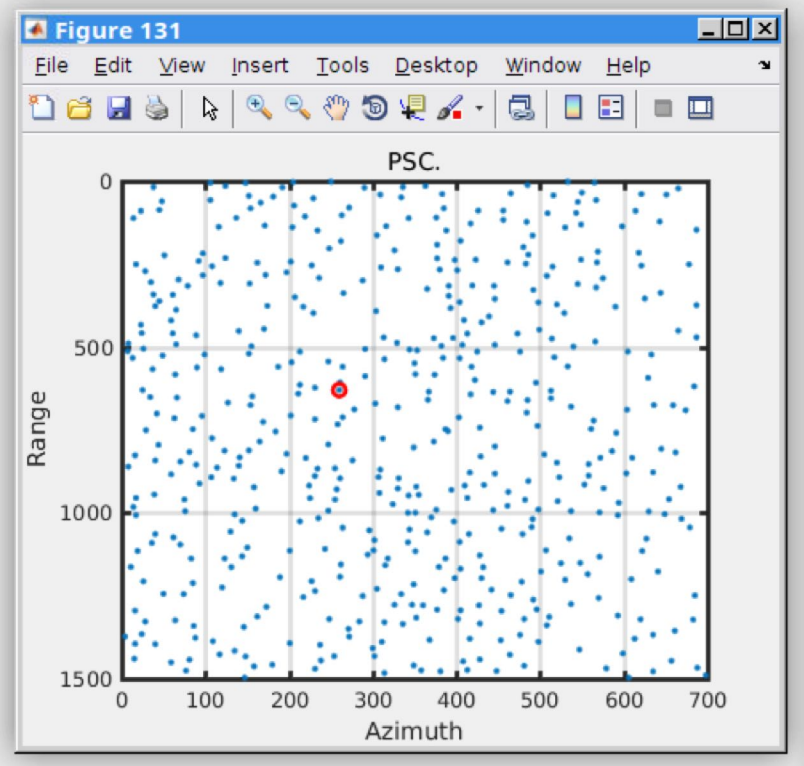
The plot of graph connection coherence. In this example, most points are connected via paths with relatively high coherence.

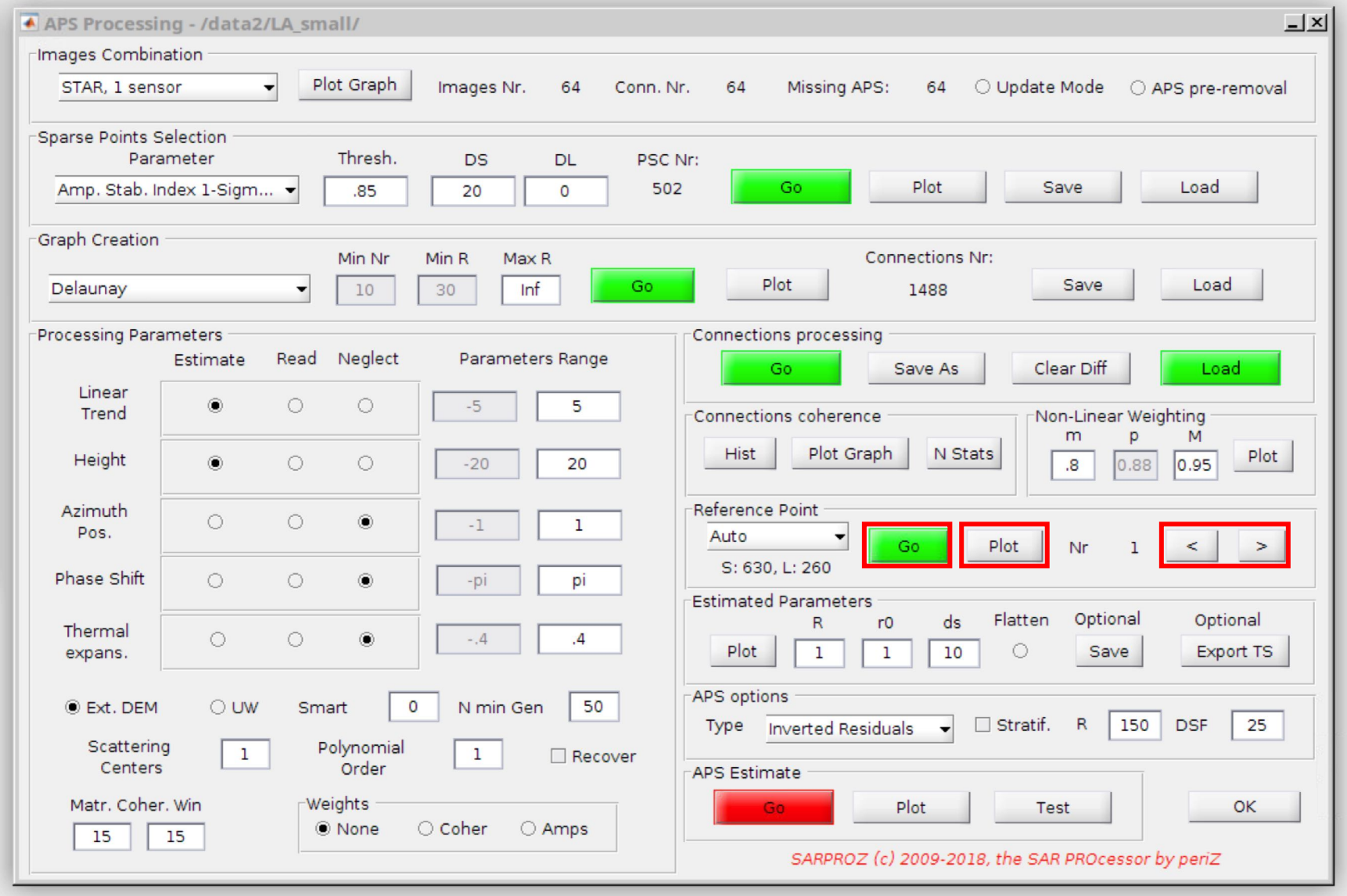


Step 2-7: non-linear weighting

Put down "0.8" as minimum (m) and keep "0.95" as maximum (M). Click "plot" to see the histogram after the non-linear weighting.

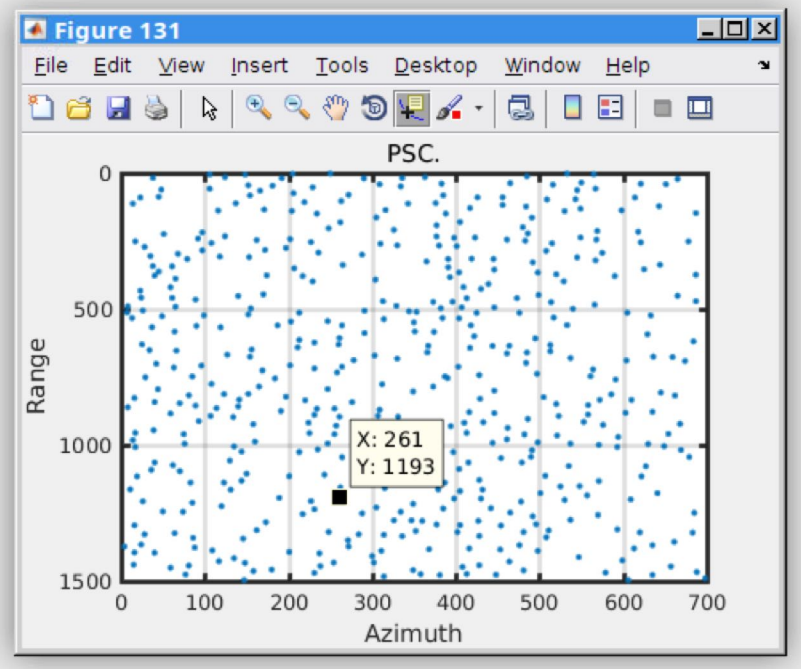






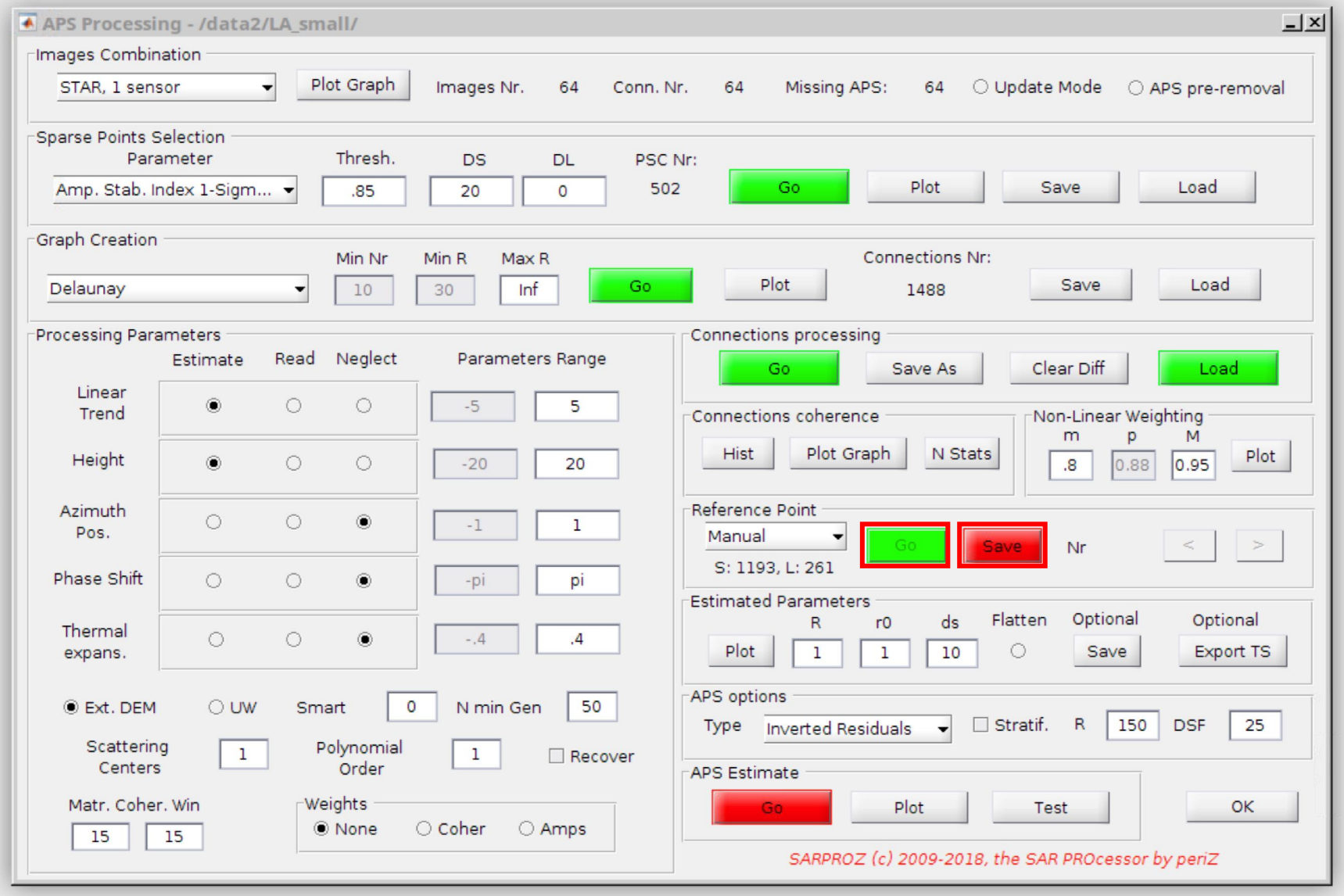
Step 2-8: automatic reference point

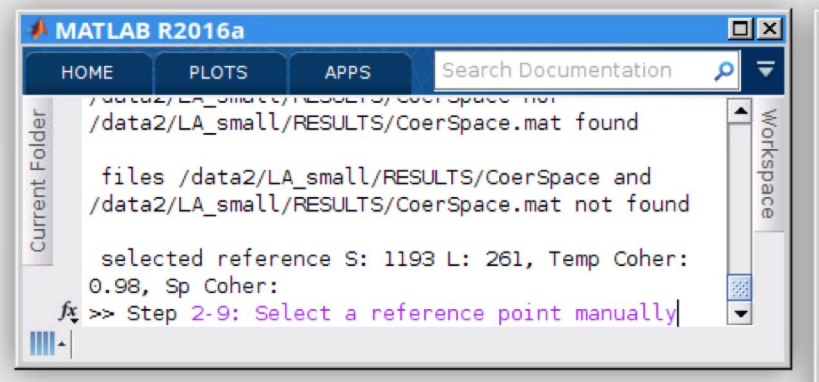
Select reference point. Click “go” to generate the automatic points, then click “plot” to show the point’s location. Click “<” and “>” to switch between reference points. Every time you switch reference point, click “plot” to see the new one.



Step 2-9: manual reference point

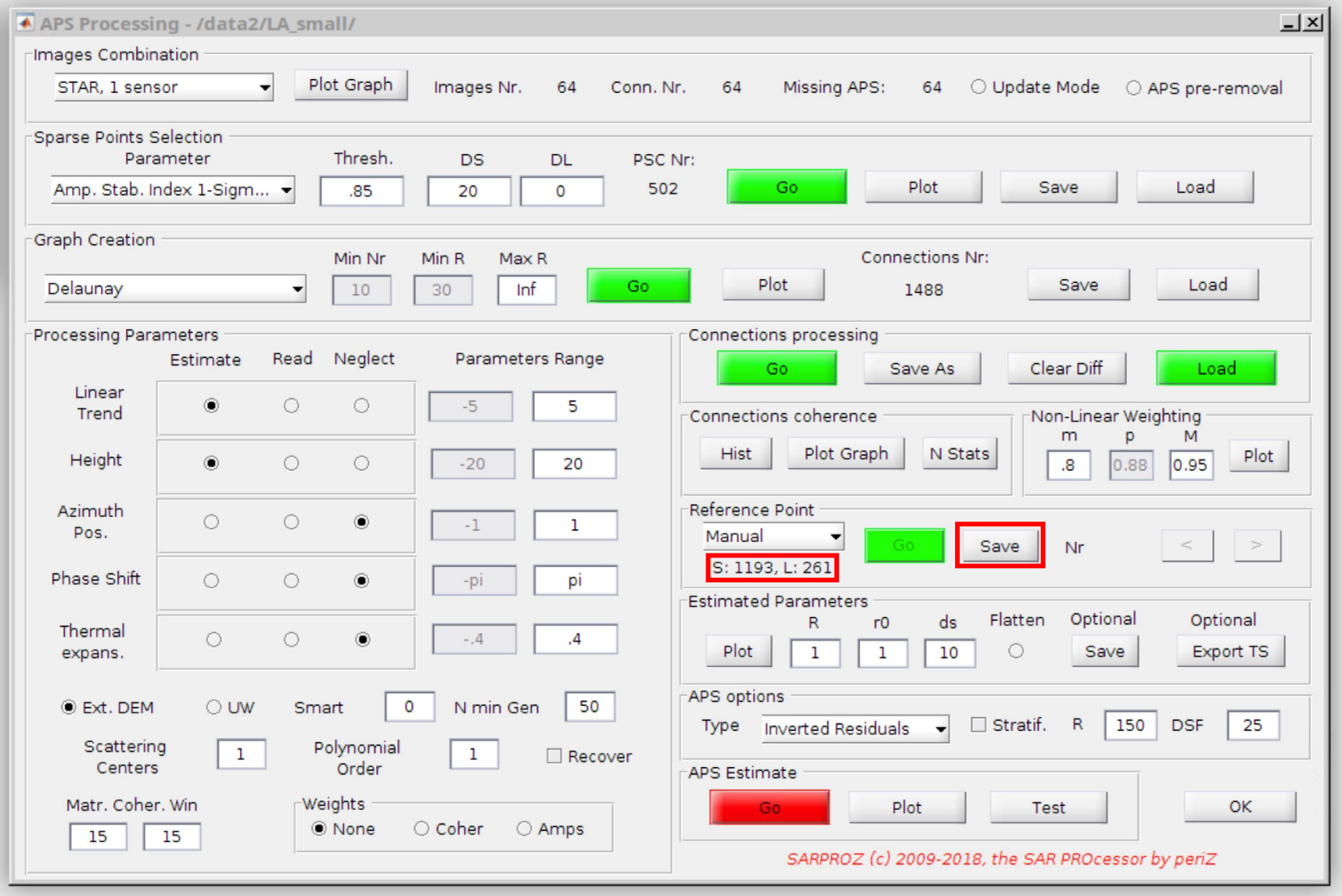
Select reference point manually. Choose "manual" from the drop down menu. A figure will pop up. Use the "data cursor" tool to select reference point. After you select a point, click "save" in "reference point" frame to record your point.





Step 2-9 (cont'd)

When you are choosing your reference points with the data cursor, you can see the coherence value of the point you selected in the command window. It is desired to have the reference point with high temporal coherence. For this exercise, we manually select point with sample: 1193 and line: 261 as the reference point.

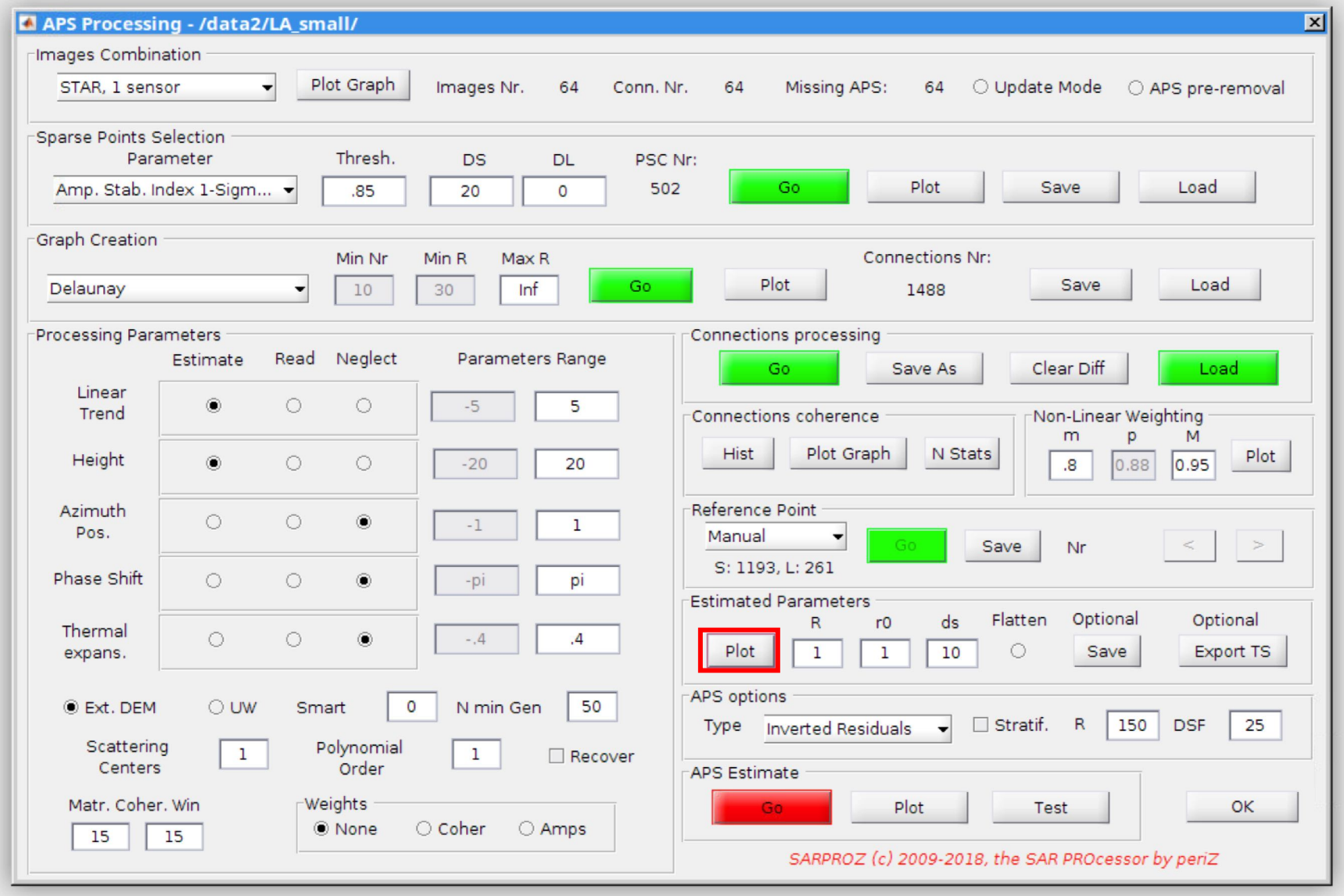


Why is selecting reference point important?

- Remember that InSAR measures the relative movement to the reference point. Hence, it is important to select a point that is most likely to be stable as the reference point.
- A stable reference point should have the following property:
  - the peak of residual height histogram should be at value 0. This indicates your reference point is on the ground (points not on the ground are more likely to be unstable);
  - the peak of estimated velocity histogram should also be at value 0. This indicates the reference point is relatively stable (assuming the majority points in your AOI is stable).

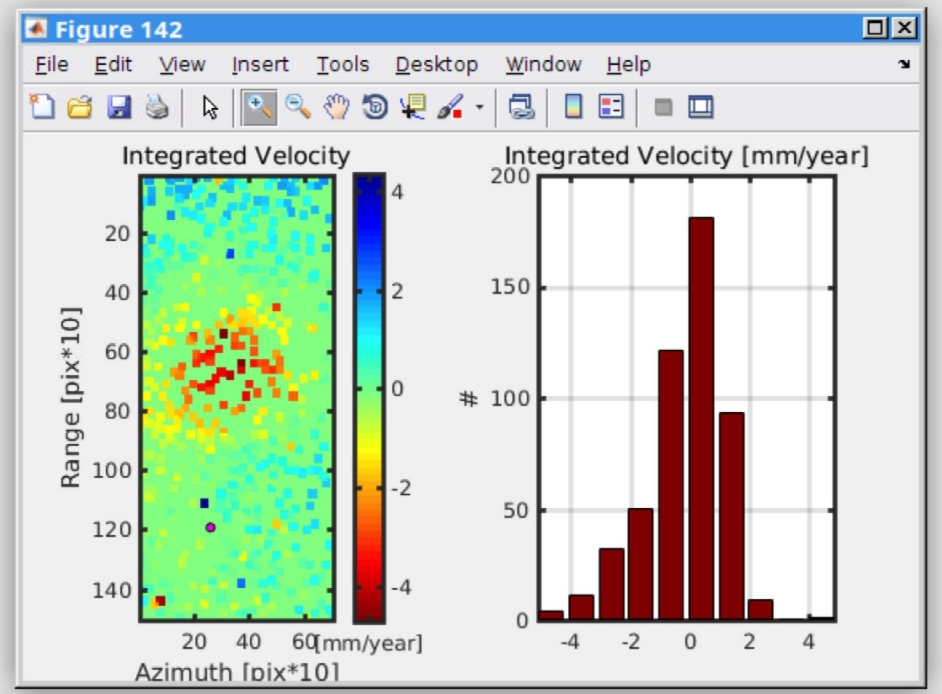
Step 2-10: plot parameters

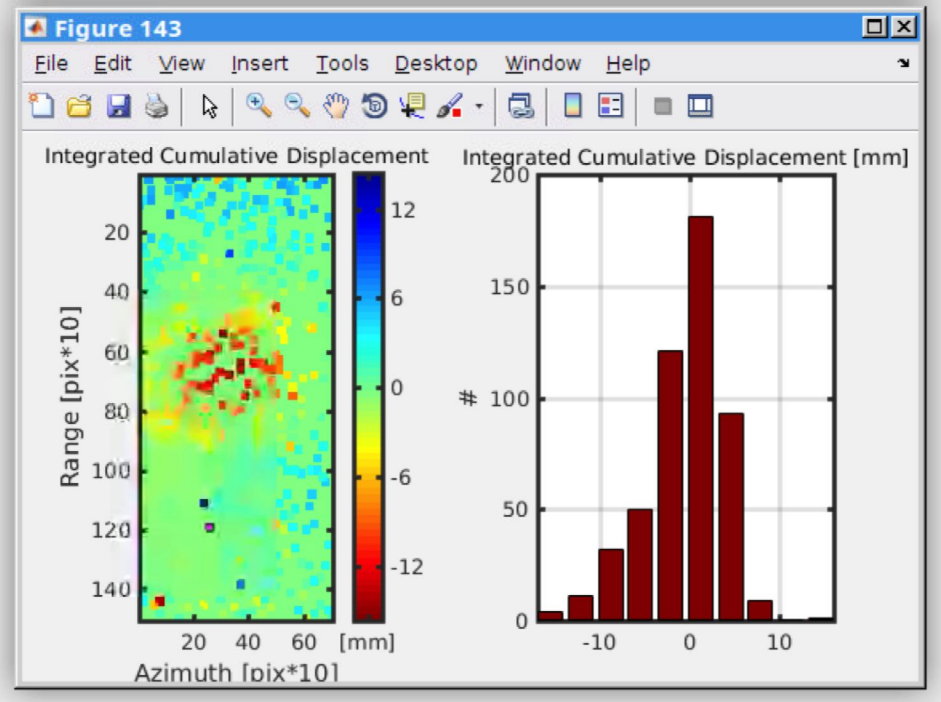
Click “plot” in the “estimated parameters” frame to check the integrated estimated parameters.



Step 2-10 (cont'd)

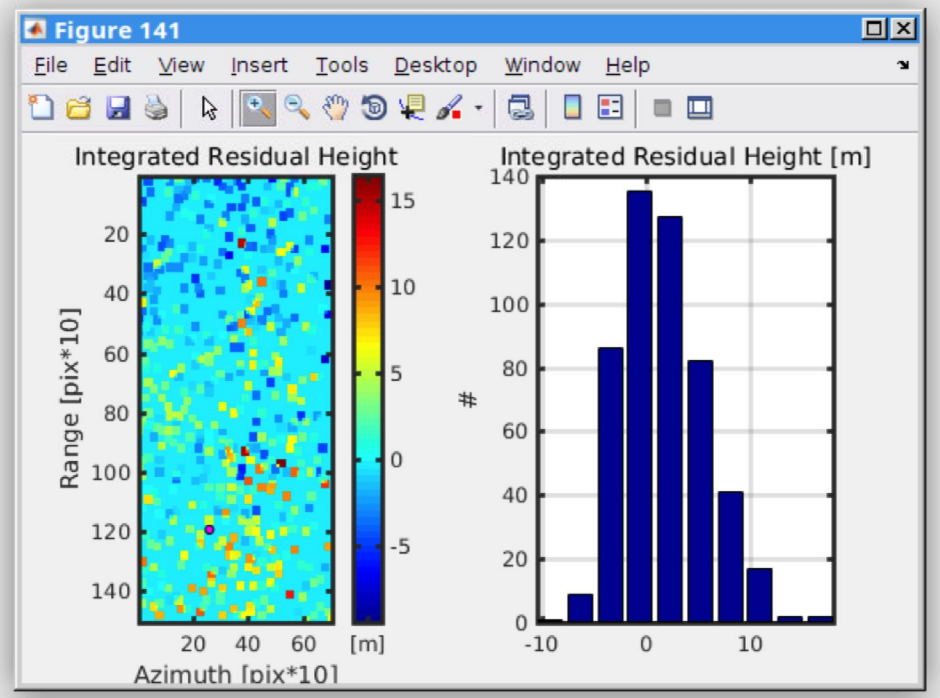
Integrated velocity and integrated cumulative displacement. Cumulative displacement = velocity × time. Note the peak of integrated velocity histogram (and integrated cumulative displacement histogram) is more or less at zero. This means that the majority of points have zero relative velocity when comparing with the reference point.

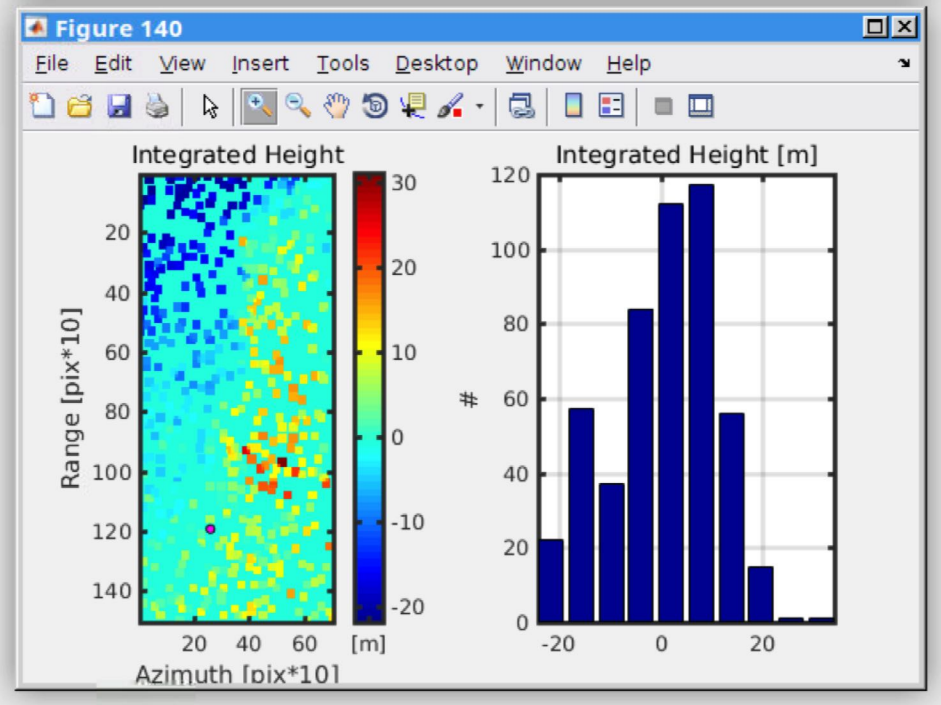


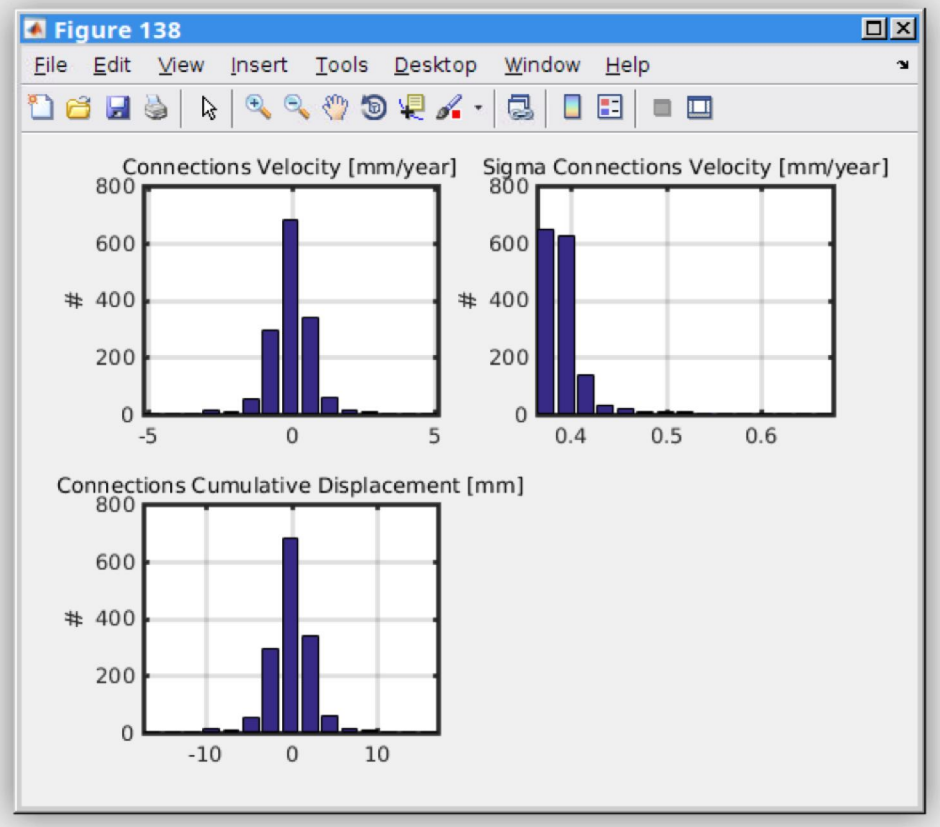


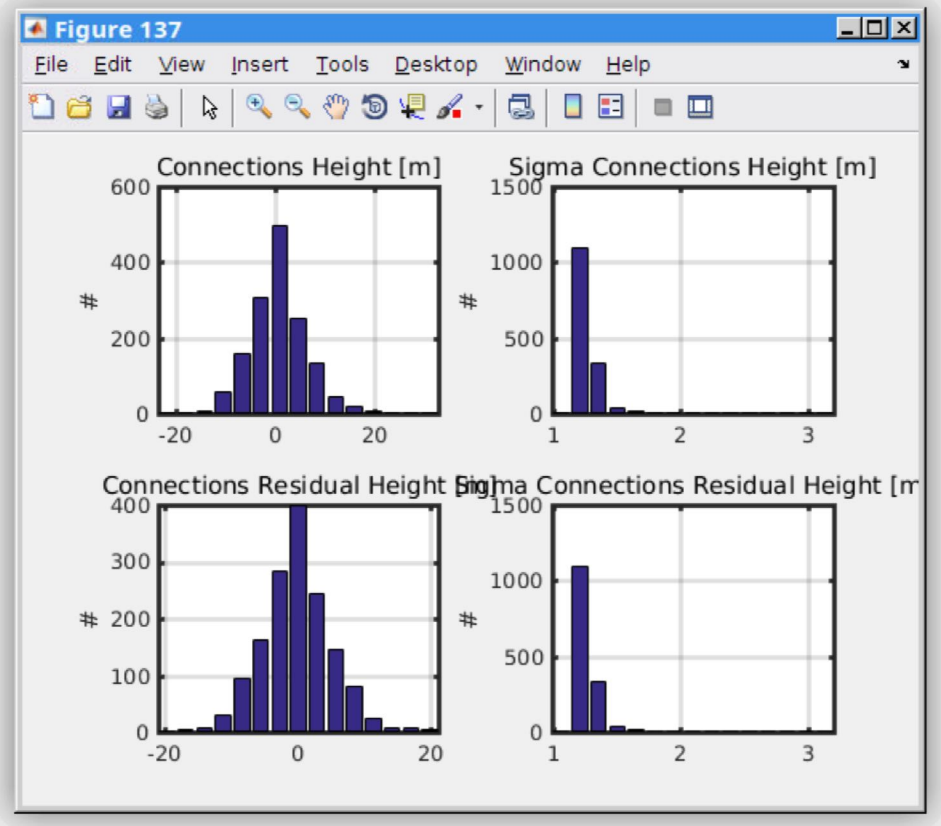
Step 2-10 (cont'd)

Integrated residual height and integrated height. Integrated residual height is the integrated height minus the external DEM. Note the peak of integrated residual height histogram is more or less at zero. This means that the majority of points have zero relative height comparing with the reference point. This is an indication that the reference point is on the ground (since the majority of points should be on the ground).









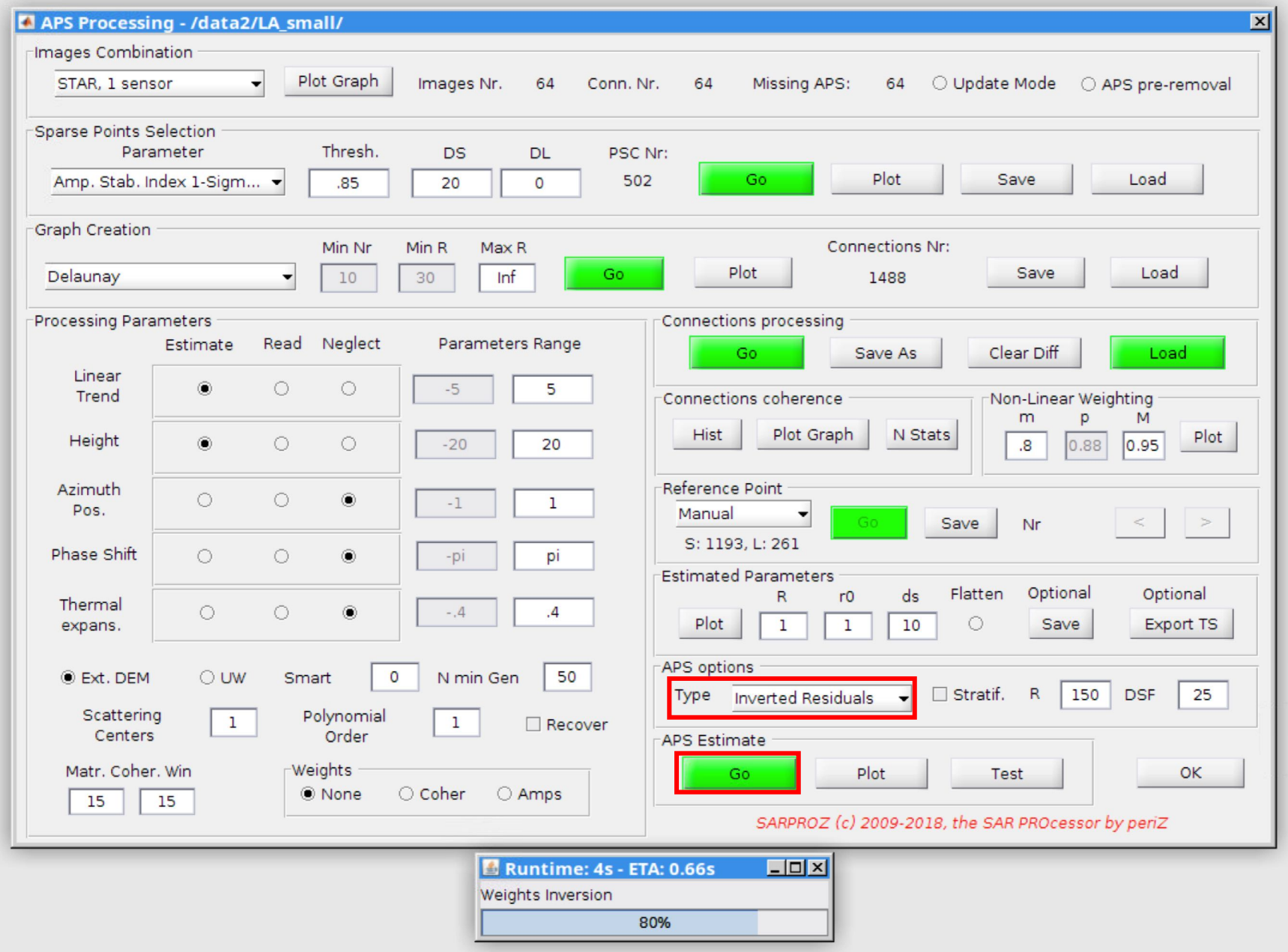
The histogram of connections velocity, connections heights and connections residual height. Note that this is the histogram of connections of the graph.

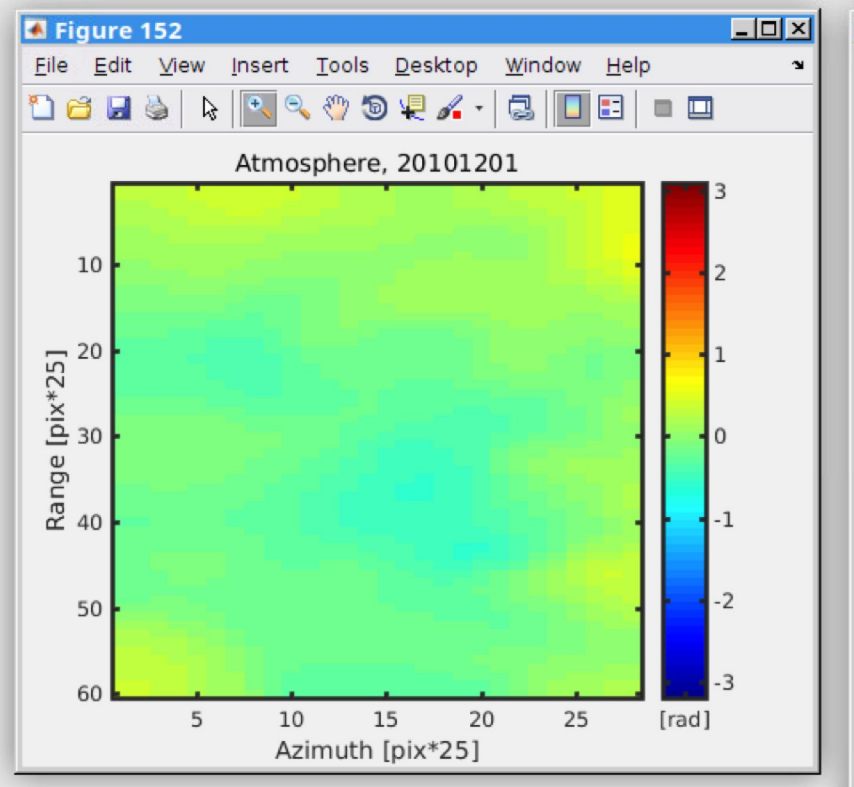
What is the difference between connections (histogram) and integrated parameters (histogram)?

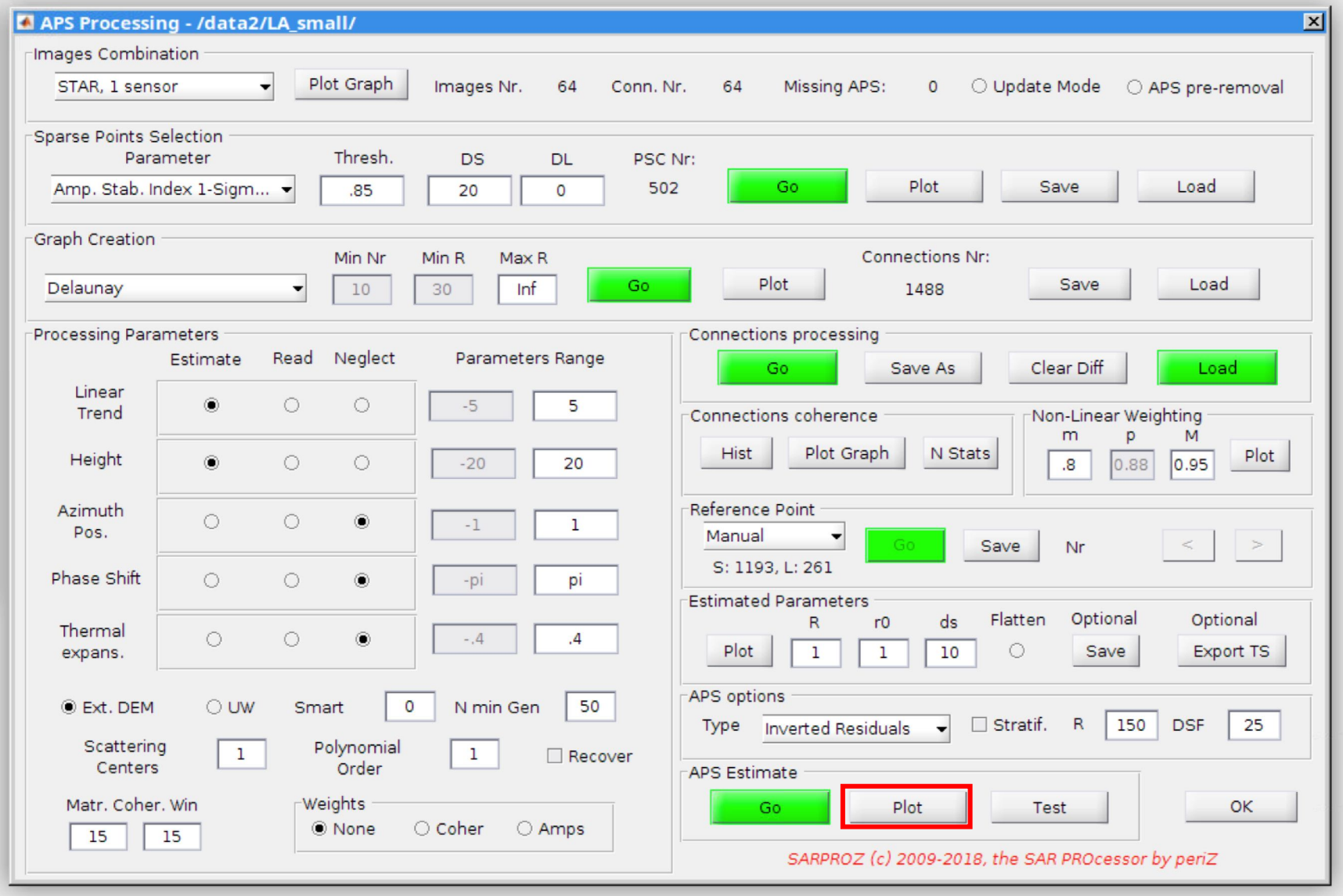
- Connections velocity/residual height is the estimated relative velocity/residual height between two points that are connected with an edge of the graph.
  - The histogram is the representation for the distribution of the connections velocity/residual height.
- Integrated velocity/residual height is the velocity/residual height with respect to the reference point after integrating the connections velocity/residual height using the given graph.
  - The histogram represents the distribution of the integrated velocity/residual height for each point with respect to the reference point.

Step 2-11: estimate APS

When you believe your estimated parameters are reasonable, you can now proceed to the APS estimation. Keep the default option of "inverted residuals" in "APS options" frame. At last, click "go" in "APS estimate" frame.





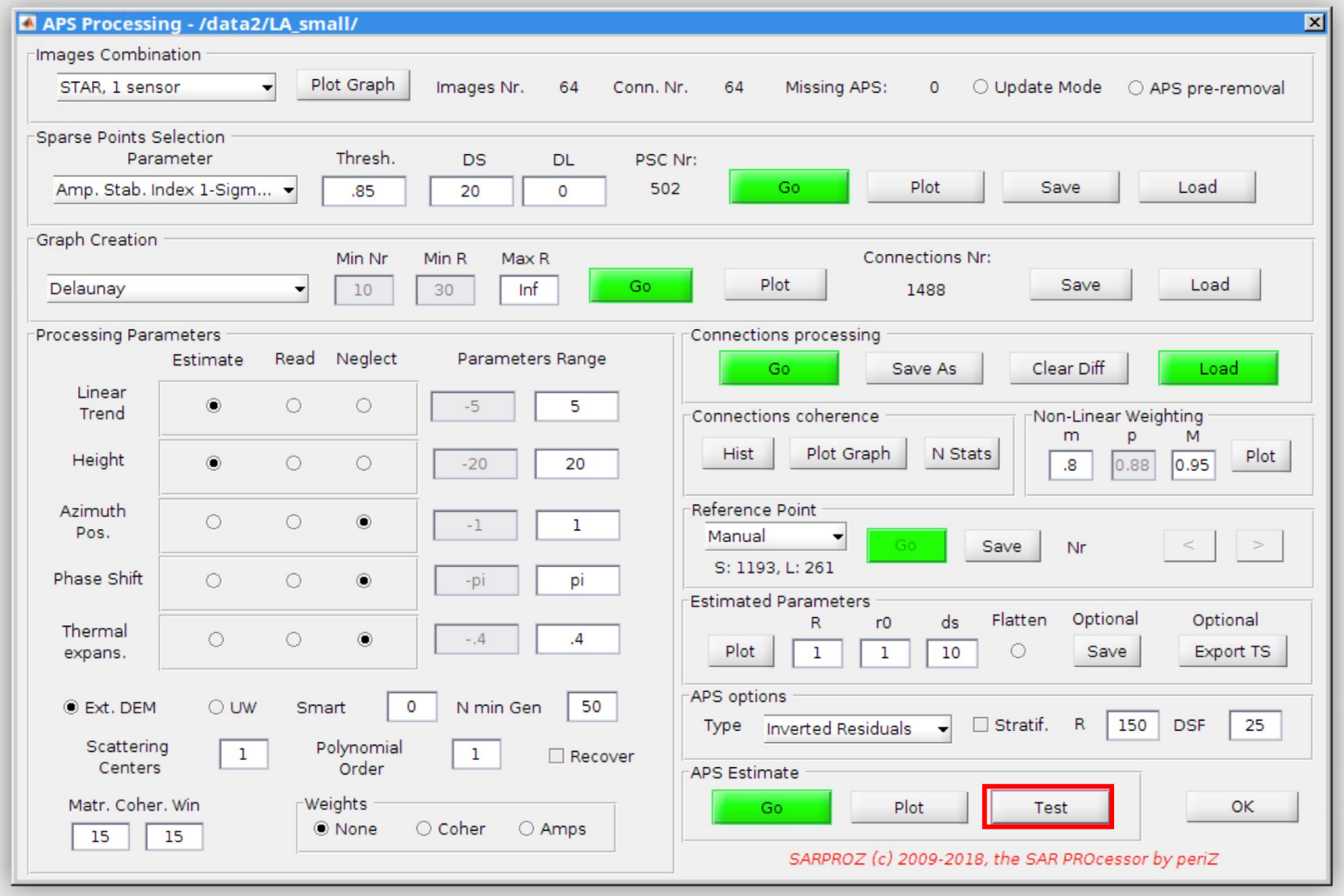


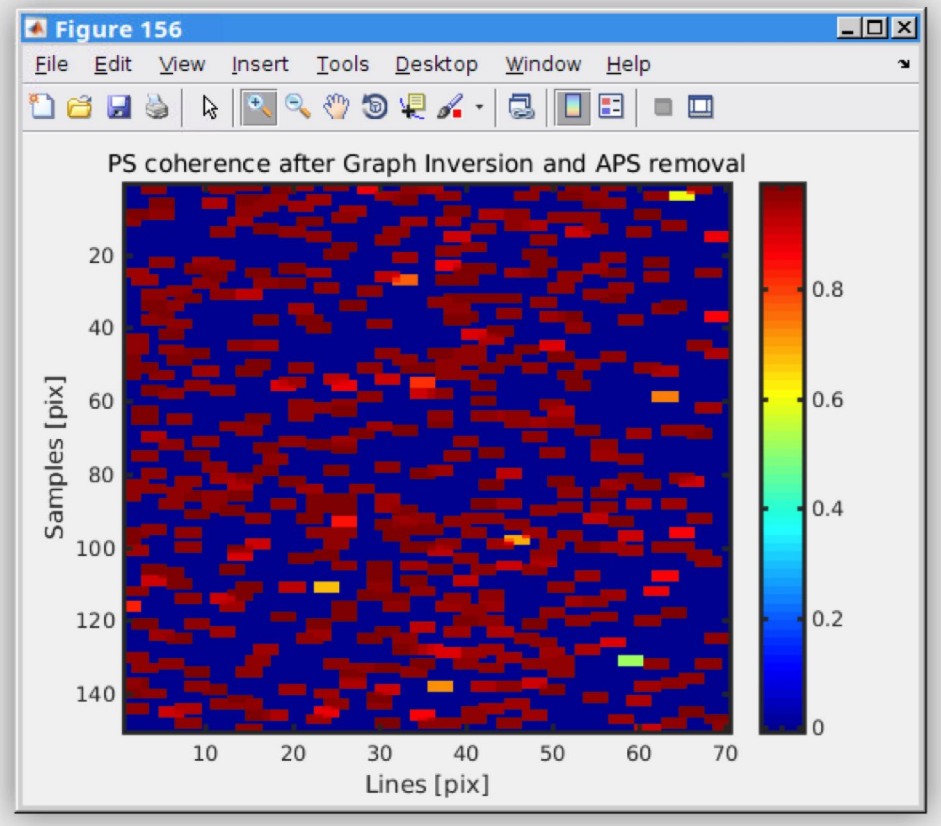
Step 2-12: plot APS

Click “plot” in “APS estimation” frame. You can browse the estimated APS contribution in phase one by one.

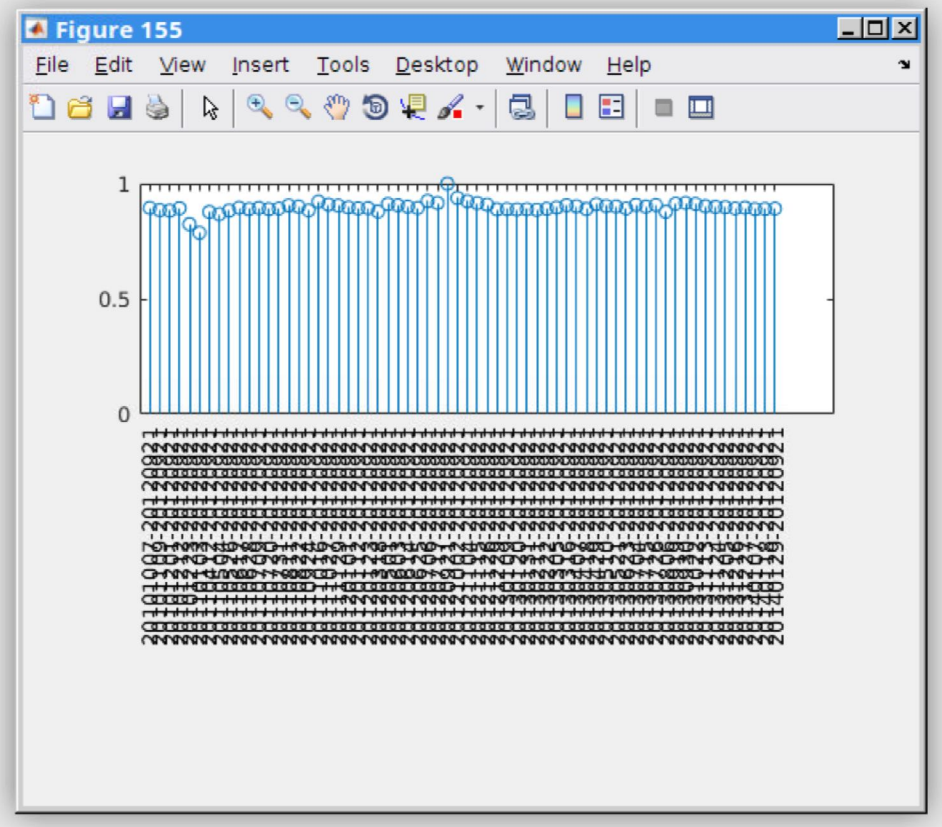
Step 2-13: test

At last, you can "test" the coherence after removing the estimated APS. If the coherence is high, it means the APS estimation is good.





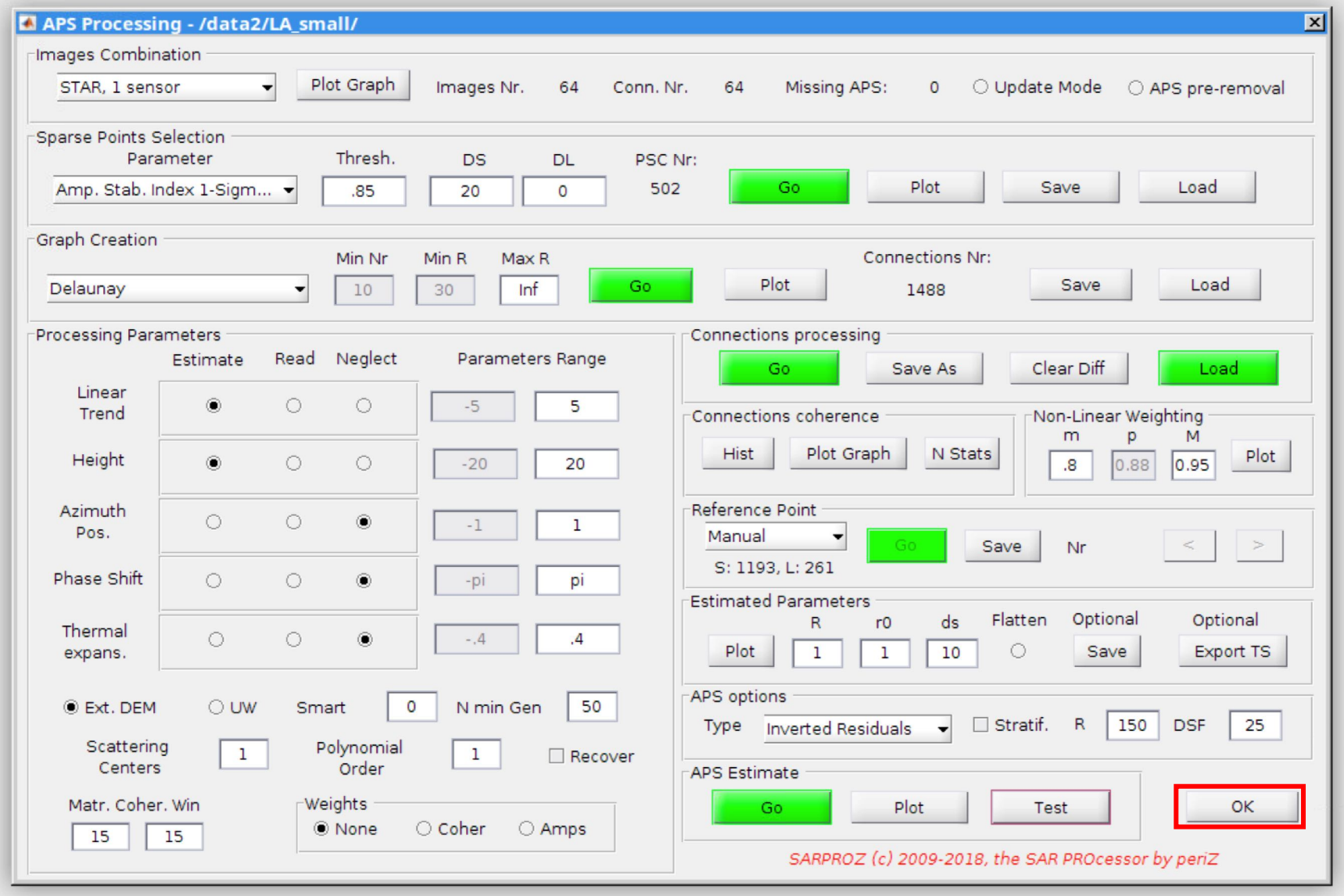
Temporal coherence of points after removing the estimated APS



Coherence between each slave date and the master date after removing the estimated APS

Step 2-14:

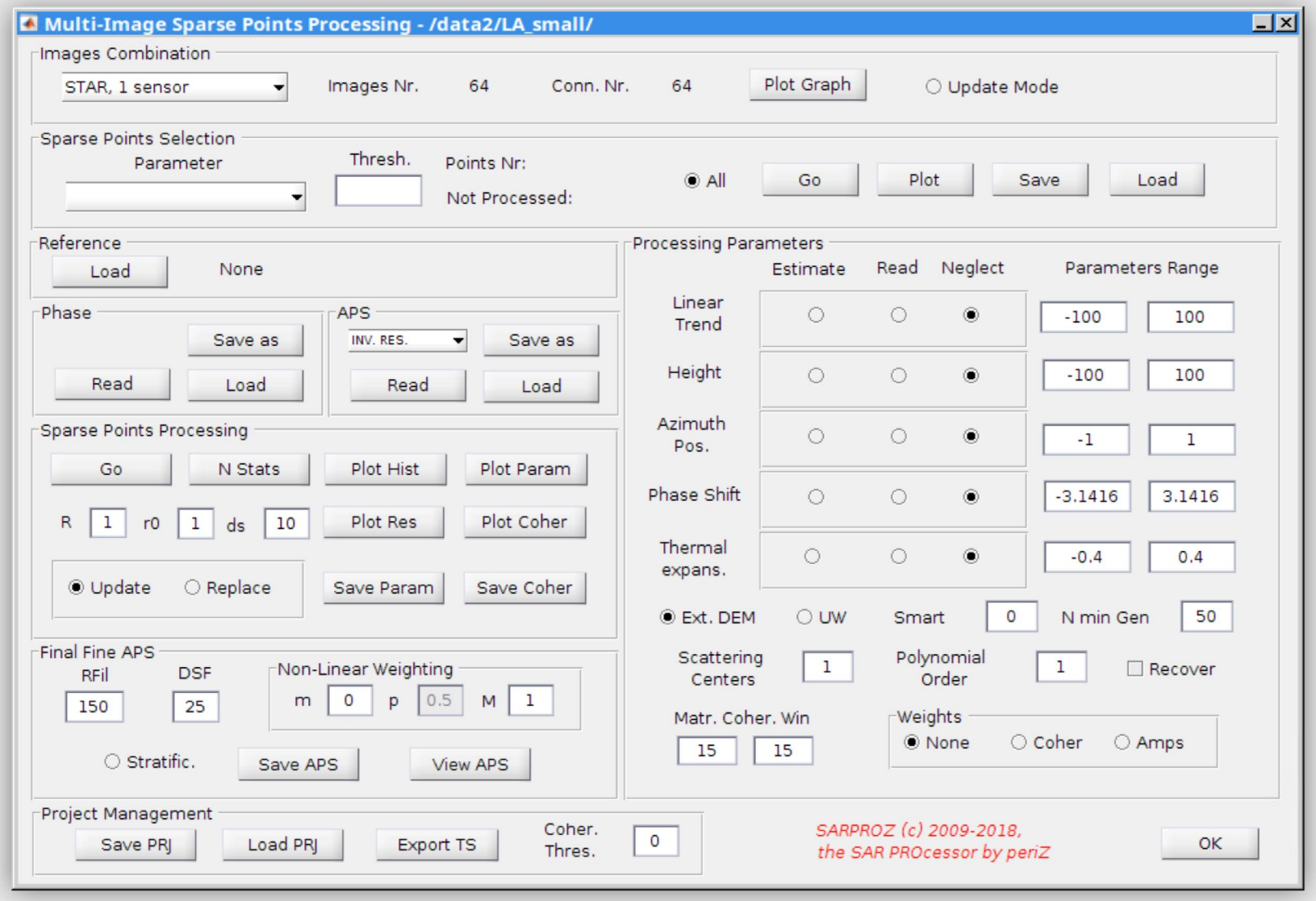
At this moment we are done with APS estimation part. You can now click “ok” to close this module.

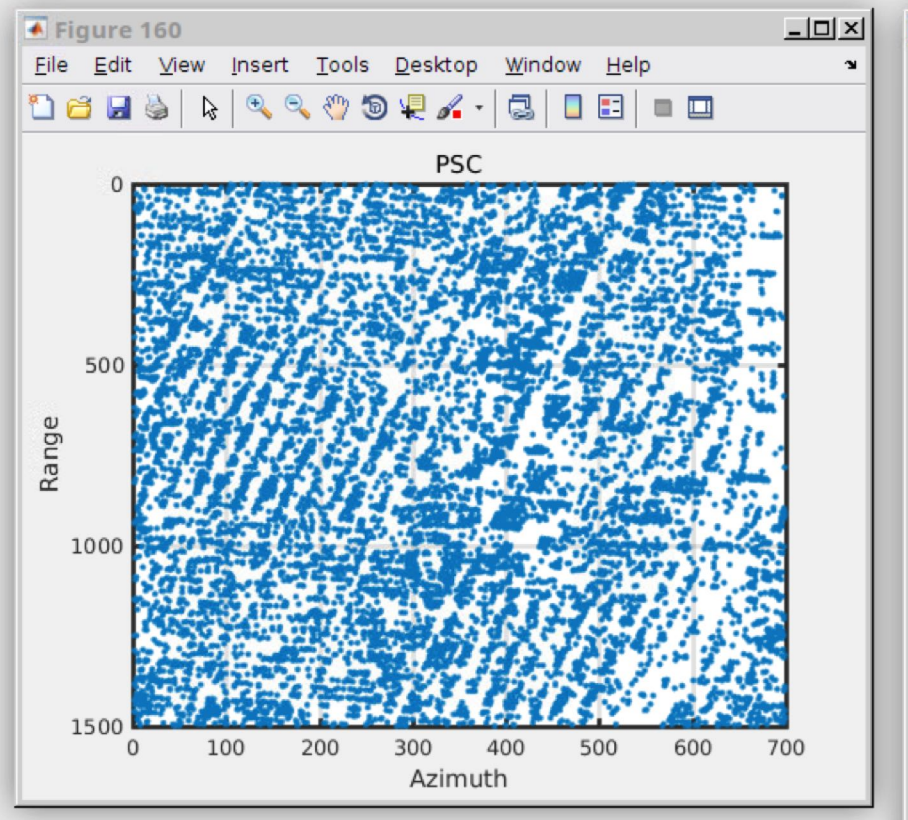


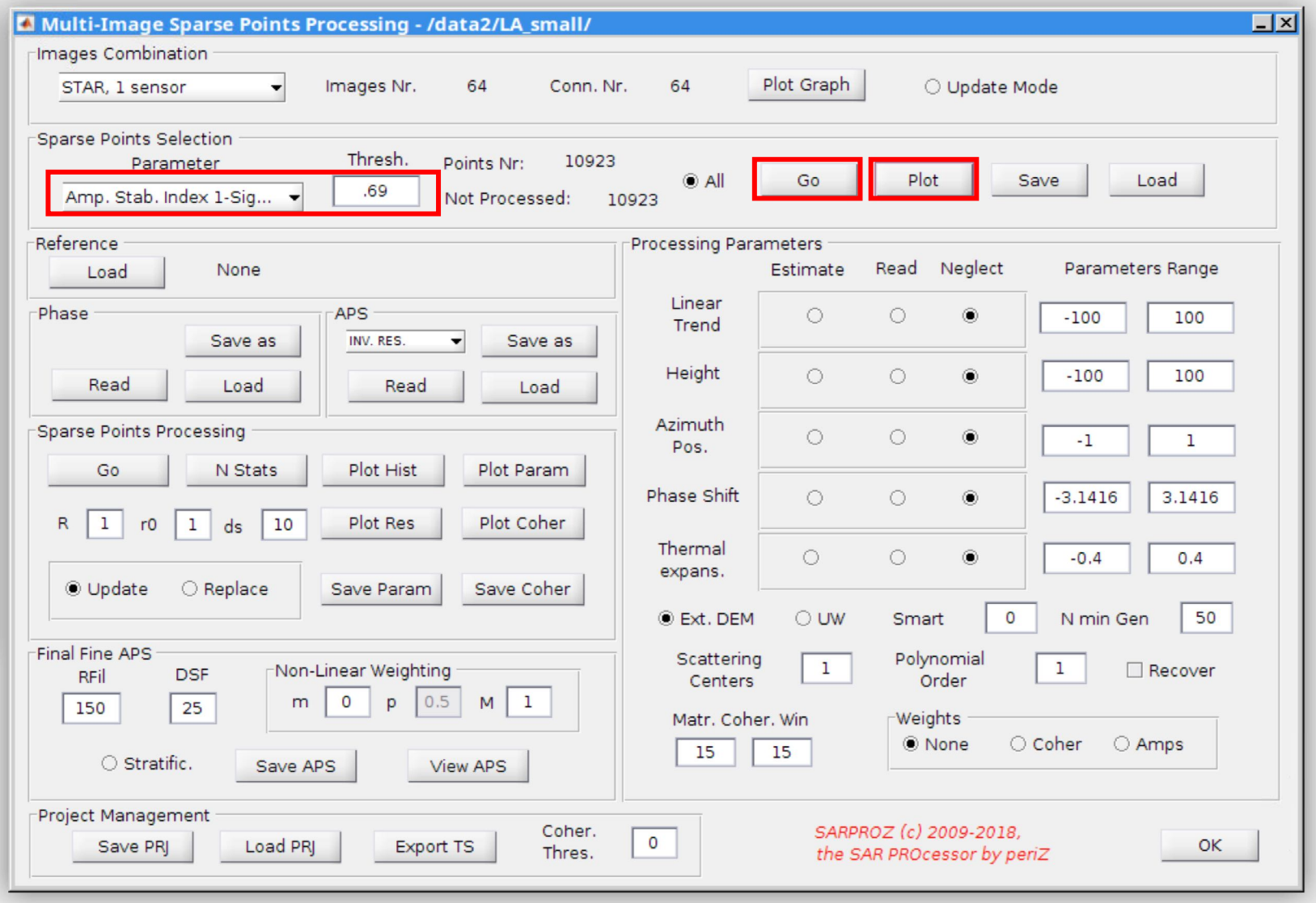
Part 3:
Multi-temporal Analysis

Step 3-1: open MISP module

Click “sparse points processing” from “site processing” panel.





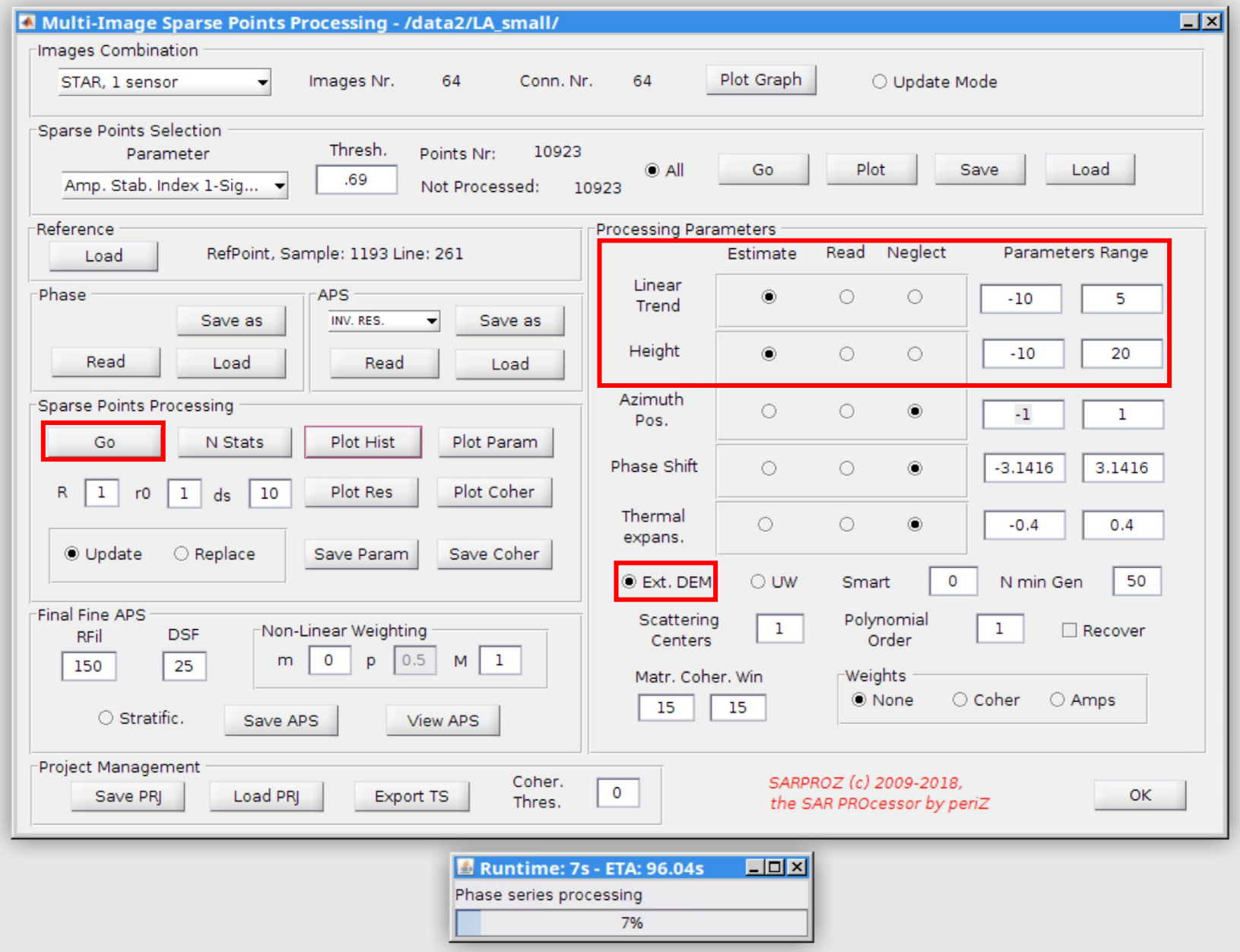


Step 3-2: select points

Choose “amplitude stability index” and put down “0.69” as the selection threshold. Click “go” to count the points. These are the points for which you will calculate the time series. Click “plot” for seeing the locations of points.

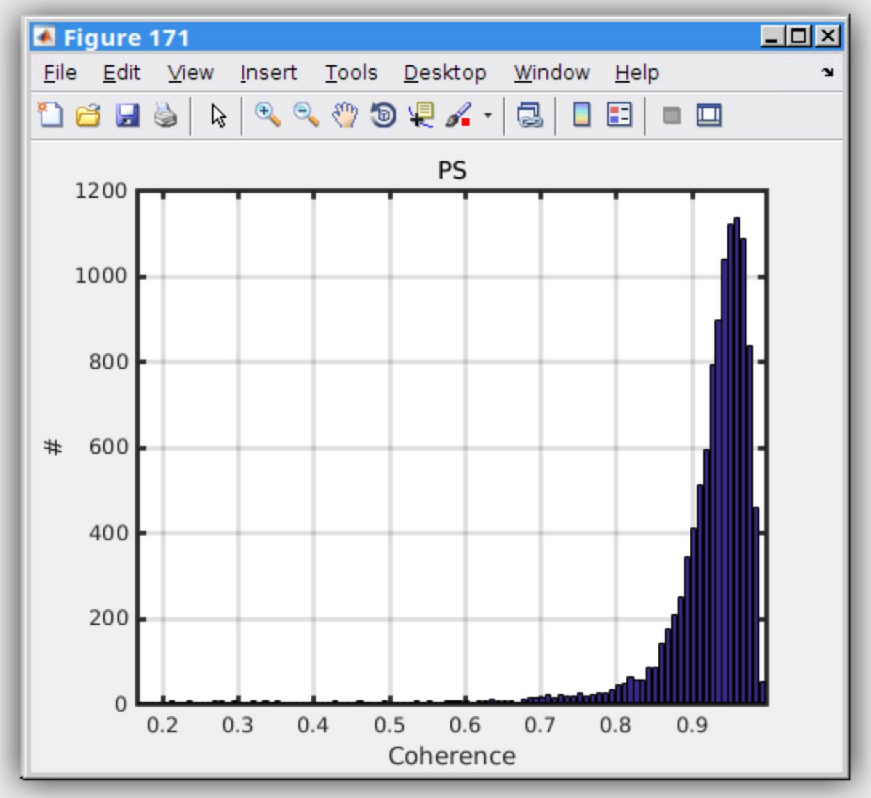
Step 3-3: estimate parameters

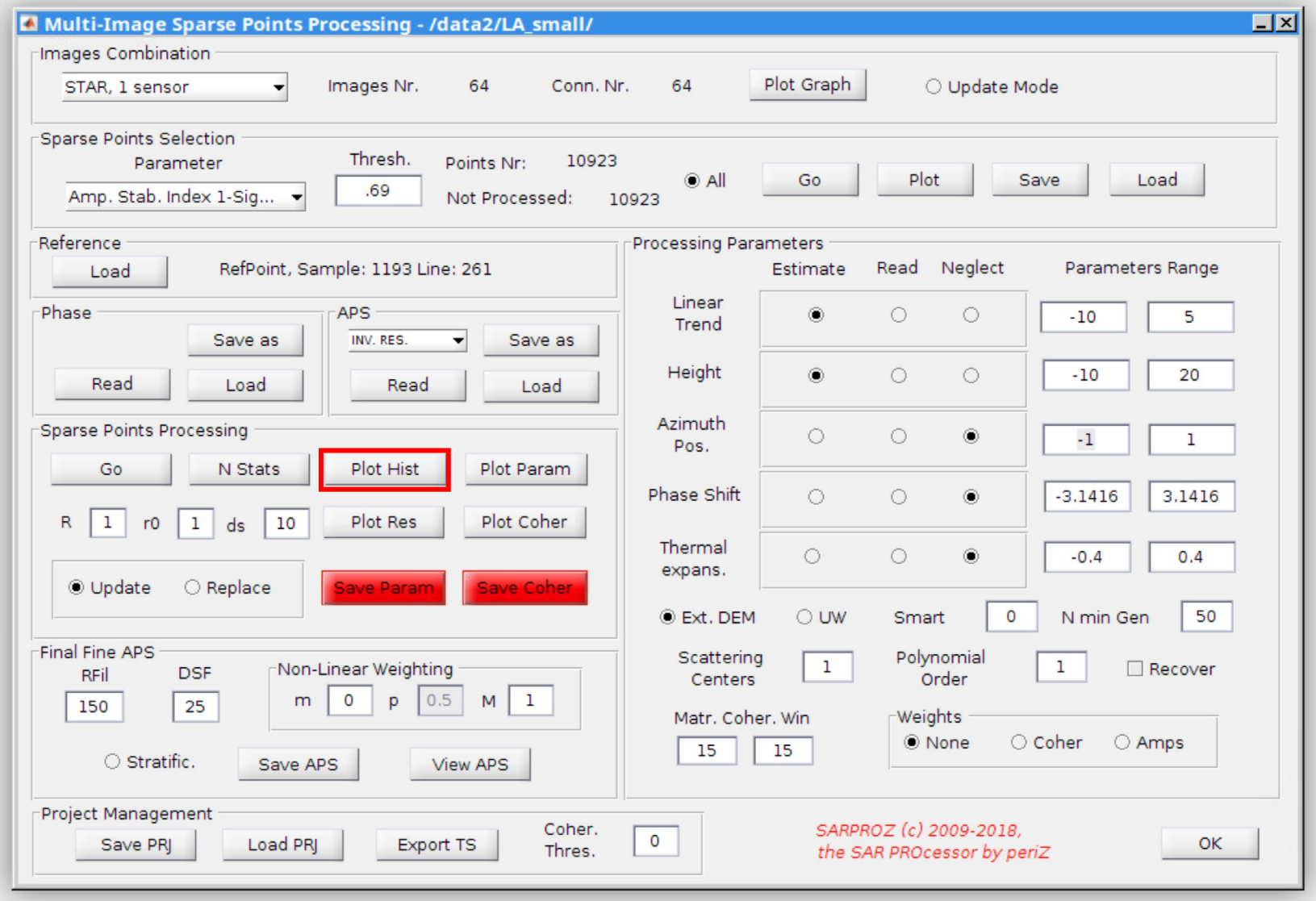
Select “estimate” for height and linear trend, and “neglect” for all other parameters. Put down [-10, 5] for linear trend estimation. Put down [-10, 20] for height estimation. Make sure that “ext. DEM” option is checked. Keep all other options as in their default settings. Click “go” in “sparse point processing” to estimate the parameters for your selected points.



How to select the range for estimation here?

- In step 2-10, you see the integrated velocity and integrated residual height with their histograms. From the color bar and histogram you should see the range (distribution) of integrated velocity and integrated residual height. Put down the range for each parameter (velocity and residual height) that is just slightly bigger than you have observed in step 2-10.



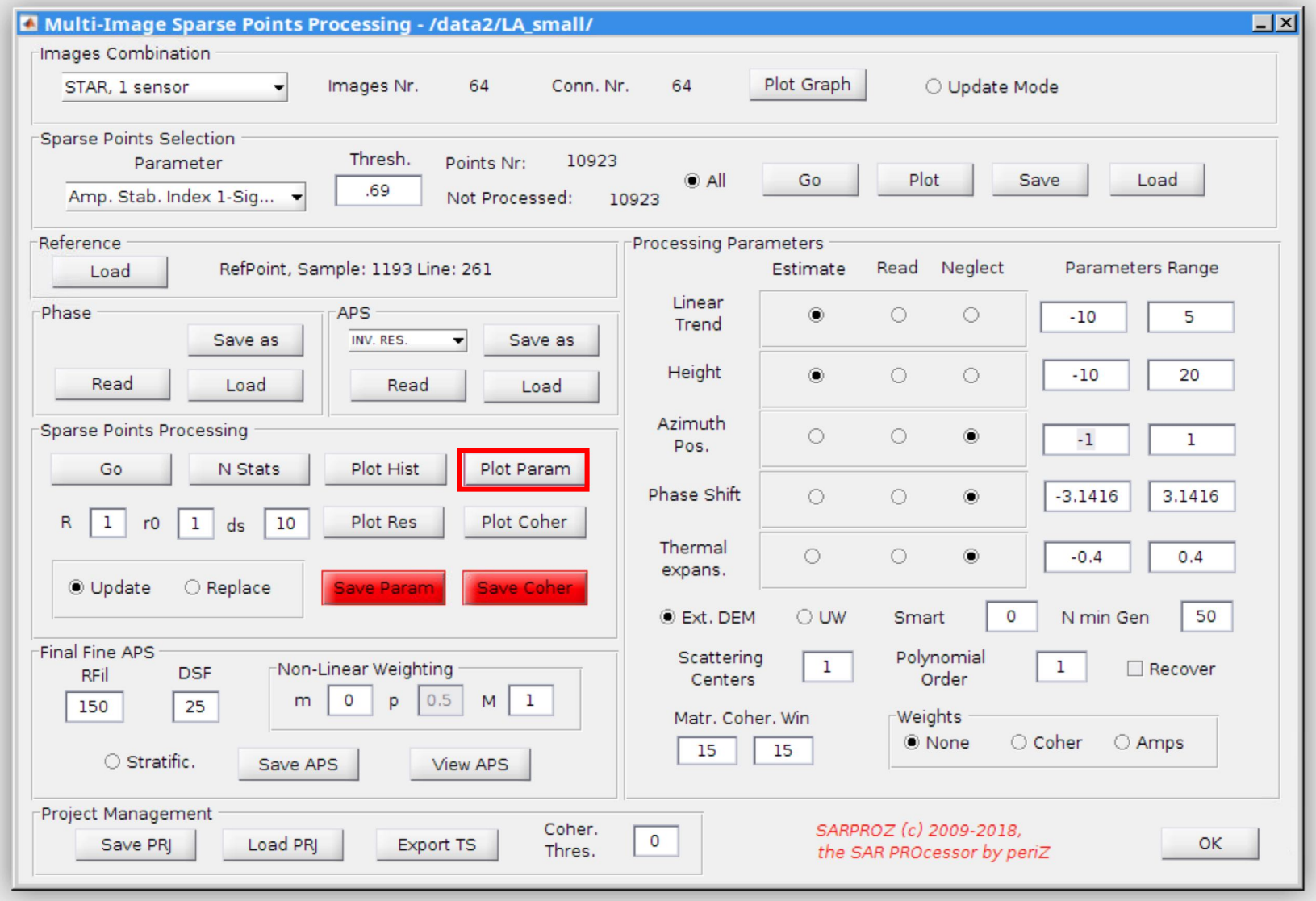


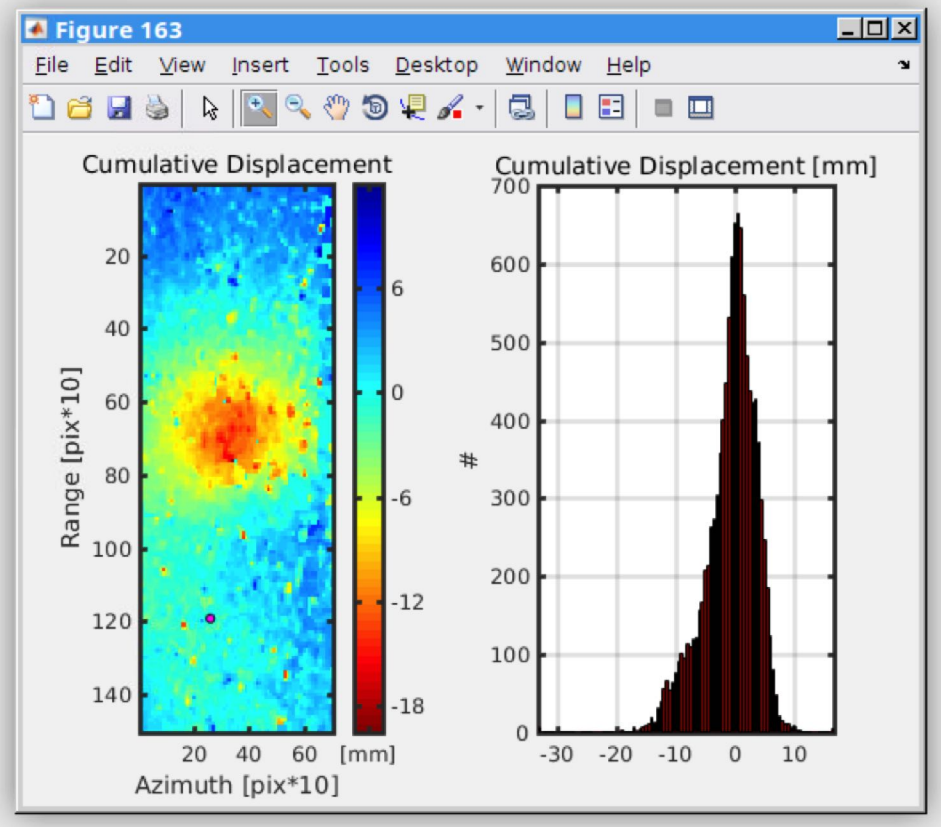
Step 3-4: check coherence histogram

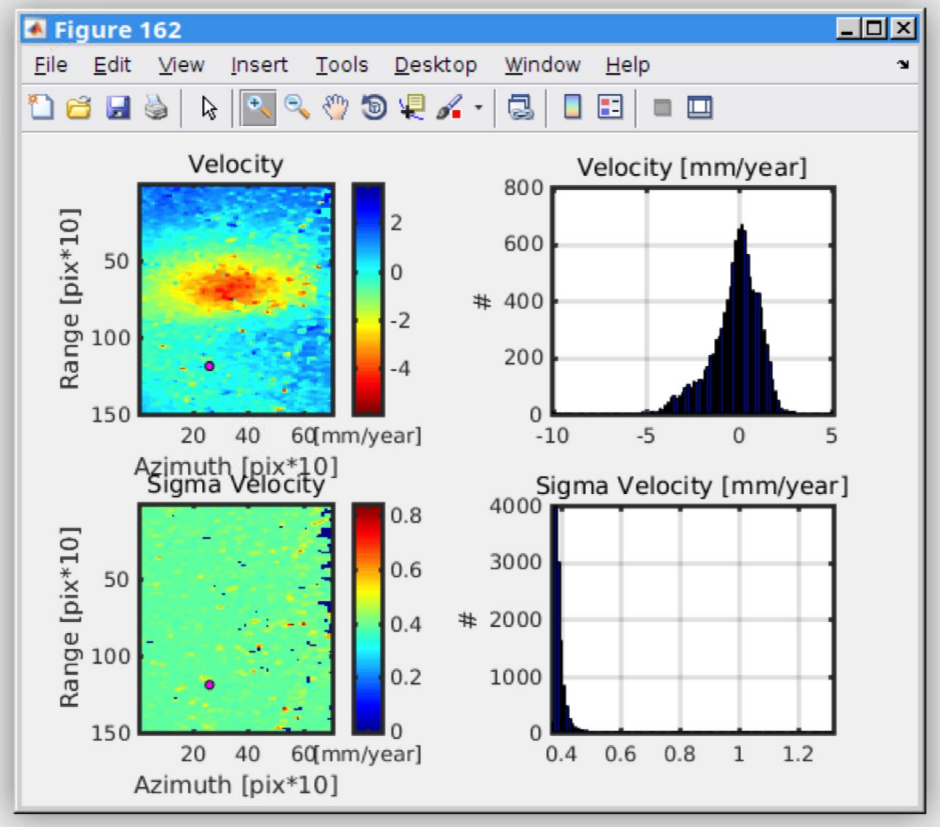
Click “plot hist.” in “sparse points processing” frame to check the temporal coherence histogram of points after parameter estimation and APS removal.

Step 3-5: plot parameters

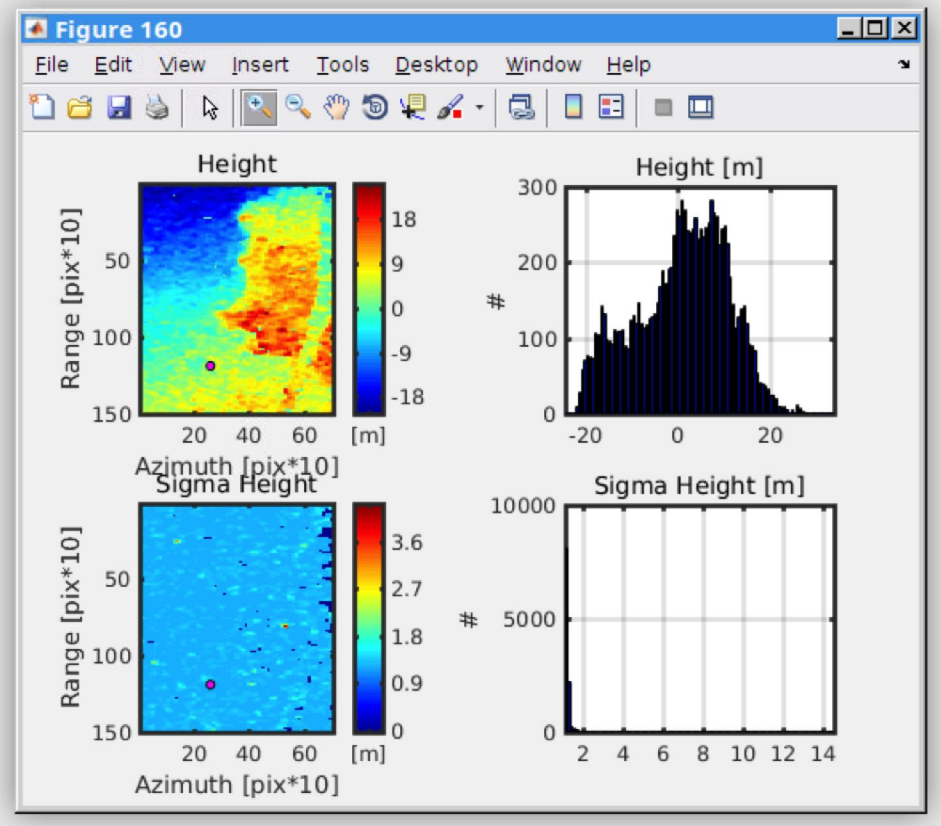
Click “plot param.” to plot your estimated parameters.

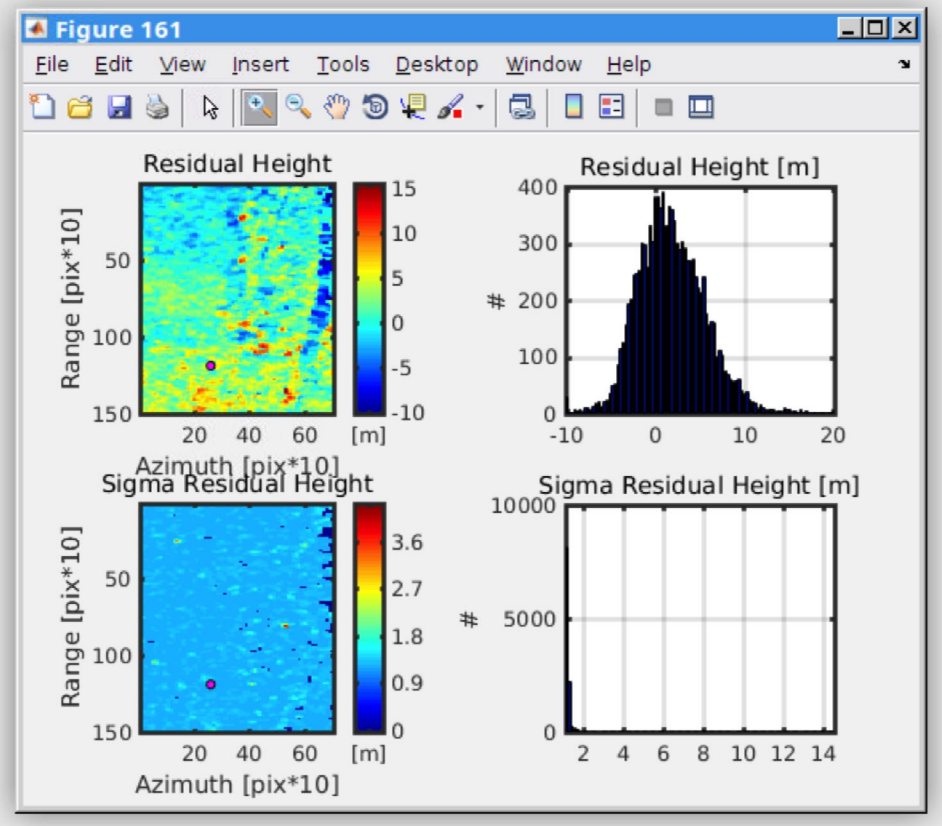




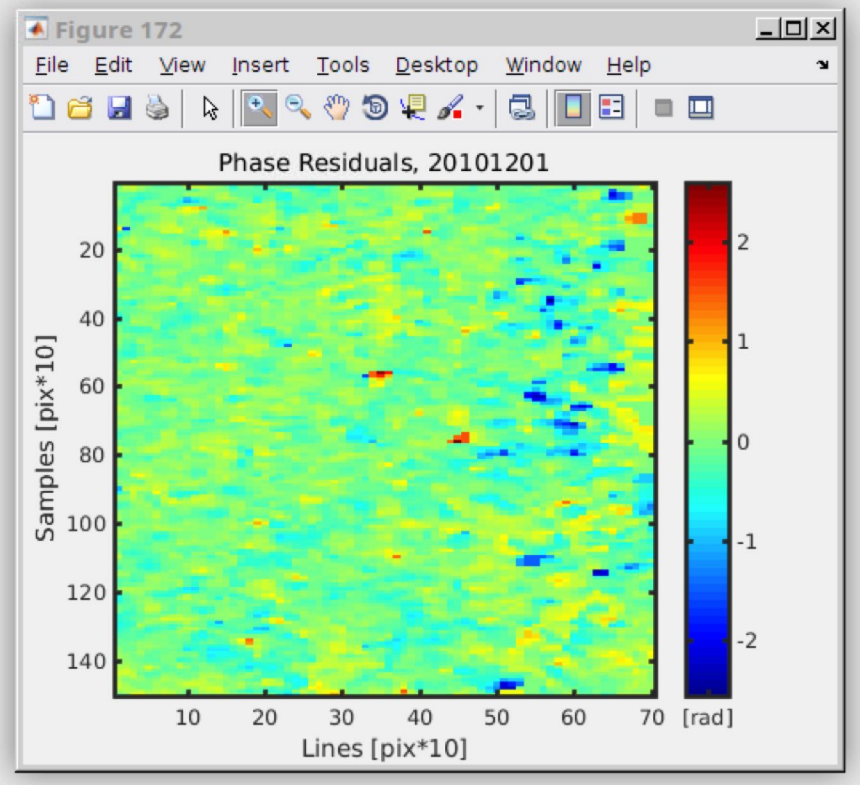


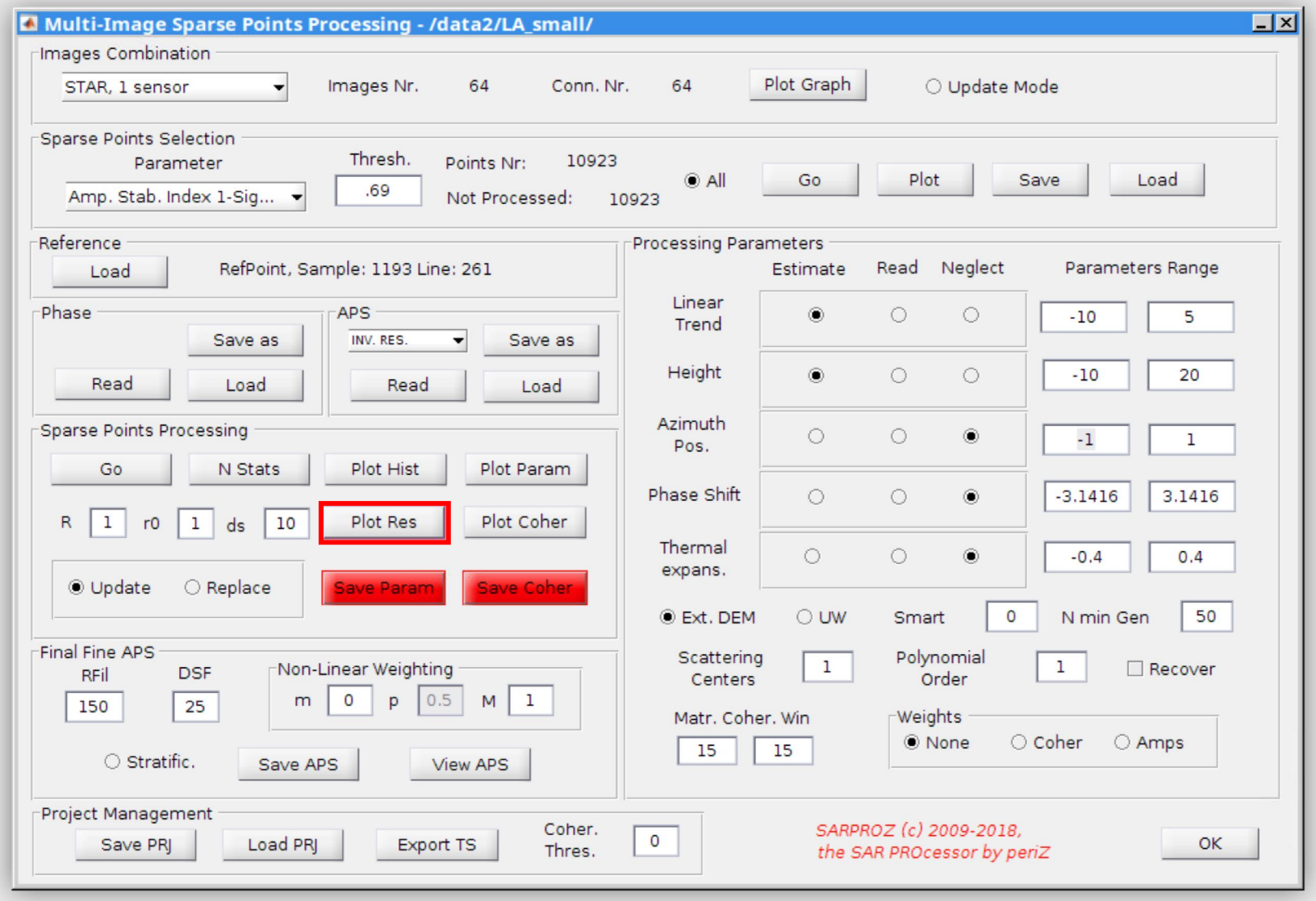
Estimated velocity and cumulative displacement for the selected points. Note that again the peak of histogram is at zero, meaning that the most points have a zero relative velocity with the reference point, indicating that the reference point we selected is most likely to be stable.





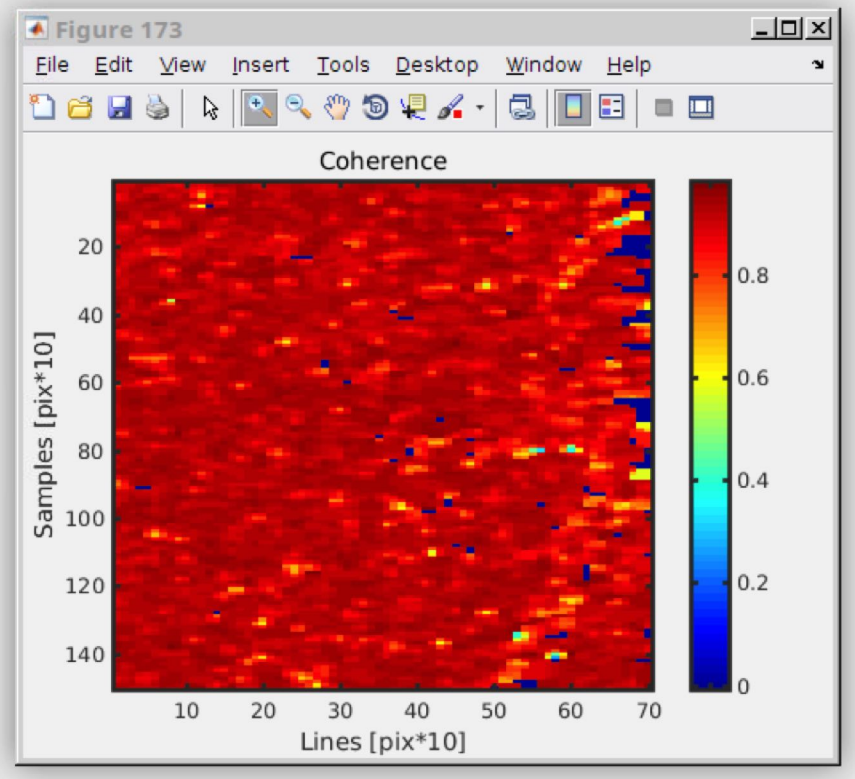
Estimated height and residual height for the selected points. Note that again the peak of residual height histogram is at zero, meaning that the most points have a zero relative *residual height* with the reference point, indicating that the reference point is located on the ground.

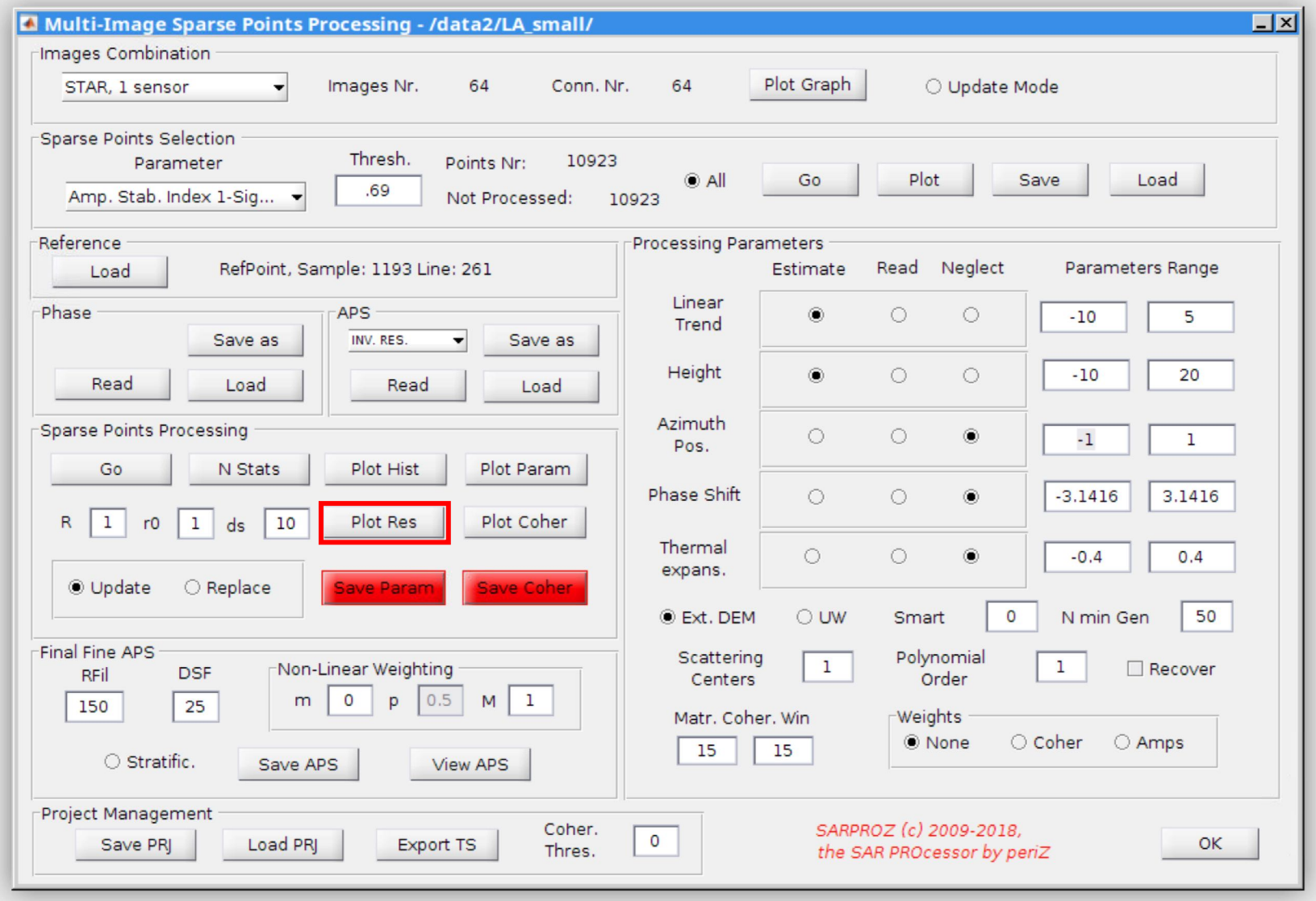




Step 3-6: residual phase

Click "plot res." to check the residual phase one by one. Residual phase is what is left by removing phase from APS and the estimated parameters. If the parameters and APS are all well estimated, the residual phase should be small.



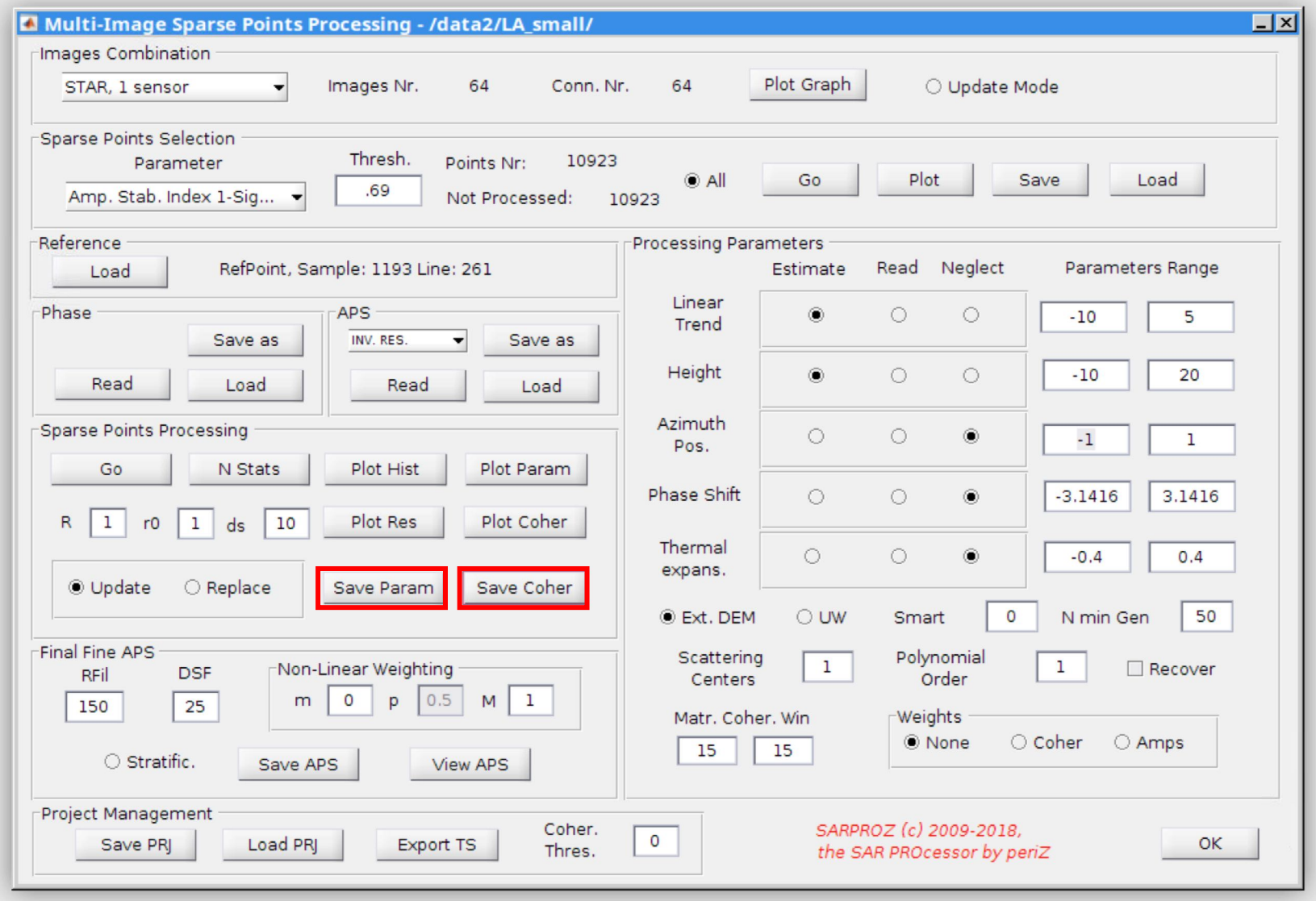


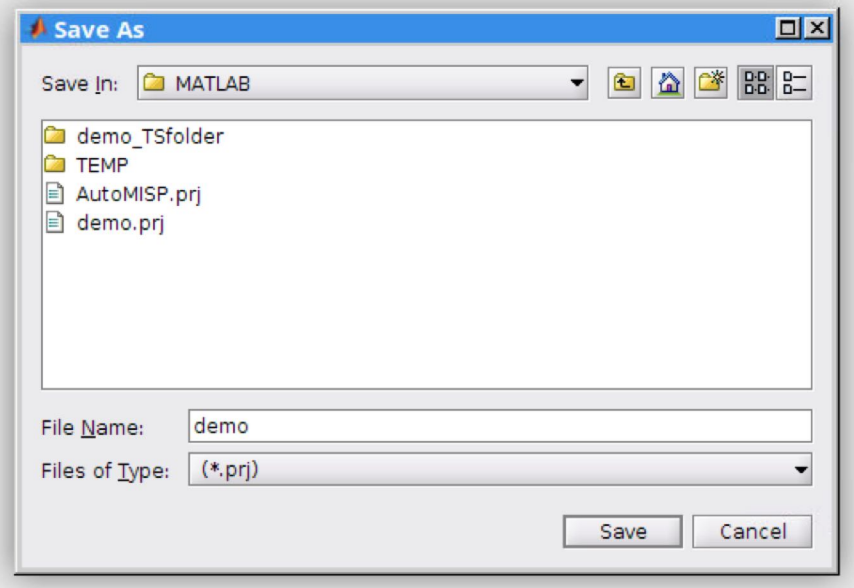
Step 3-7: temporal coherence

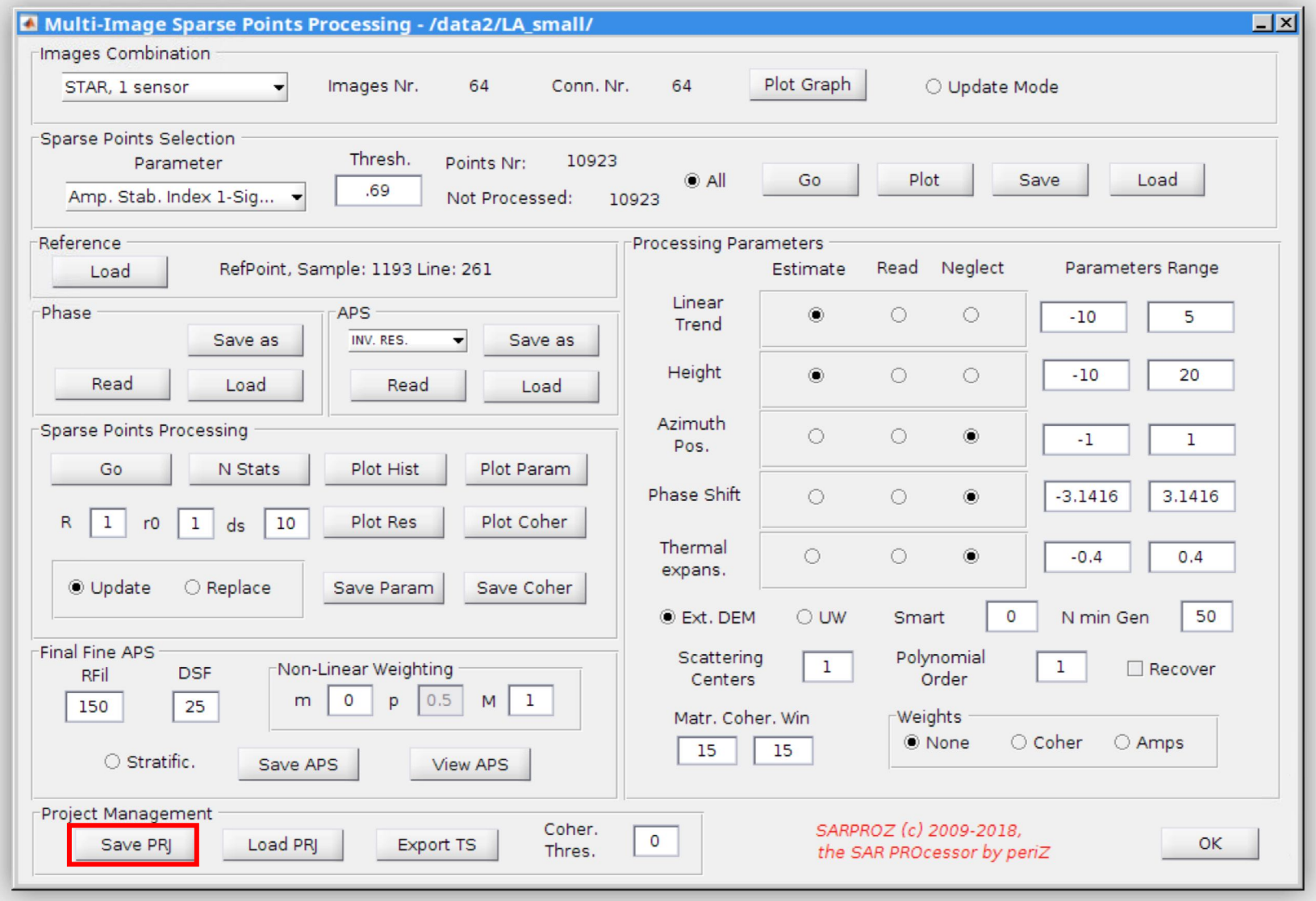
Click “plot coher.” to check the temporal coherence for the selected points. The higher the temporal coherence the better is the estimated parameters and APS.

Step 3-8: save parameters

If you are satisfied with the estimated parameters, click “save param.” to save the parameters (velocity, residual height, …). Click “save coher.” to save the temporal coherence. The red will go away after parameters and coherence are saved.

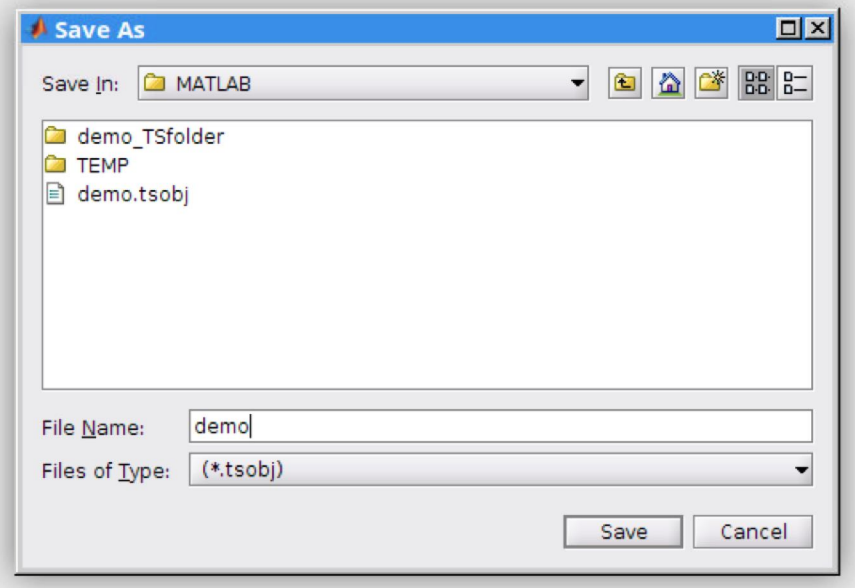


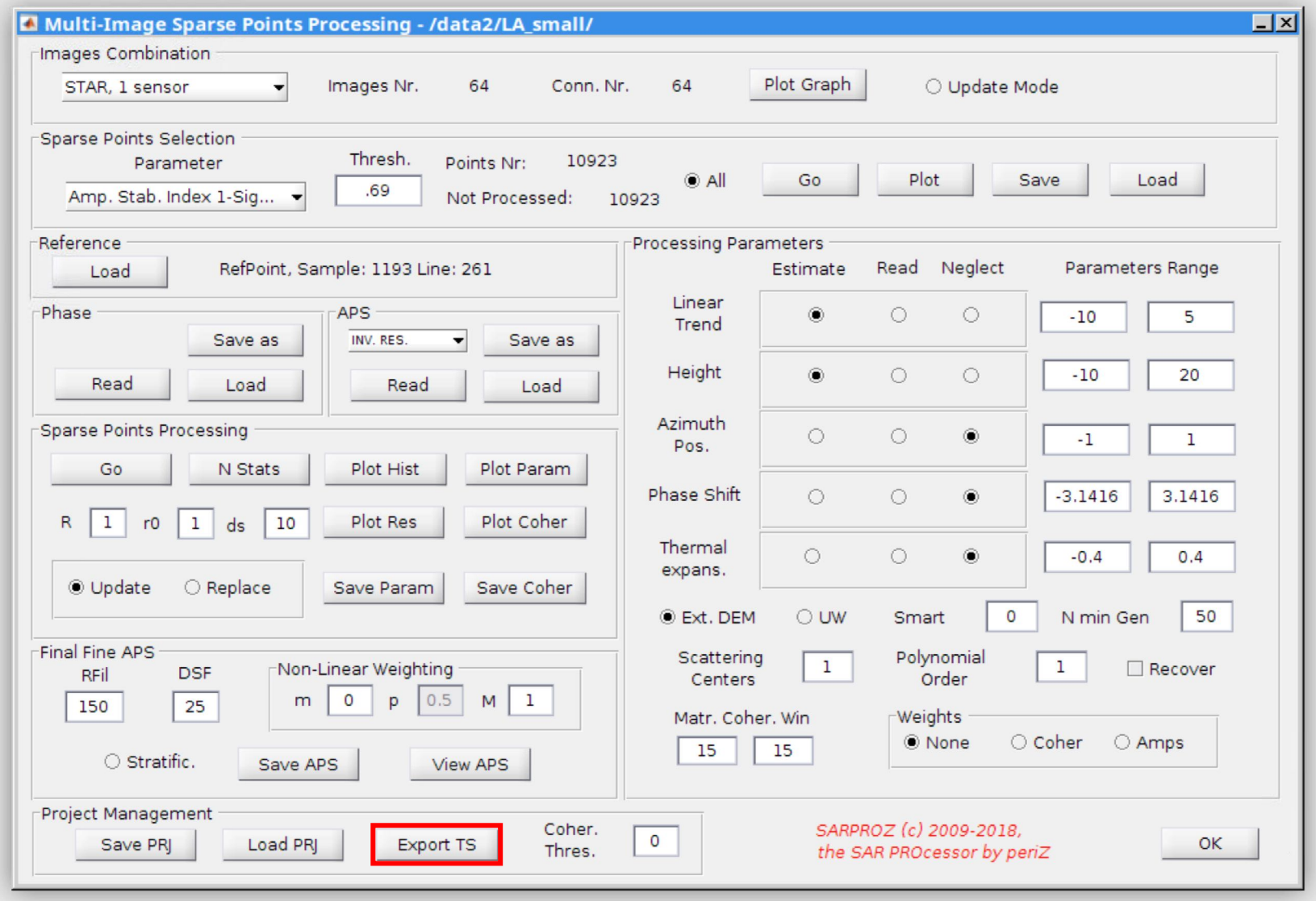




Step 3-9: save project

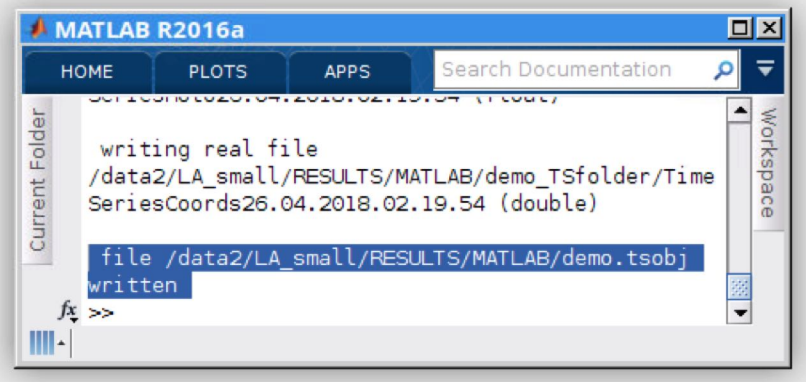
Click “save prj.” to save the project with your own name. Note that the file extension is “.prj”.

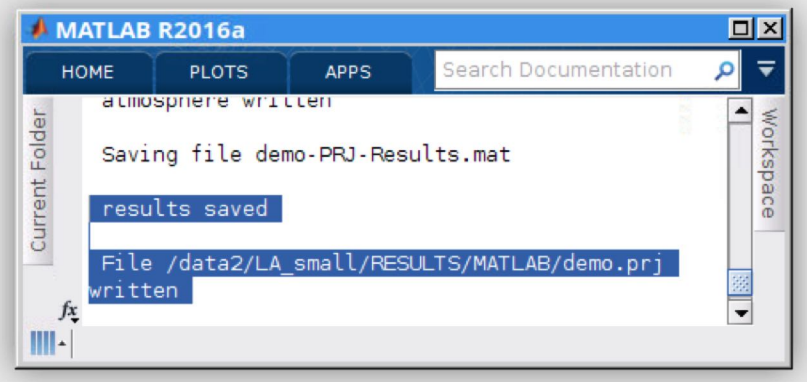




Step 3-10: save time series

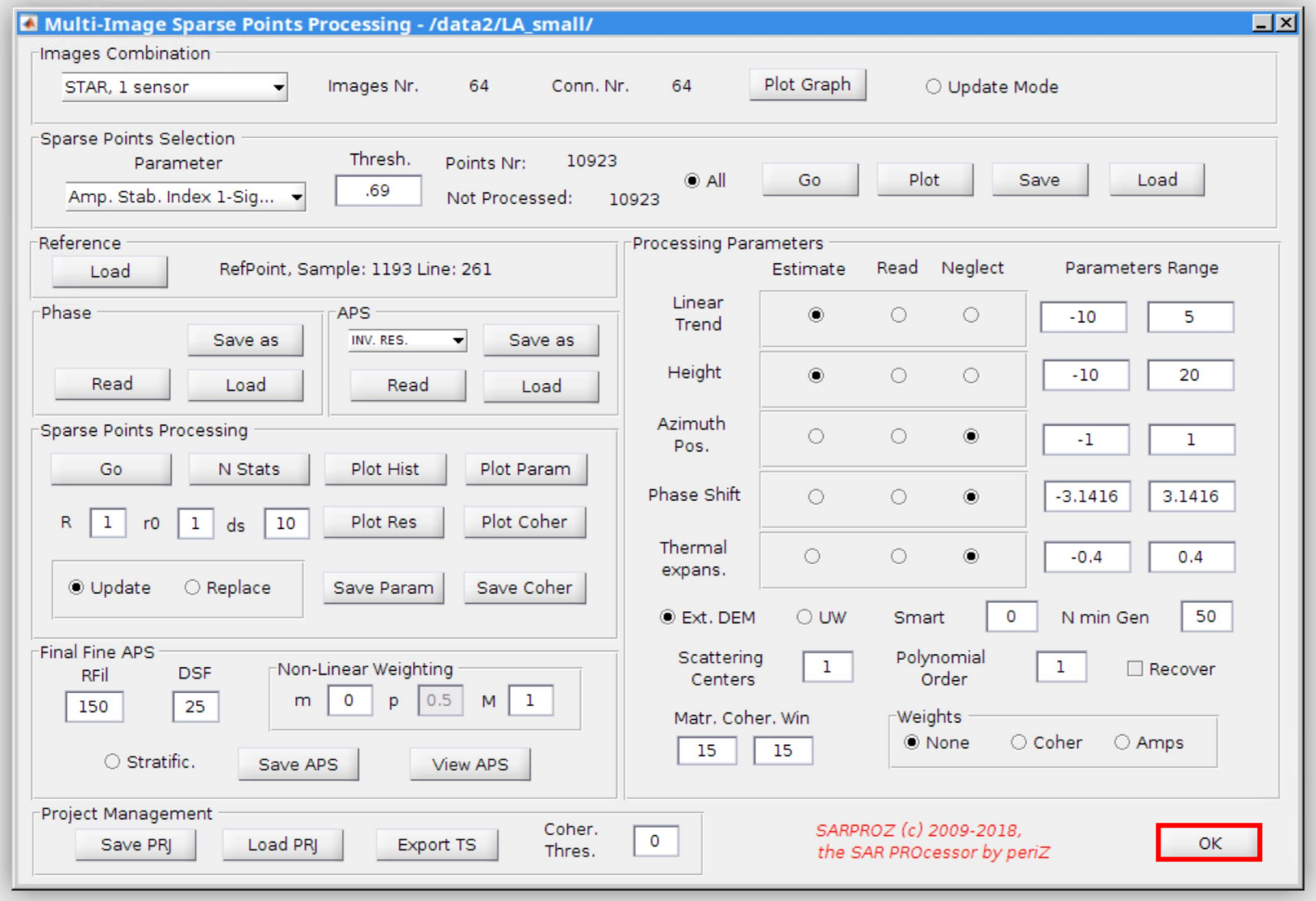
Click “export TS” to export the time series with your own filename. We will later use this file to geocode time series to Google Earth. Note that the file extension is “.tsobj”.





Step 3-11: Exit

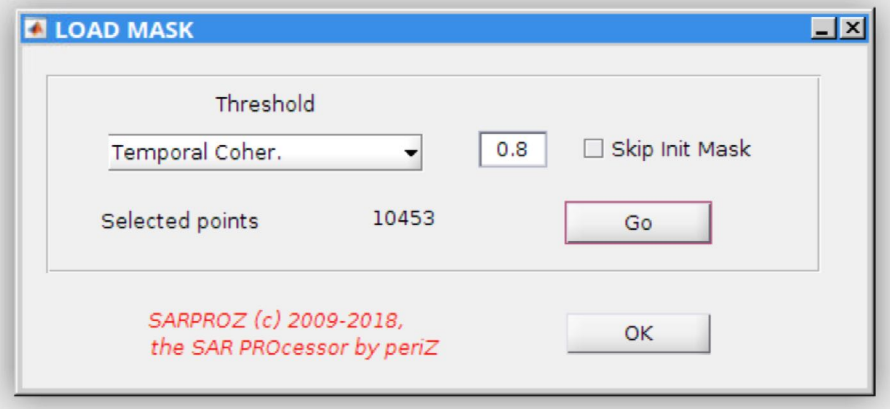
At last, note that when you save something in Sarproz, you will always receive a prompt in the command window. We are now done with this part. Click "ok" to close the module.



Part 4:
Display the results

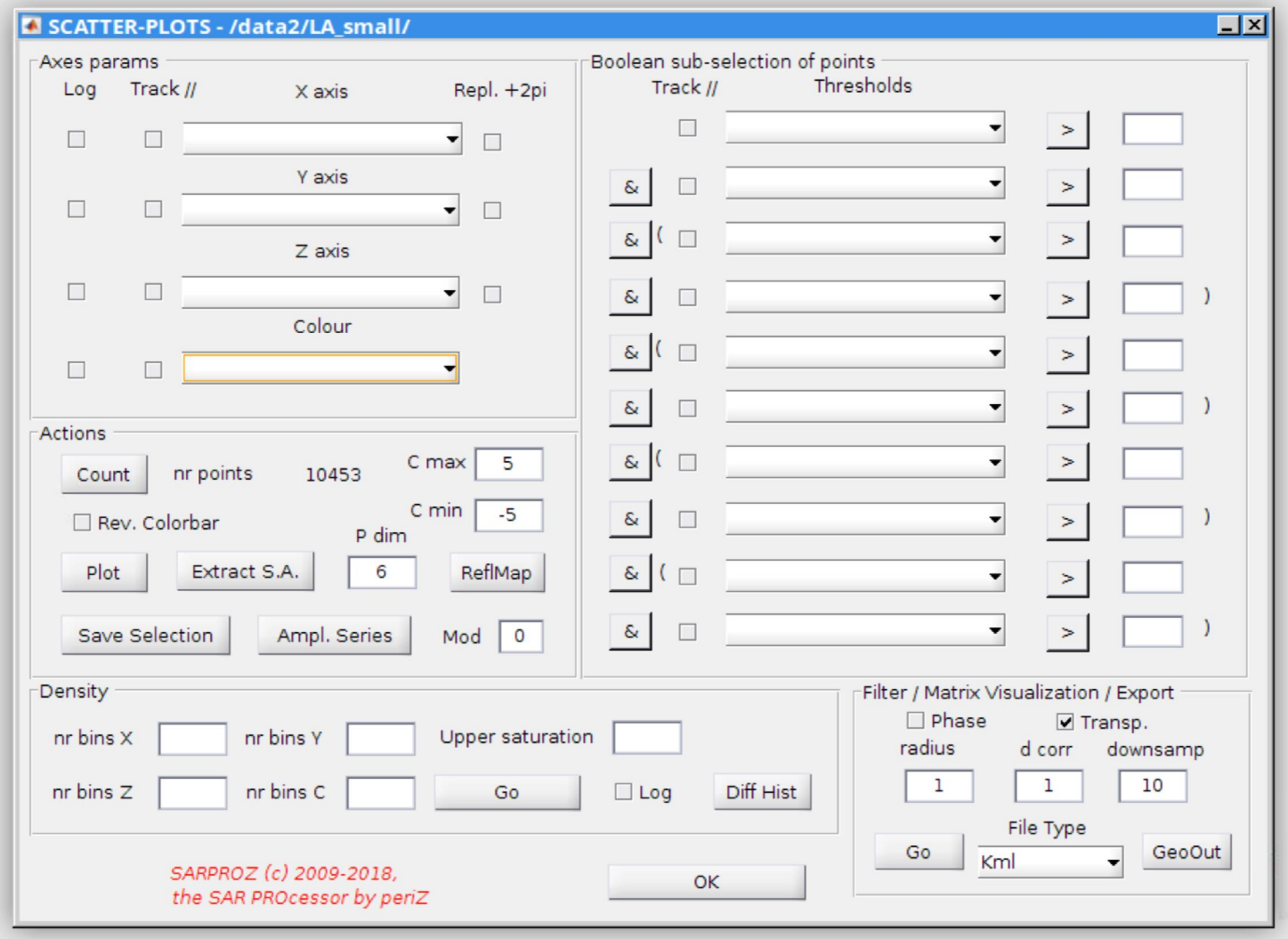
Step 4-1: load mask

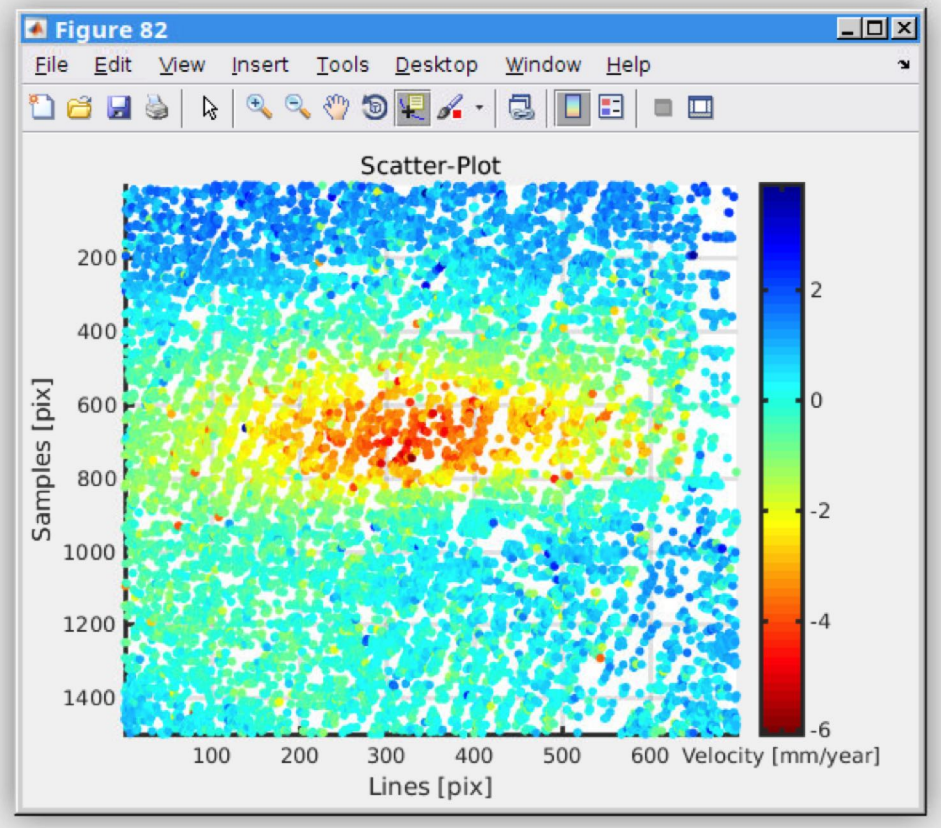
In this section we will use the “scatter plots” module to quickly check (and export) the results we just processed. The first step is to load an initial number of points to be displayed.
Open “load mask” module from “site processing”. Select “temporal coherence” as the parameter, and select “0.8” as the threshold. Click “go” to calculate the number of points that are above threshold.

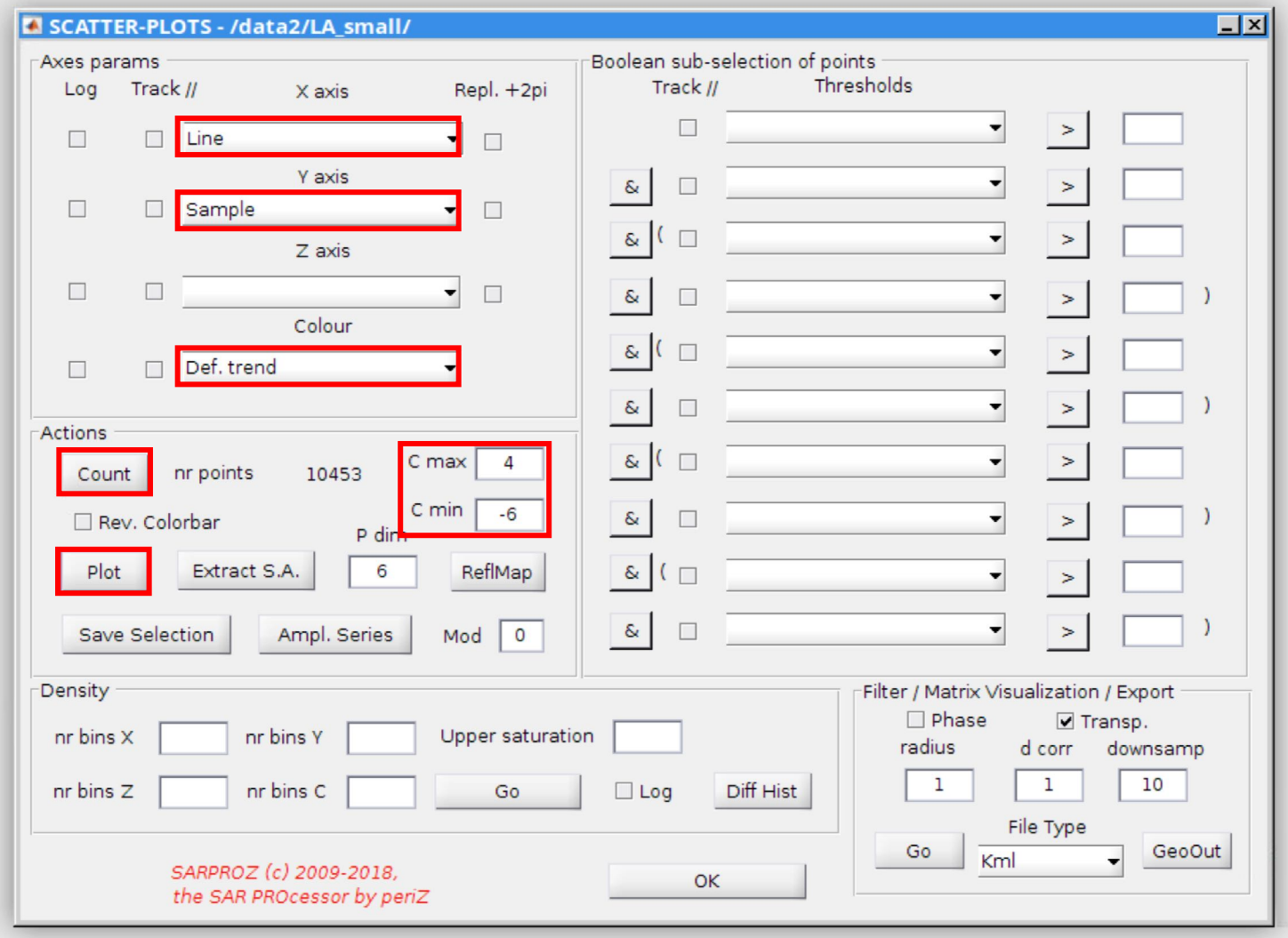


Step 4-1: scatter plots

Open “scatter plots” module from “site processing”. The scatter plots module is a powerful module to display results with very flexible options.

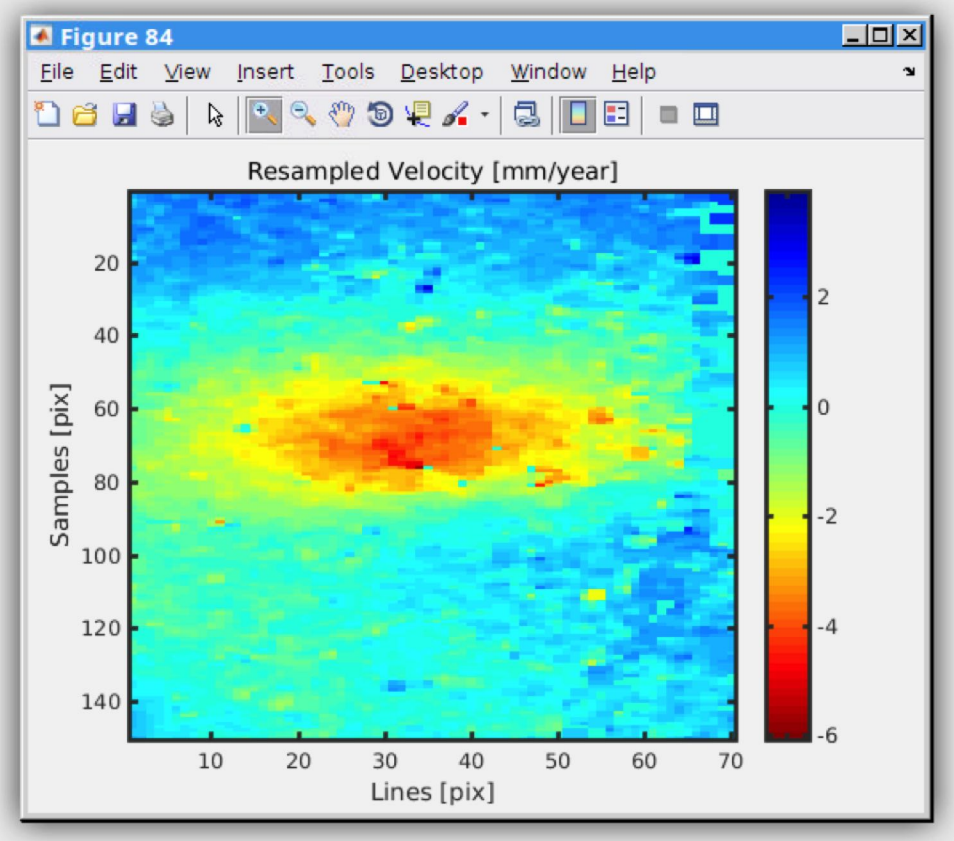


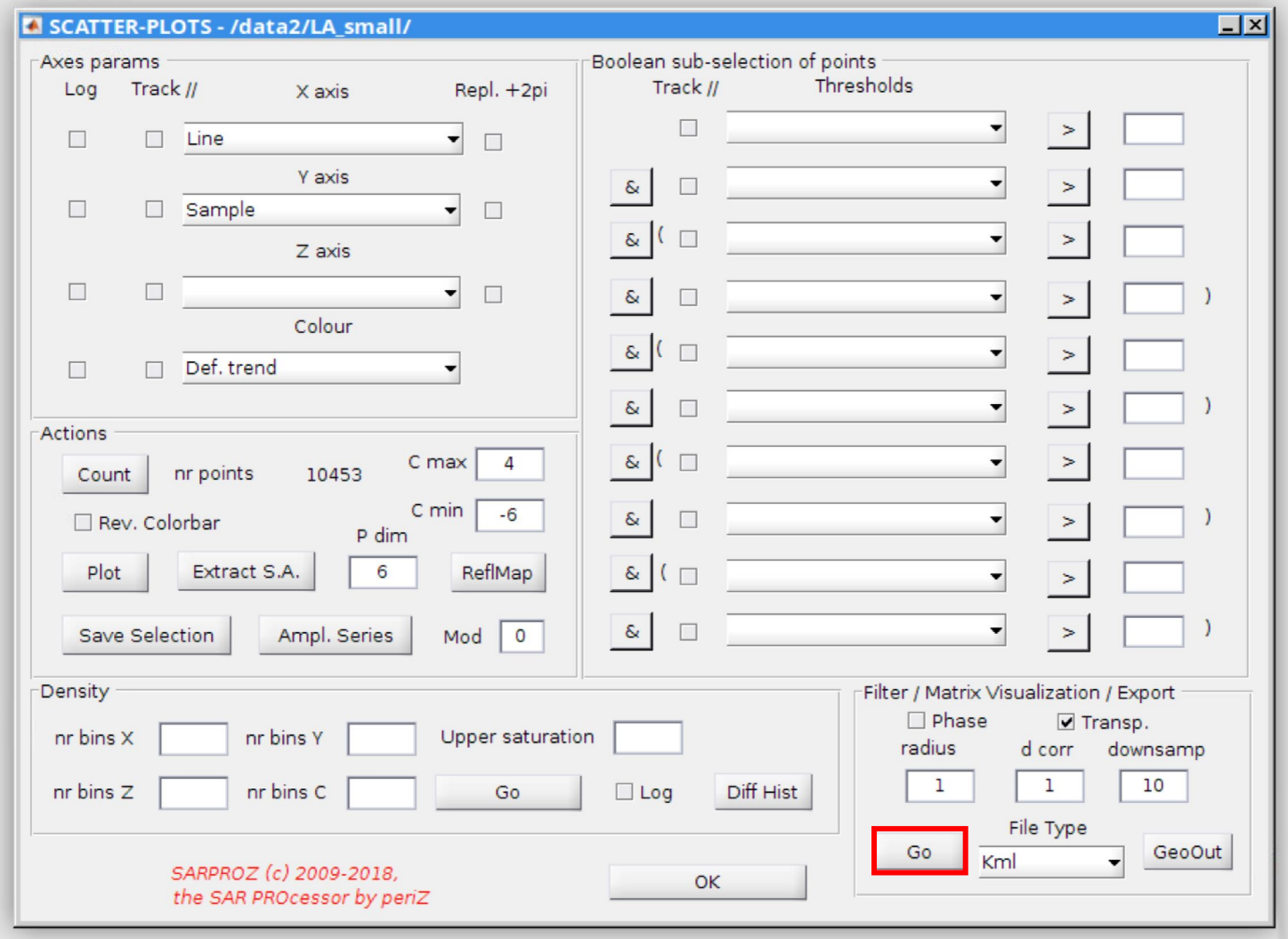




Step 4-3: plot

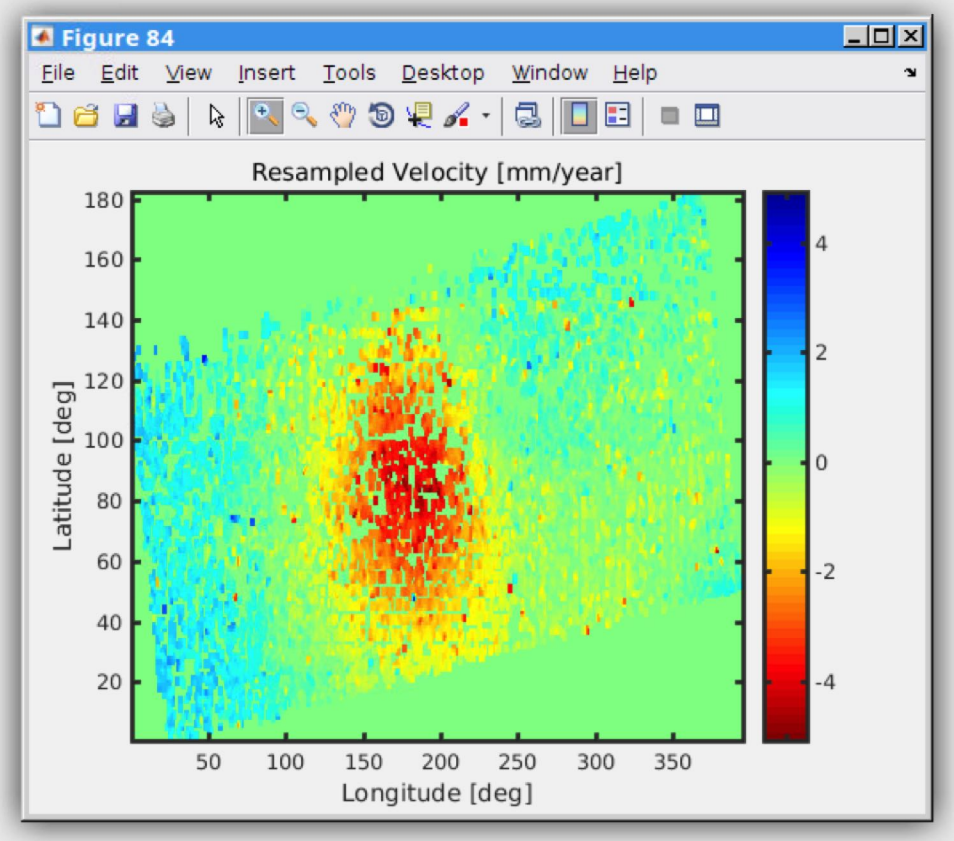
In “axes params.” frame, select “line” for x-axis and “sample” as y-axis and “deformation trend” (velocity) as the color. In “actions” frame, click “count” to count the number of points. Then click “plot” to plot the displacement.

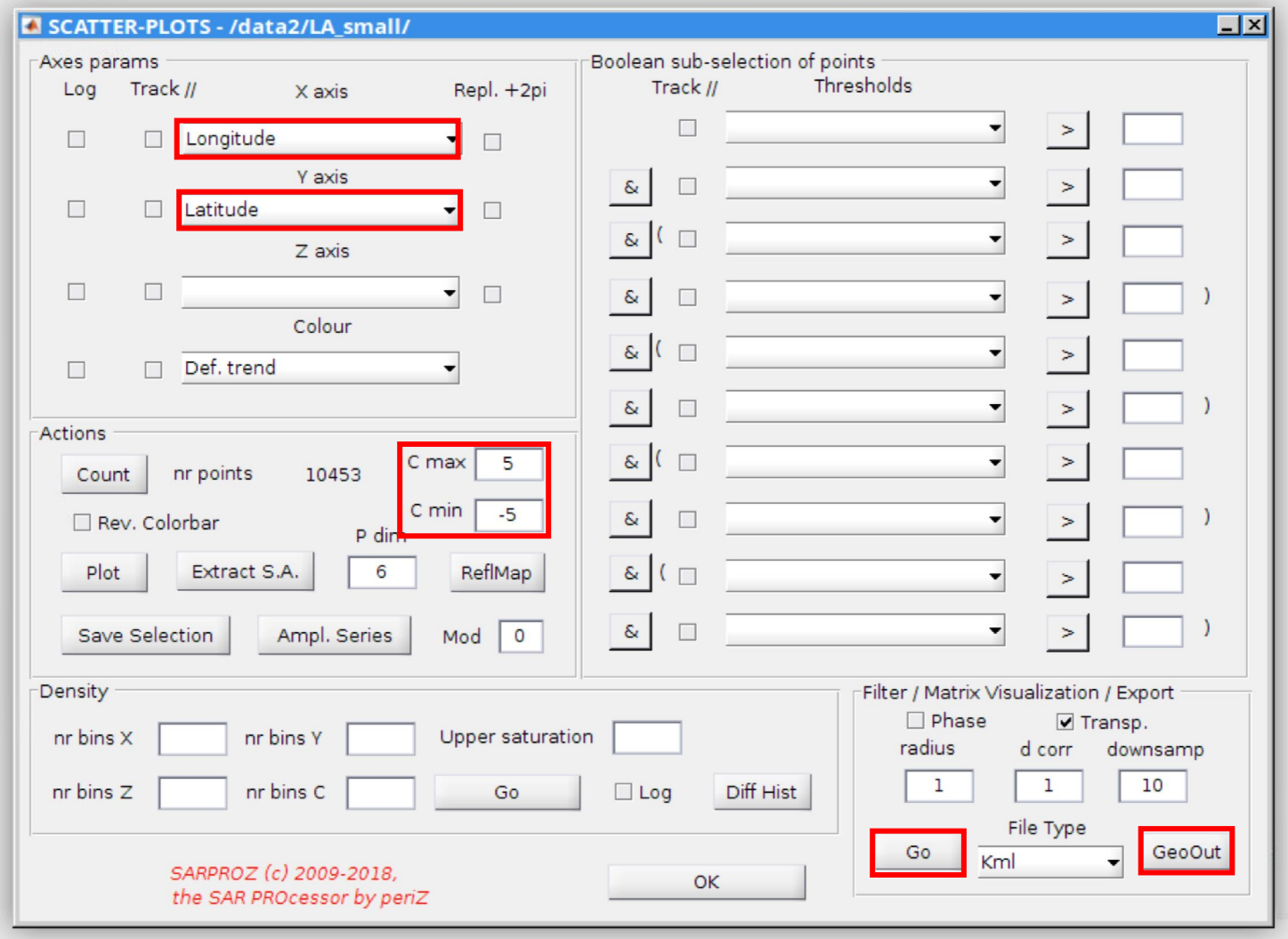




Step 4-3 (cont'd)

You can also click "go" in the "filter/matrix visualization/export" frame to view the results in matrix and down sampled way, instead of the scatter plot.



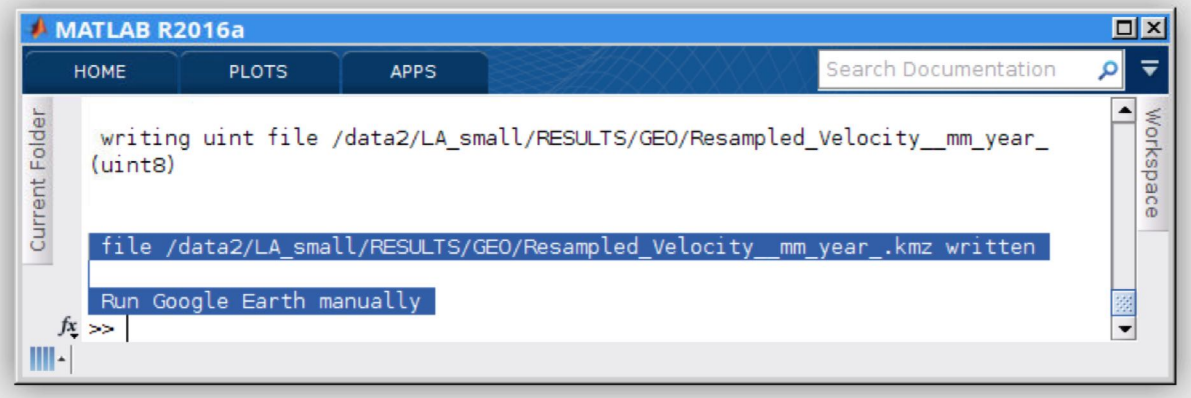


Step 4-4: geocode to Google Earth

If you wish to geocode this result to Google Earth, you need to select “longitude” as x-axis and “latitude” as y-axis. Then click “go” again to see the result in lat/lon coordinate. At last, click “GeoOut” to export the result in .kmz format.

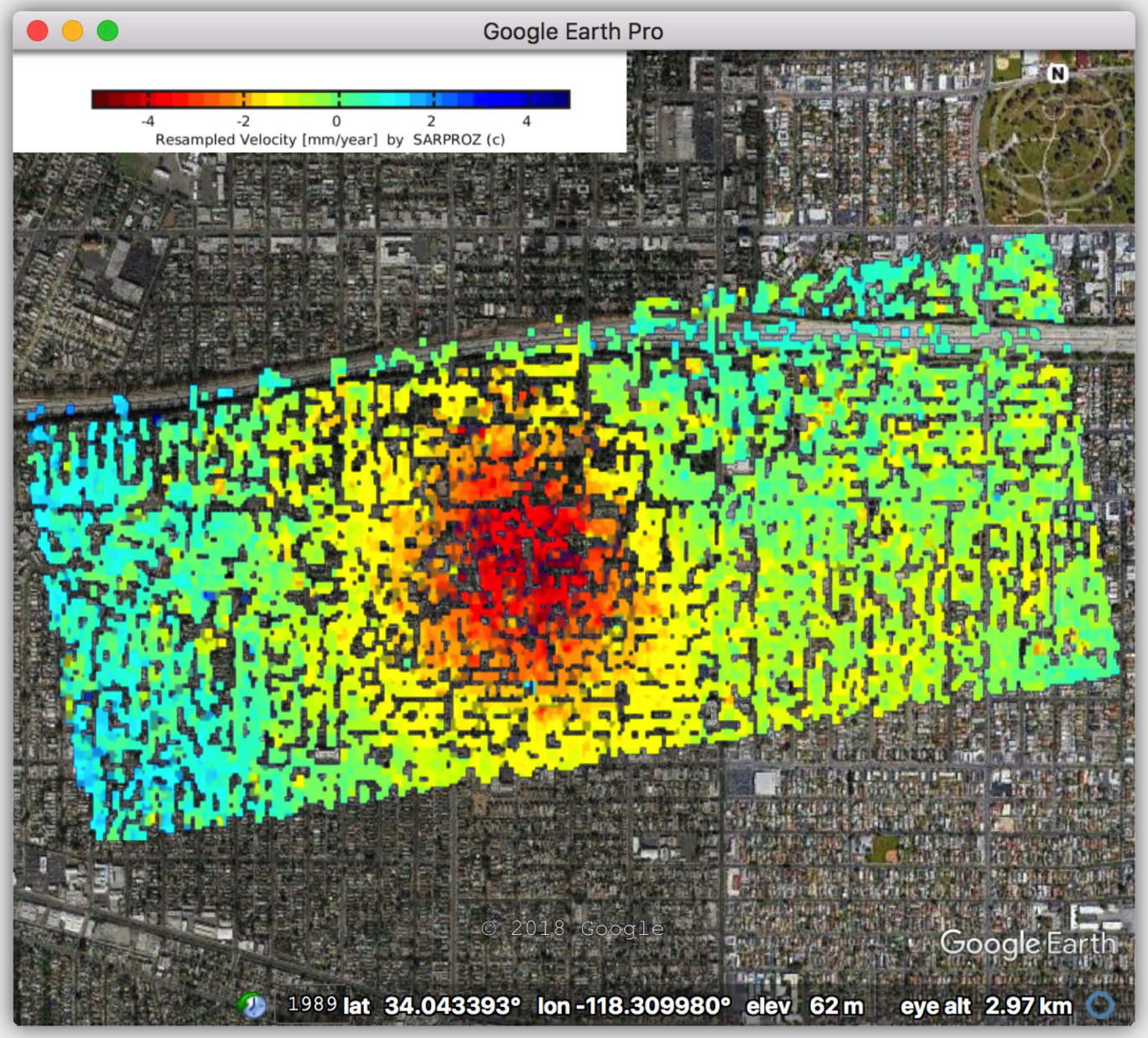
Step 4-4 (cont'd)

If your Google Earth does not open automatically, locate the .kmz file path as shown in the Matlab command window and run Google Earth manually.



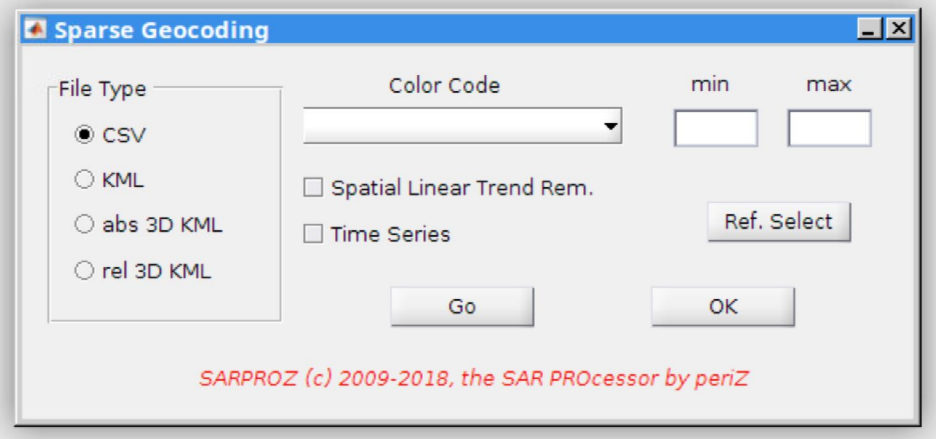
Step 4-5: open Google Earth

Open the kmz file in Google Earth. Please note that in step 4-4, we specified the color range with a symmetric interval ([-5, 5]), so that here the green color means zero velocity.



Step 4-6: sparse geocoding

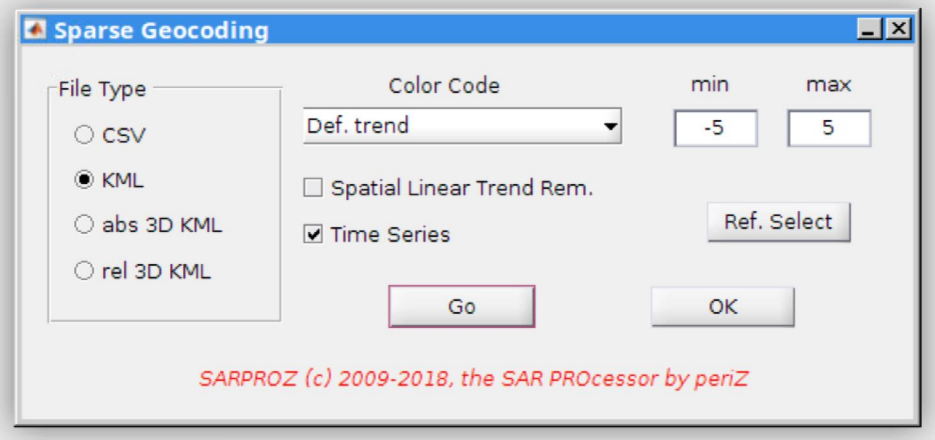
In addition, you can quickly export the the results you have just processed in section 3 with the “sparse geocoding” module. You can open this module from “site processing”. Note that this module will only export the most recent parameters you have estimated in “sparse points processing” module. We recommend you to use the “time series module” for exporting results because it is more powerful and comes with more options (the “time series module will be introduced in the next section”).

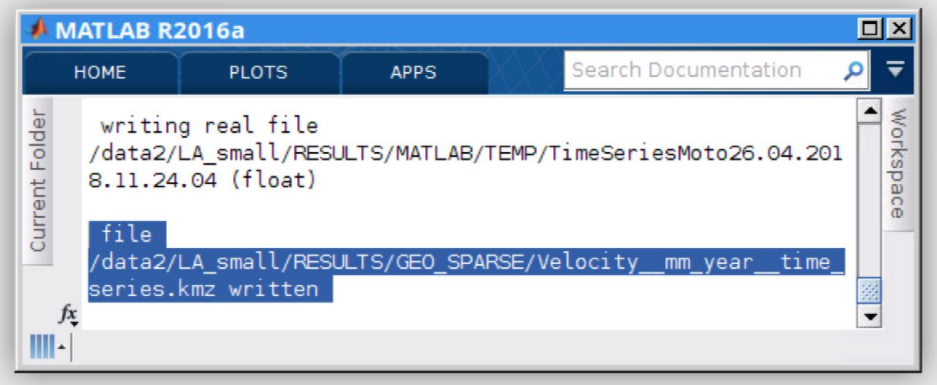


Step 4-6 (cont'd)

You can choose here to export your results in csv format or kml format. Here we choose to export "deformation trend" with a symmetric range of [-5, 5] (mm/year). We tick "time series" so that the time series of points will be shown in Google Earth. Click "go" to export. Again, if Google Earth does not open automatically, check the prompt in the command window for the file path and open it manually.

The final results are shown in the next section.

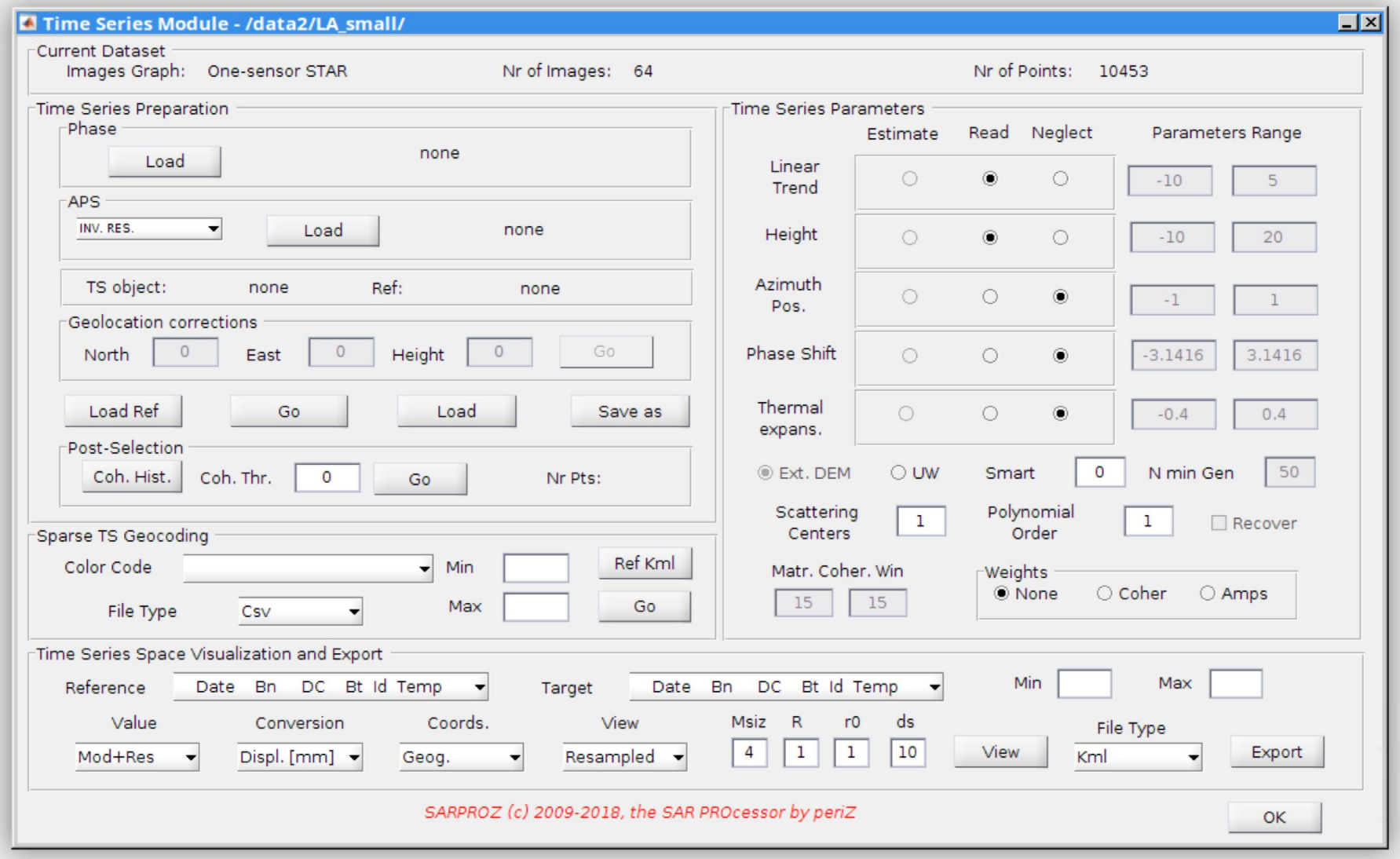




Part 5:
Geocode Time Series

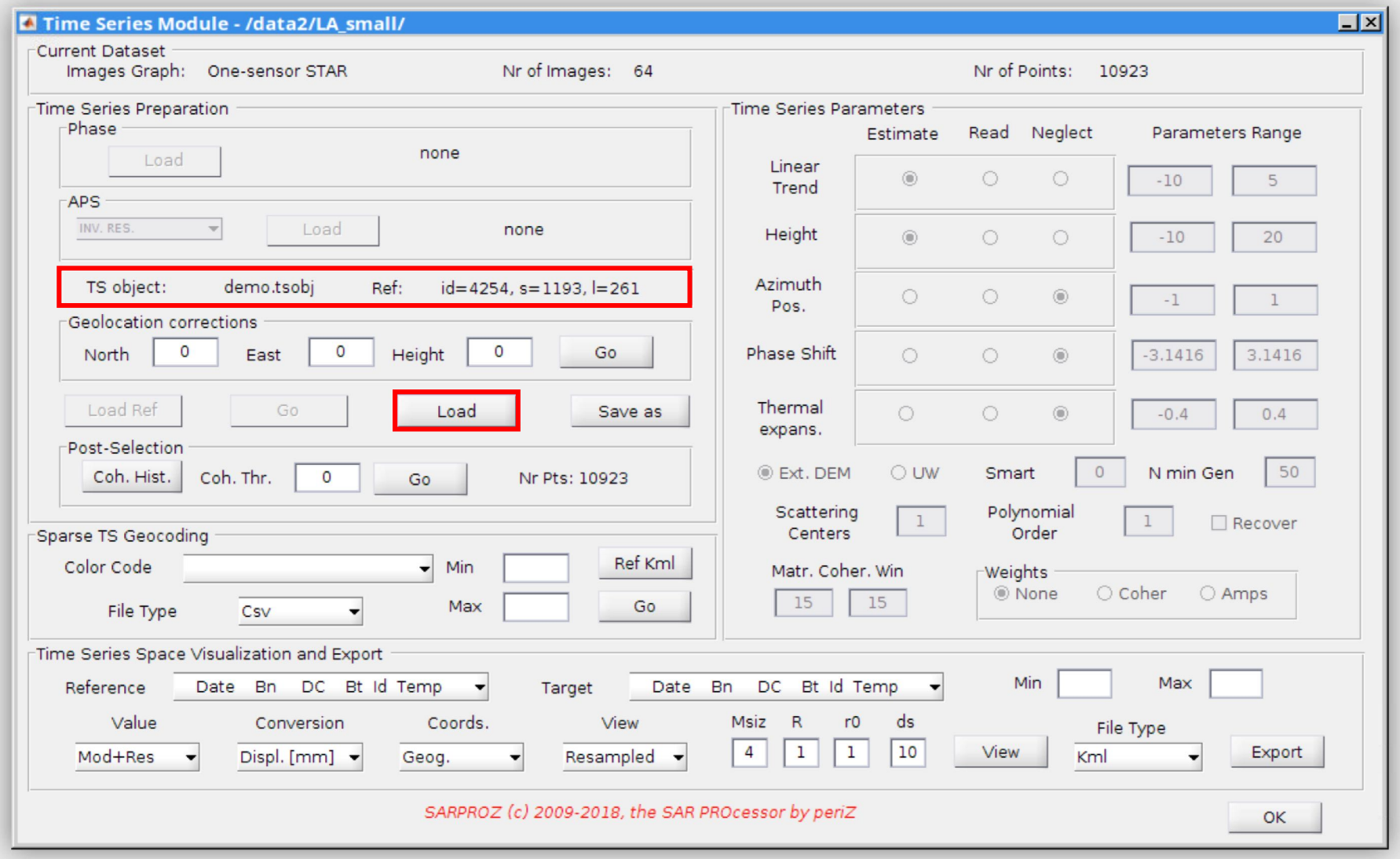
Step 5-1: time series module

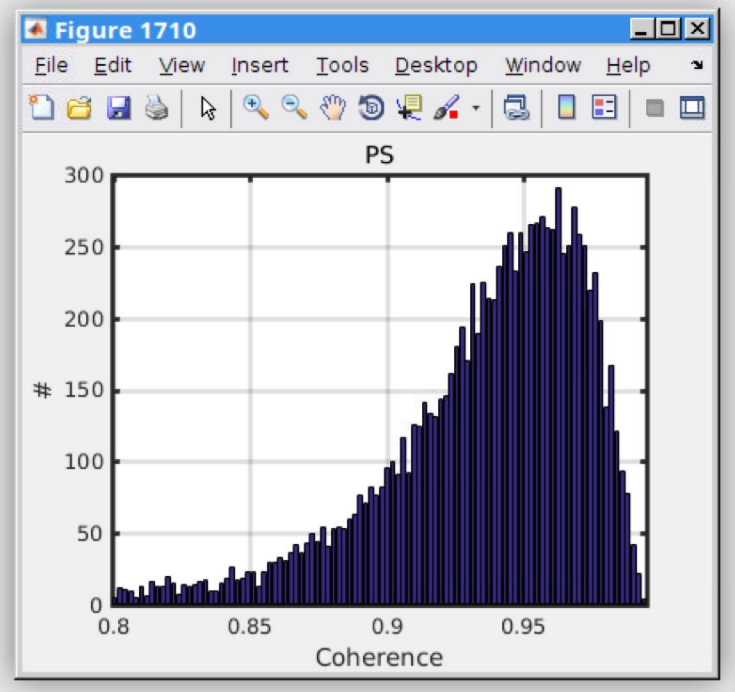
In this section we introduce a more powerful module for exporting time series. Open “time series module” from “site processing”.



Step 5-2: load tsobj

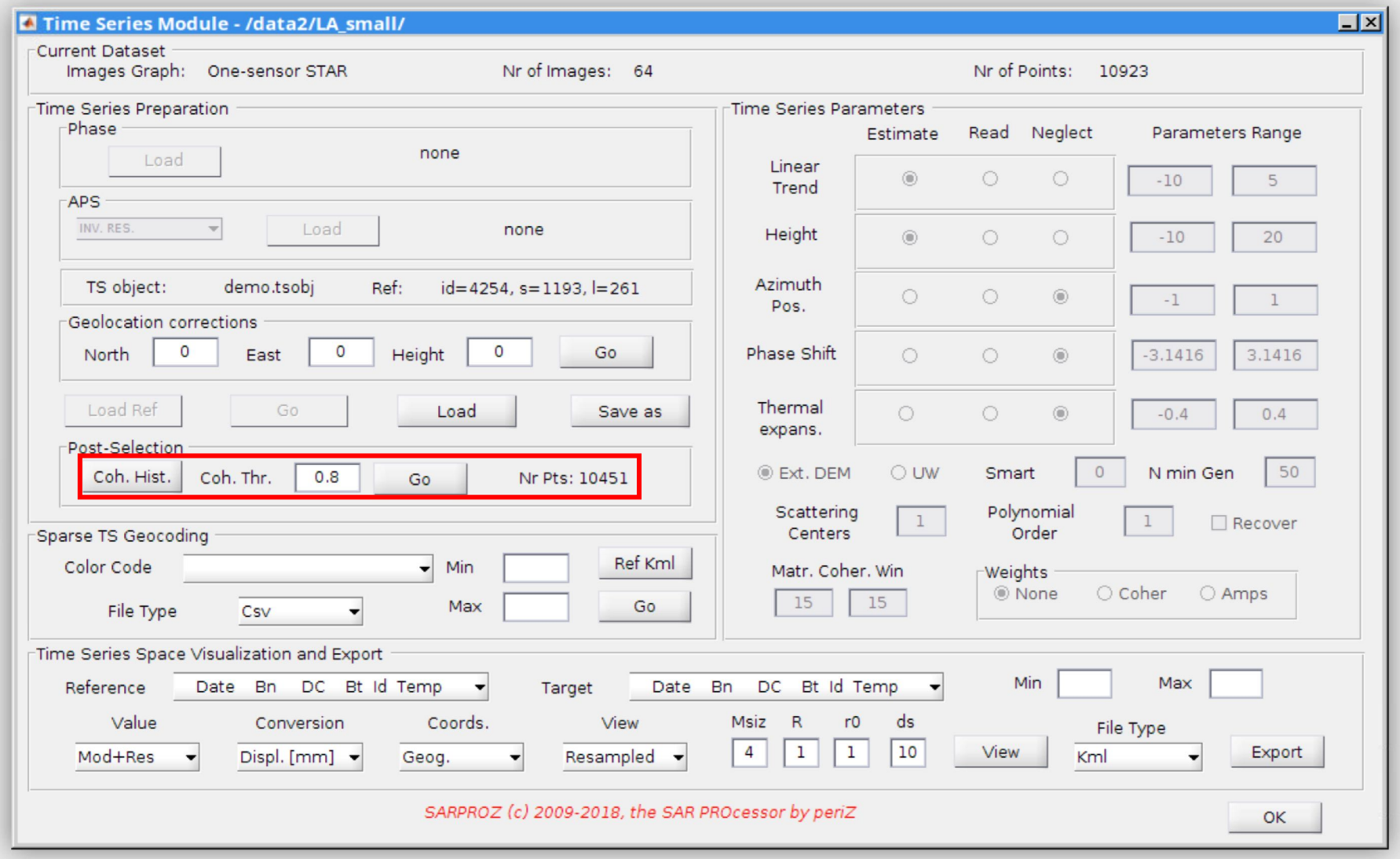
Click “load” in the “time series preparation” frame. Load the .tsobj file you saved in step 3-10. When the file is loaded you can see the information (filename, reference point) in the frame.

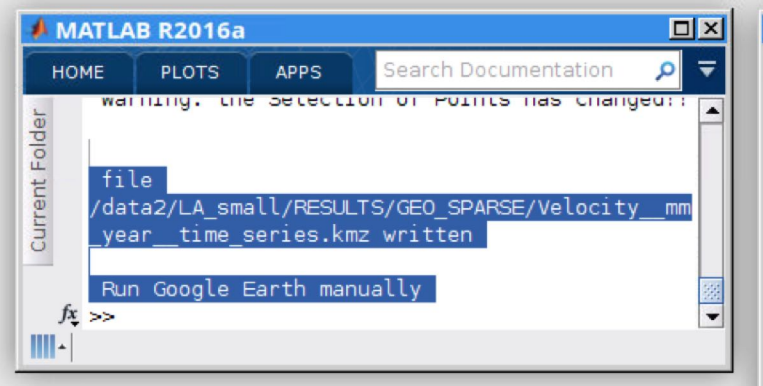


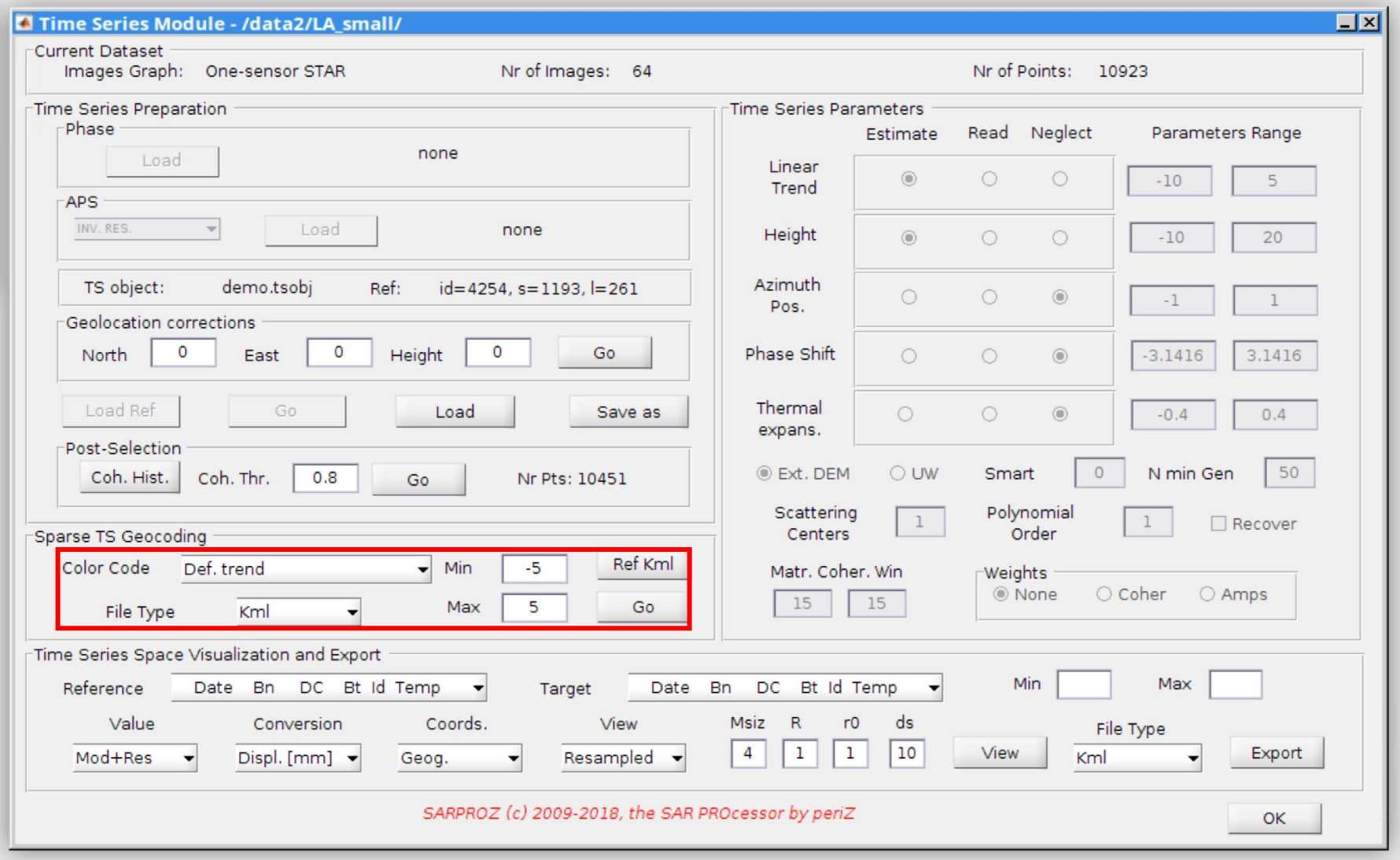


Step 5-3: select points

You can also set a threshold to specify the points you want to export. Here we use "0.8" as the threshold of temporal coherence. Click "go" to count the number of points. Click "Coh. Hist." to check the histogram after thresholding.





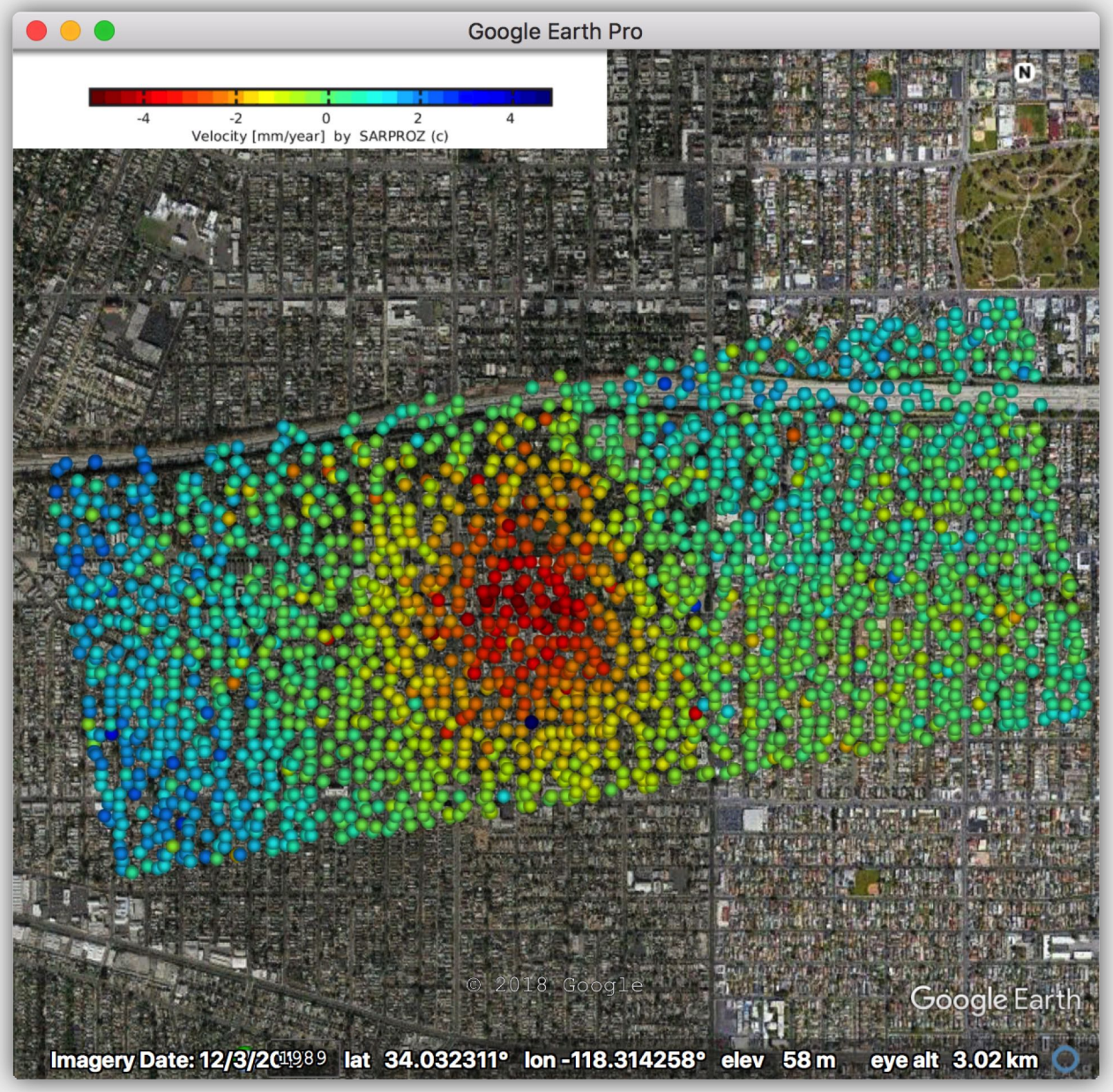


Step 5-4: geocoding

In “sparse TS geocoding” frame, select “deformation trend” as color code, “kml” as the file type. Use a symmetric color range, [-5, 5]. Then click “go” to export the time series.

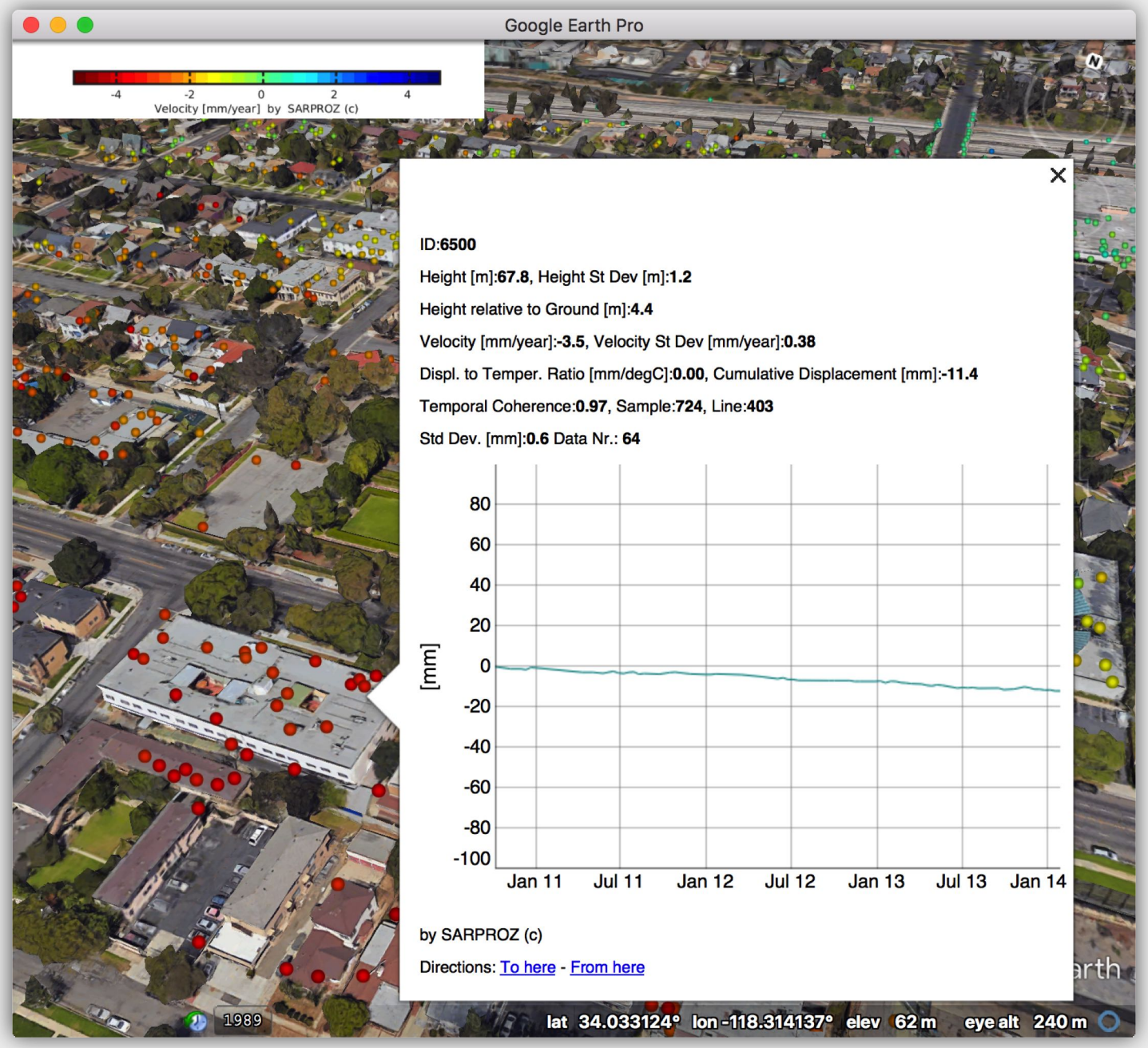
Step 5-5: open Google Earth

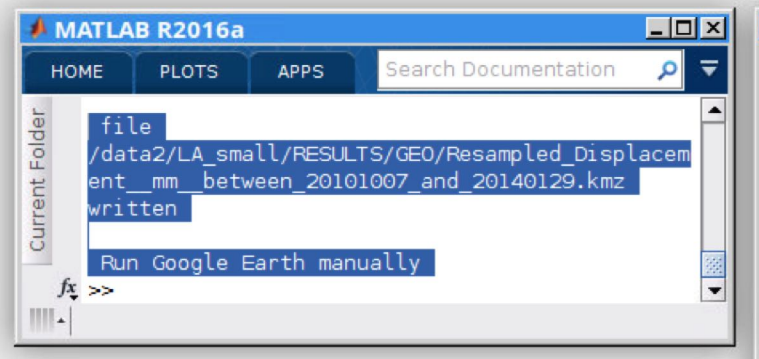
Open the `Velocity__mm_year__time_series.kmz` file in Google Earth.



Step 5-6: check time series

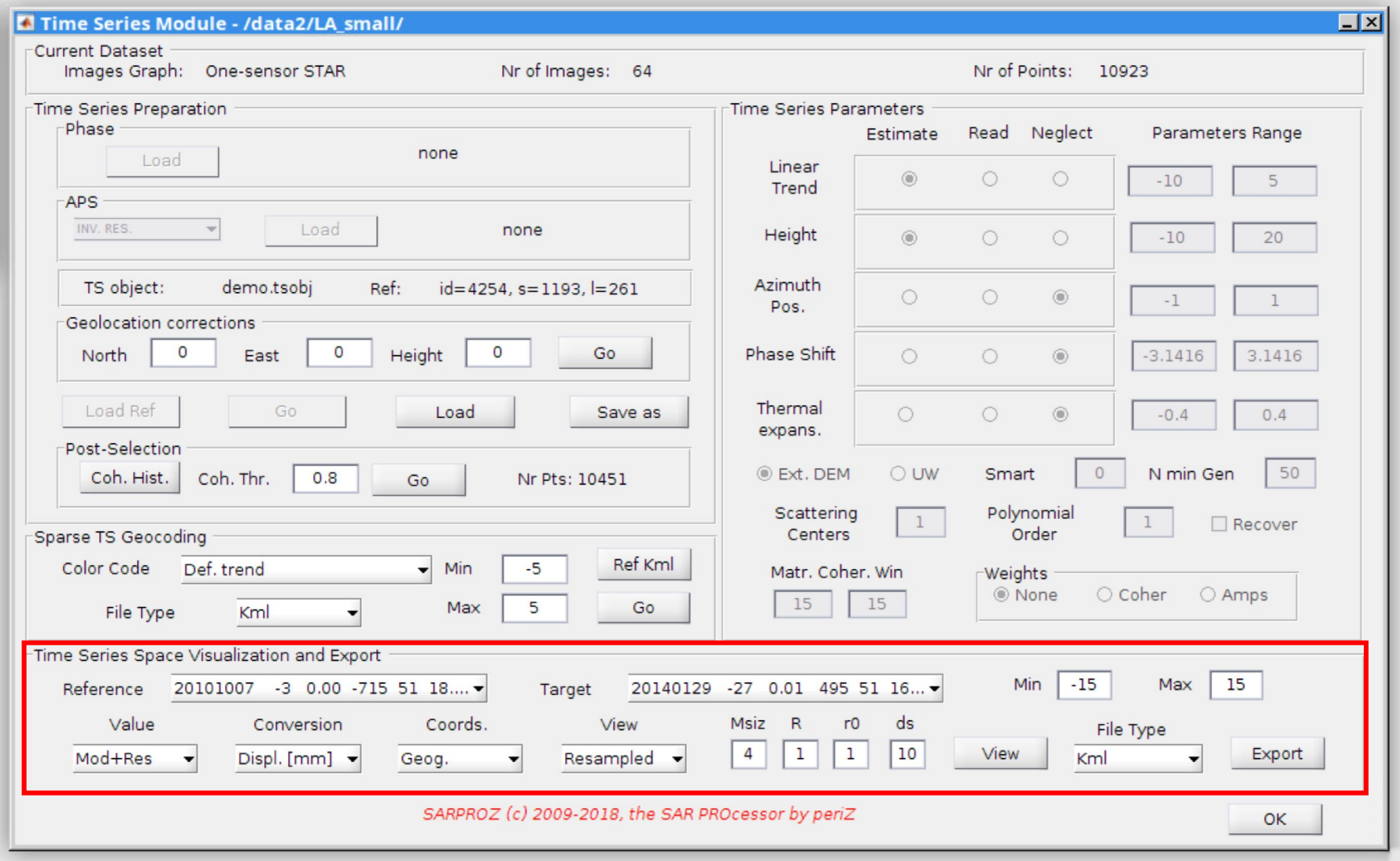
You can zoom in, click on any points, check the time series of that point along with other parameters, such as residual height, velocity, temporal coherence, etc.

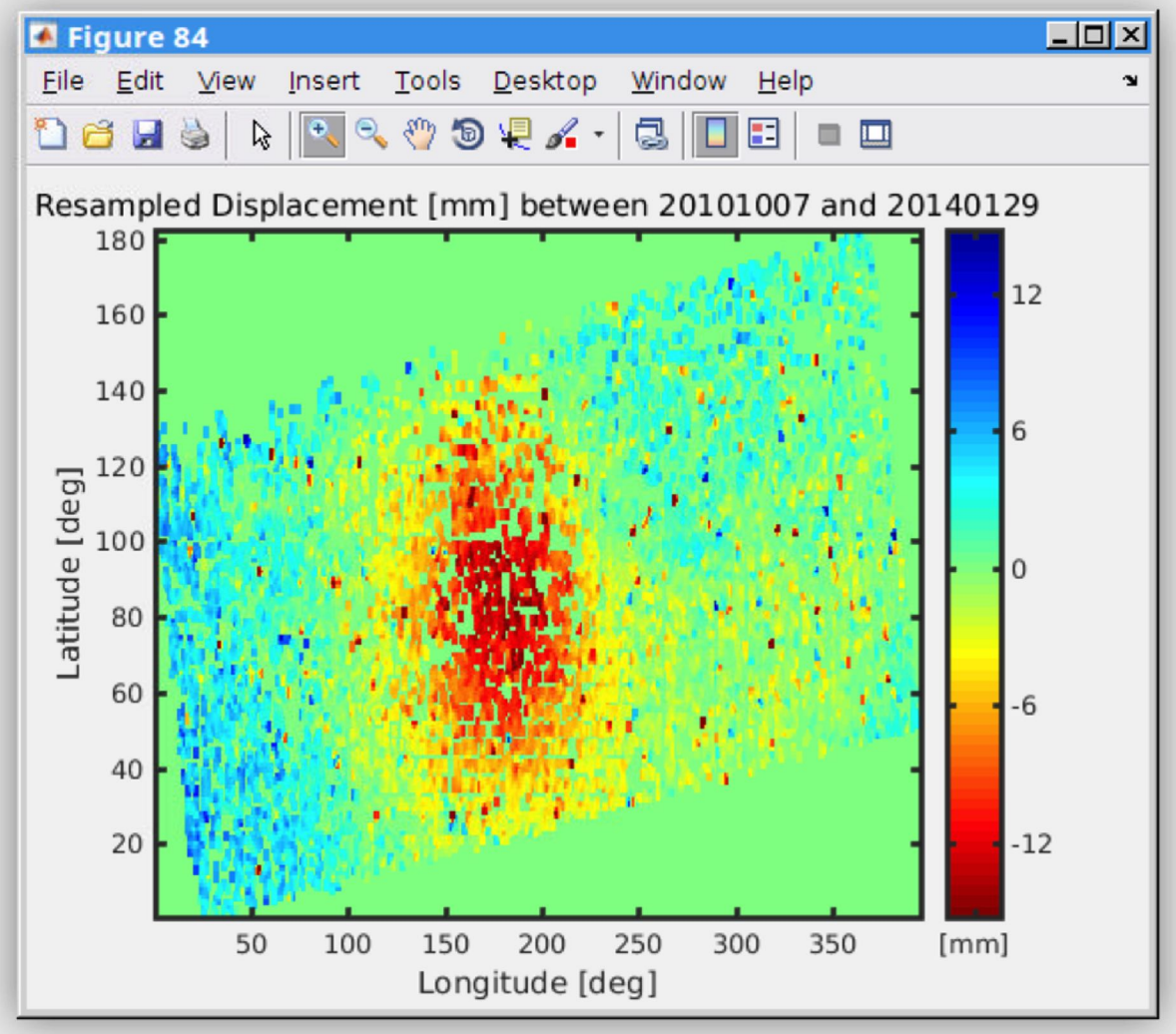




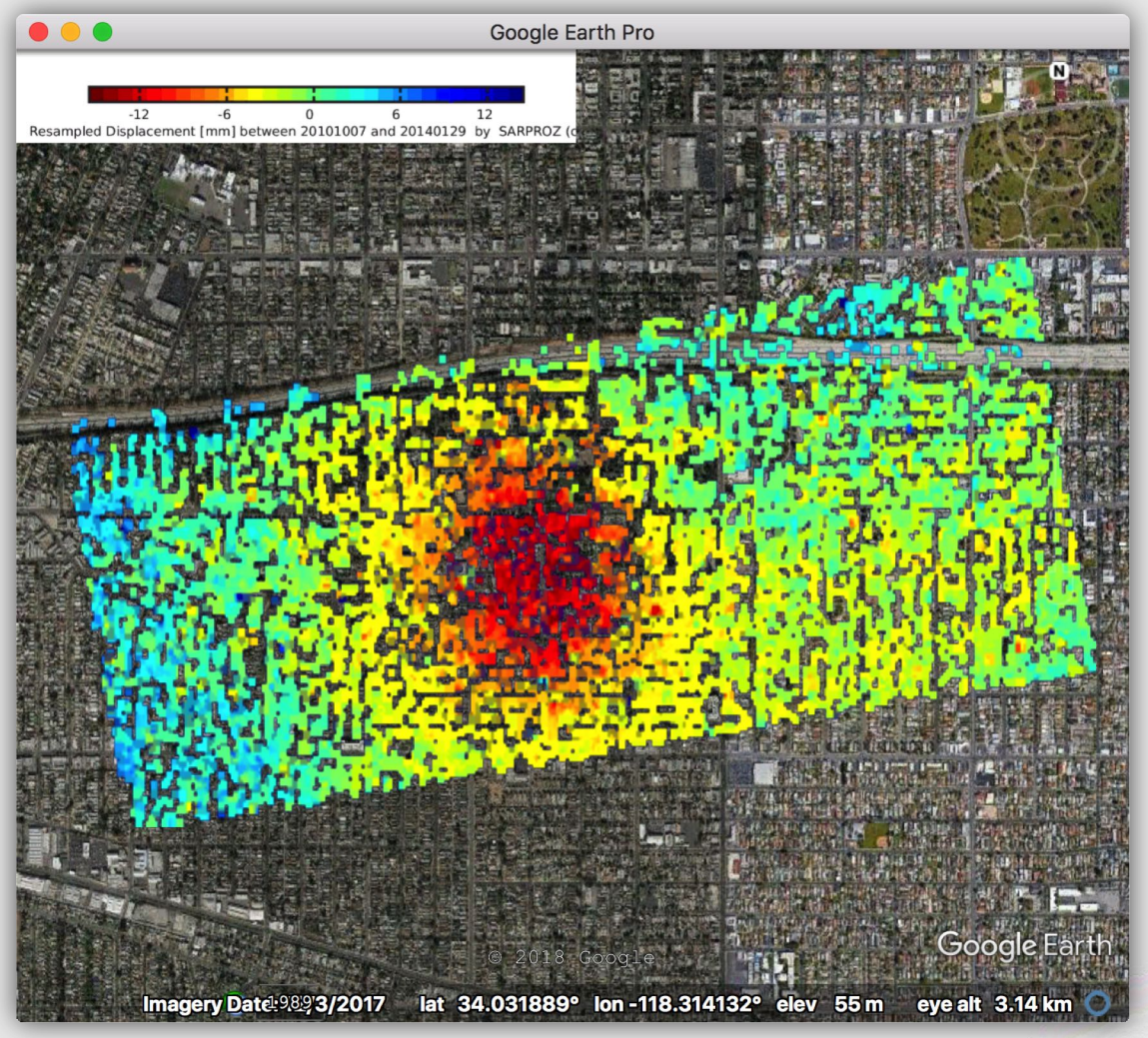
Step 5-7: time series space visualization and export

In "time series space visualization and export" frame, you can check the displacement between any two given dates. For example, select 2010-10-07 as the reference date, and 2014-01-29 as the target date. Keep other options as their default values. Click "view" to view in Sarproz and click "Export" to geocode the result to Google Earth.





Resampled displacement figure in Sarproz



Resampled displacement geocoded to Google Earth

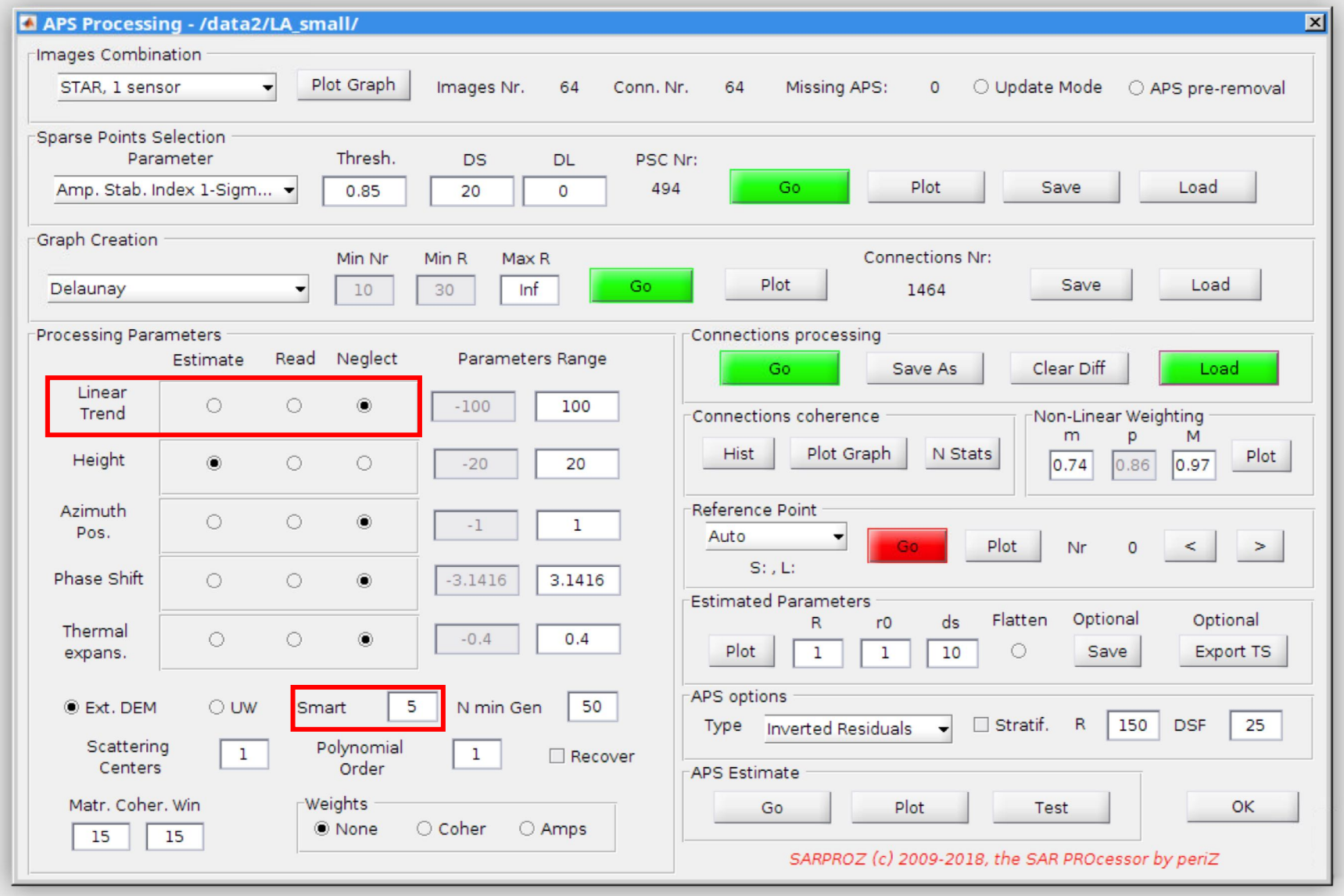
Appendix A:
Estimate non-linear movement

Estimating non-linear movement

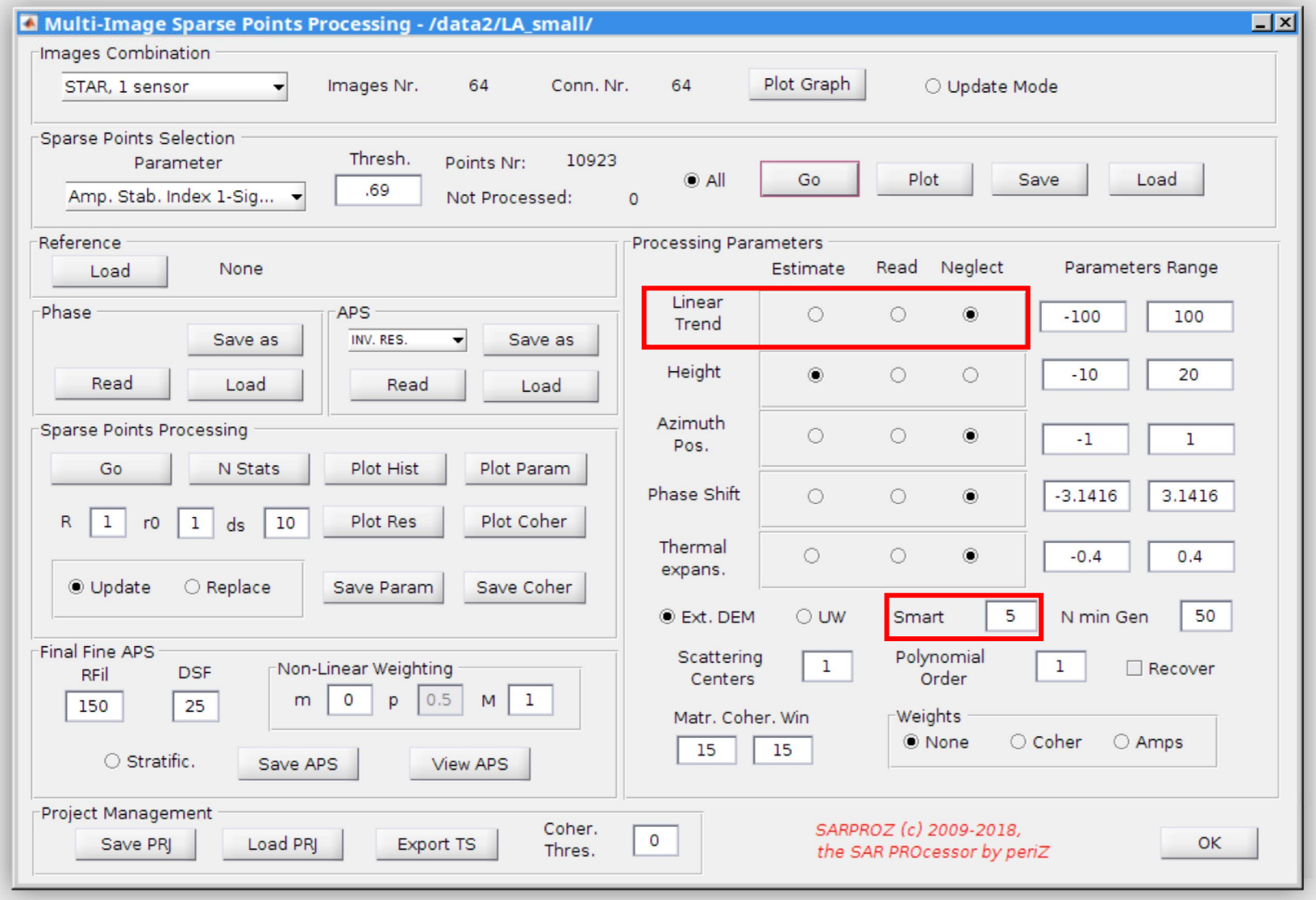
- Sometimes the ground movement might not always be linear. In such case where it is not the best to use a linear model, the software also provides a way to estimate non-linear movement:
  - In “APS estimation” and “sparse point processing”, instead of checking “estimate” for linear trend, check “neglect” for “linear trend”, and put down “5” in the “smart” option box.
  - The rest of the steps are identical.
- An application with the non-linear model could be find here.

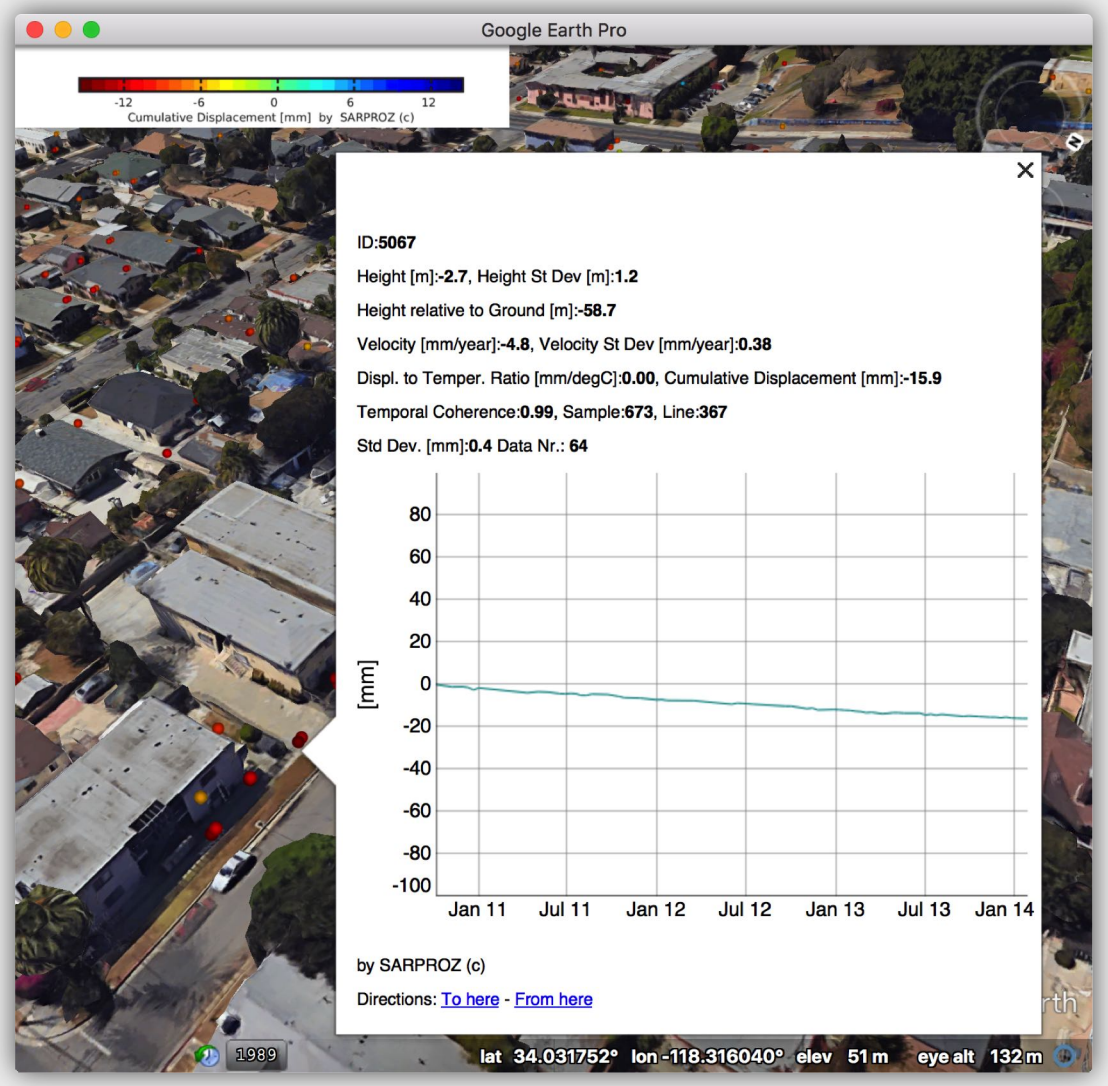
Step A-1: use “smart” in APS

To use a non parametric model for movement estimation, choose “neglect” for “linear trend” and put down “5” in “smart” box for step 2-4. Other steps remain the same.

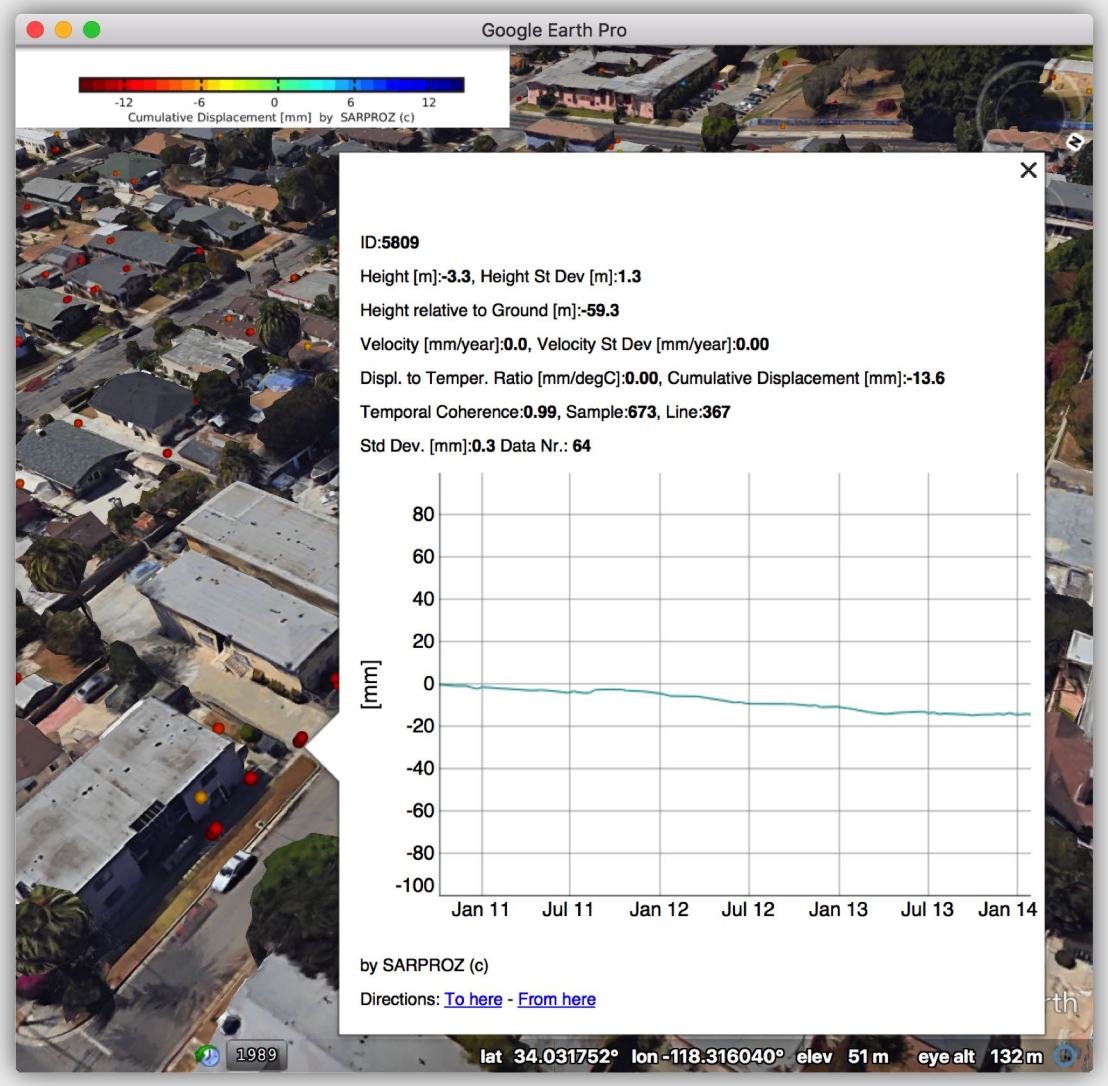


Step A-2: use “smart” in MISP





One example using the linear model.



One example using the "smart" model. Note that the velocity is "0" because we did not estimate velocity.

Bye