Tutorial on Atmospheric Delay Mitigation on Single (or few) Interferograms using Sarproz

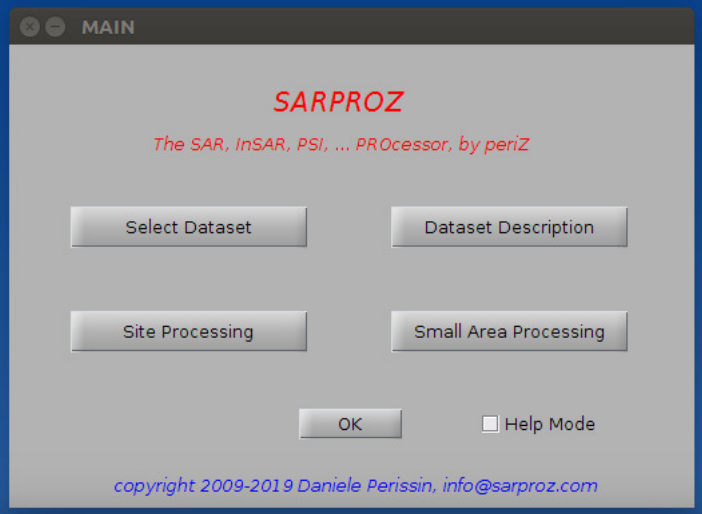
Mining activities detection in Poland

Data: 2 Sentinel-1 images

Objectives:

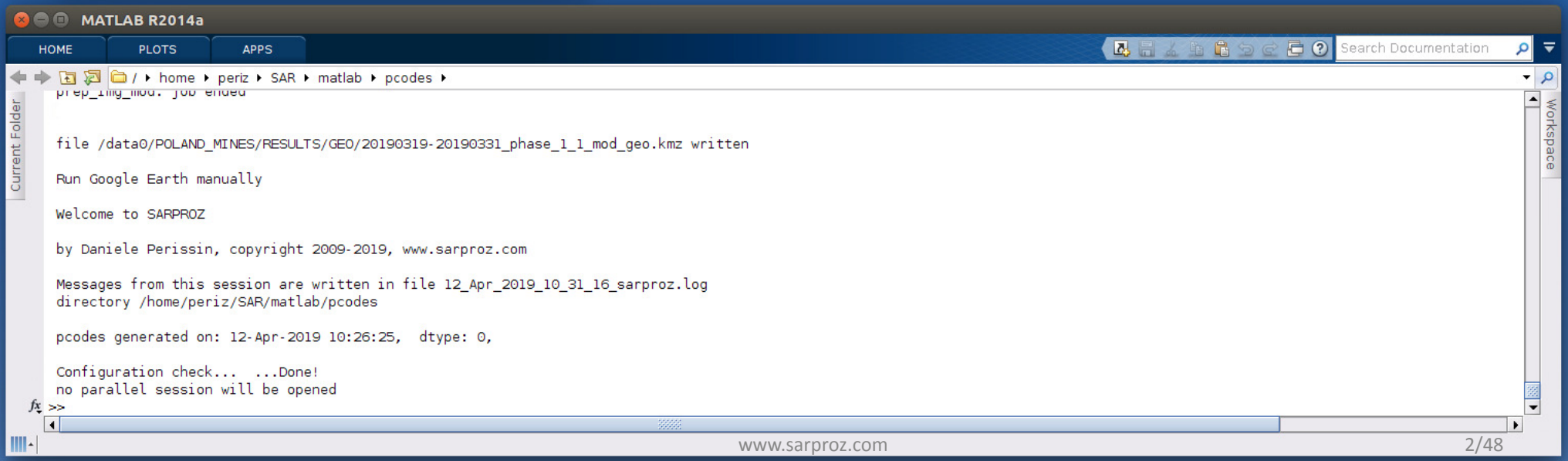
- understanding the concept behind atmospheric delay mitigation with few images
- Getting familiar with the new Sarproz module for extended data visualization/export

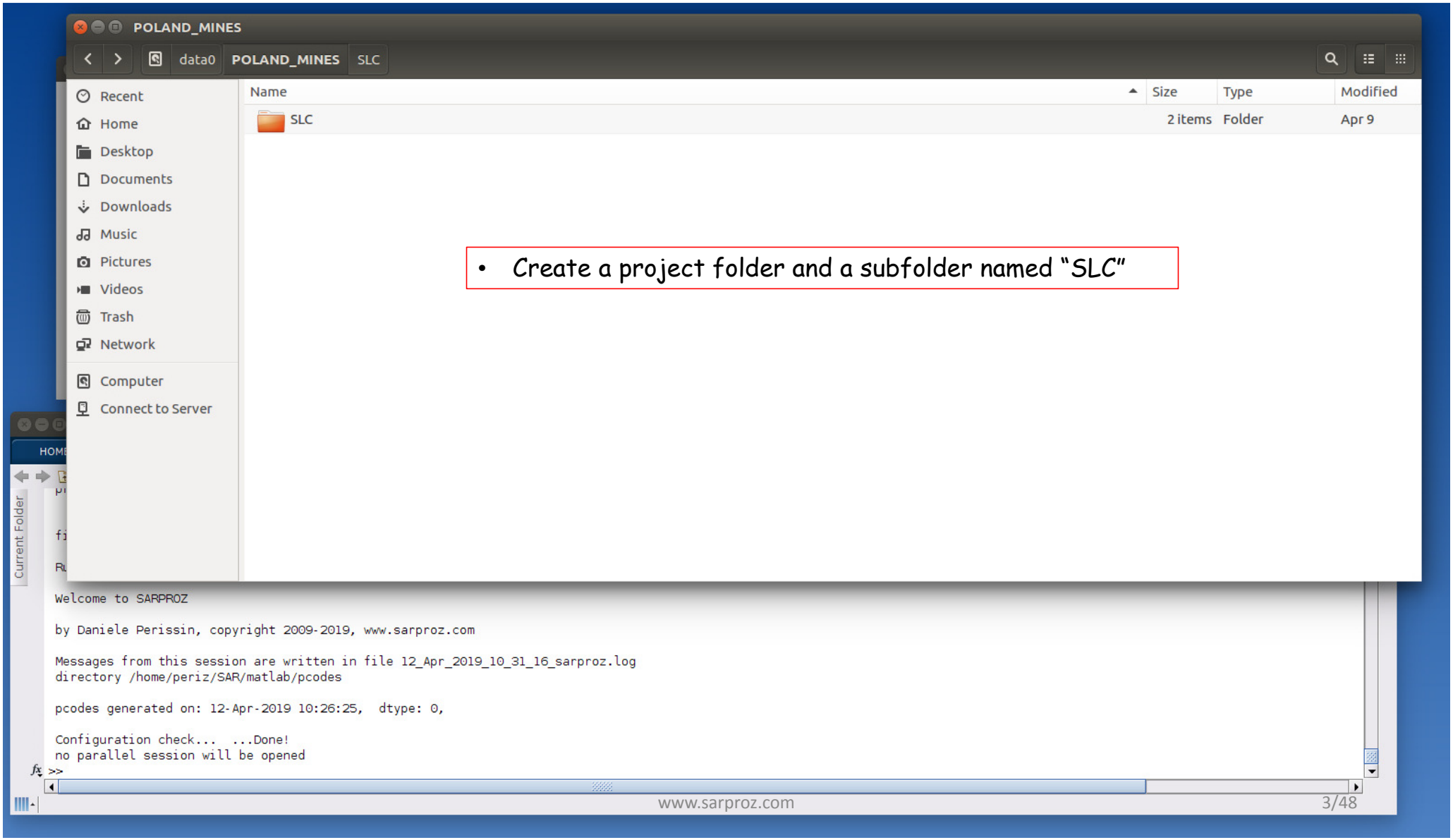
www.sarproz.com

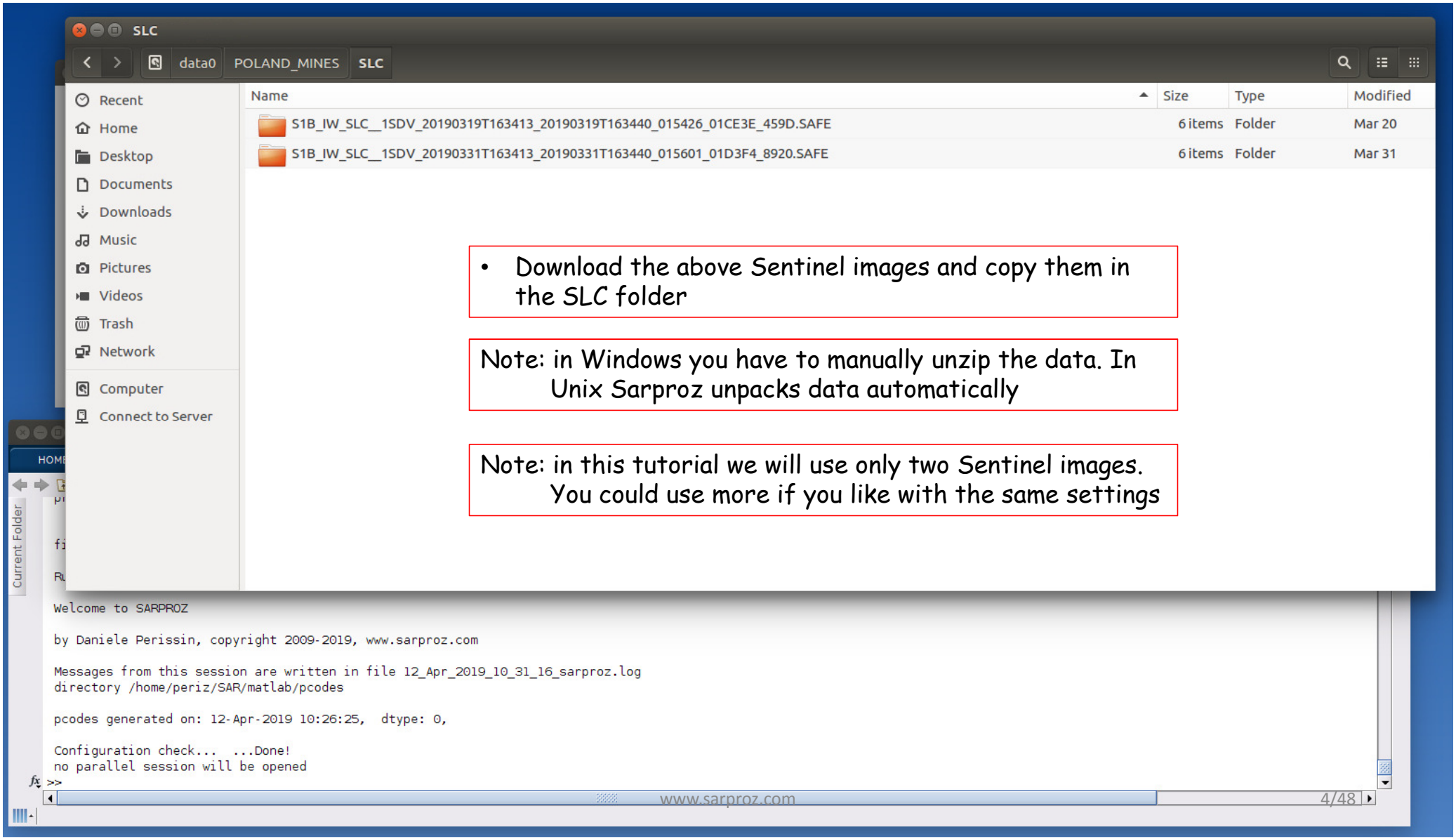


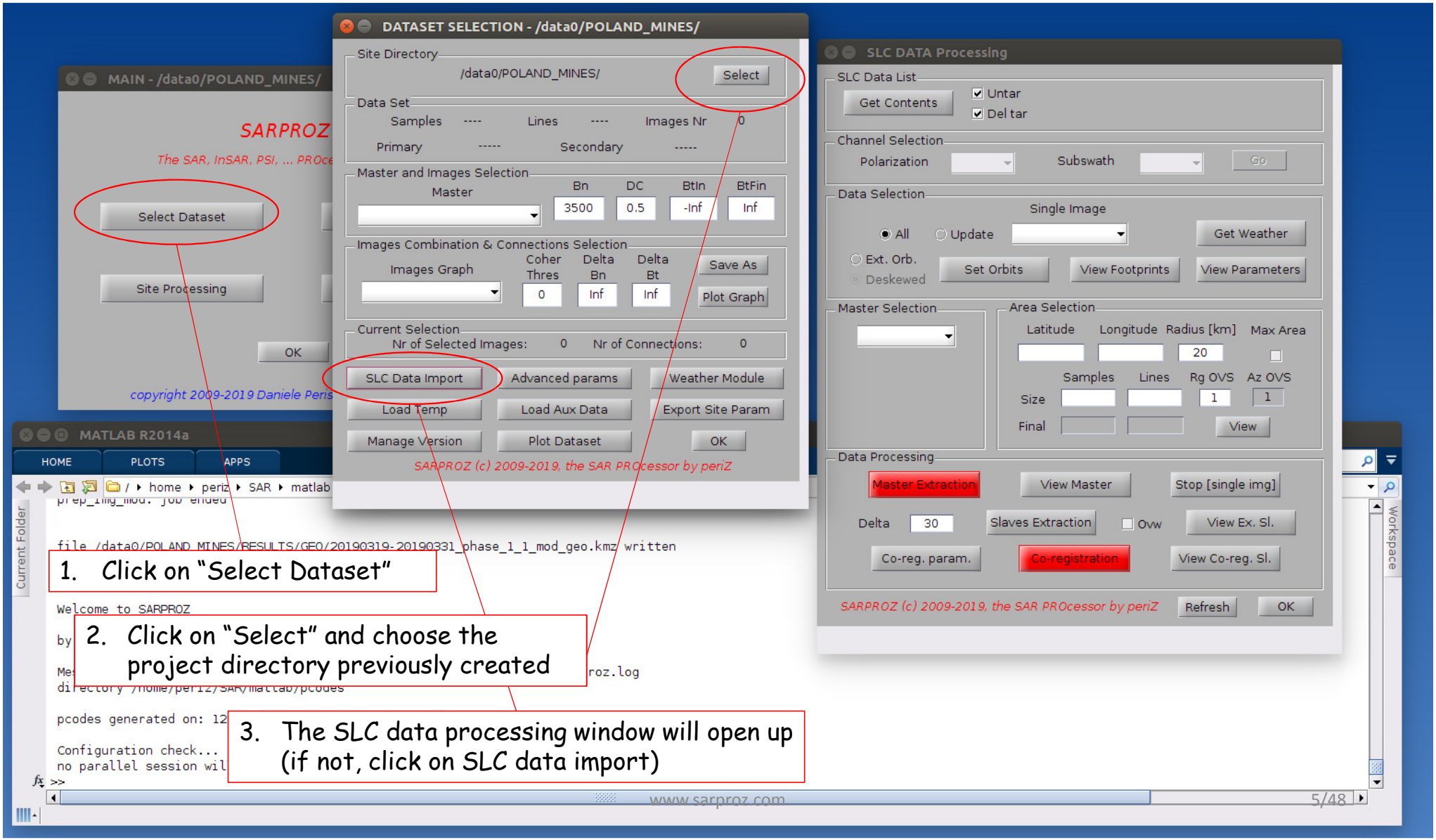
- Run Sarproz and make sure you have a version later than 12 April 2019

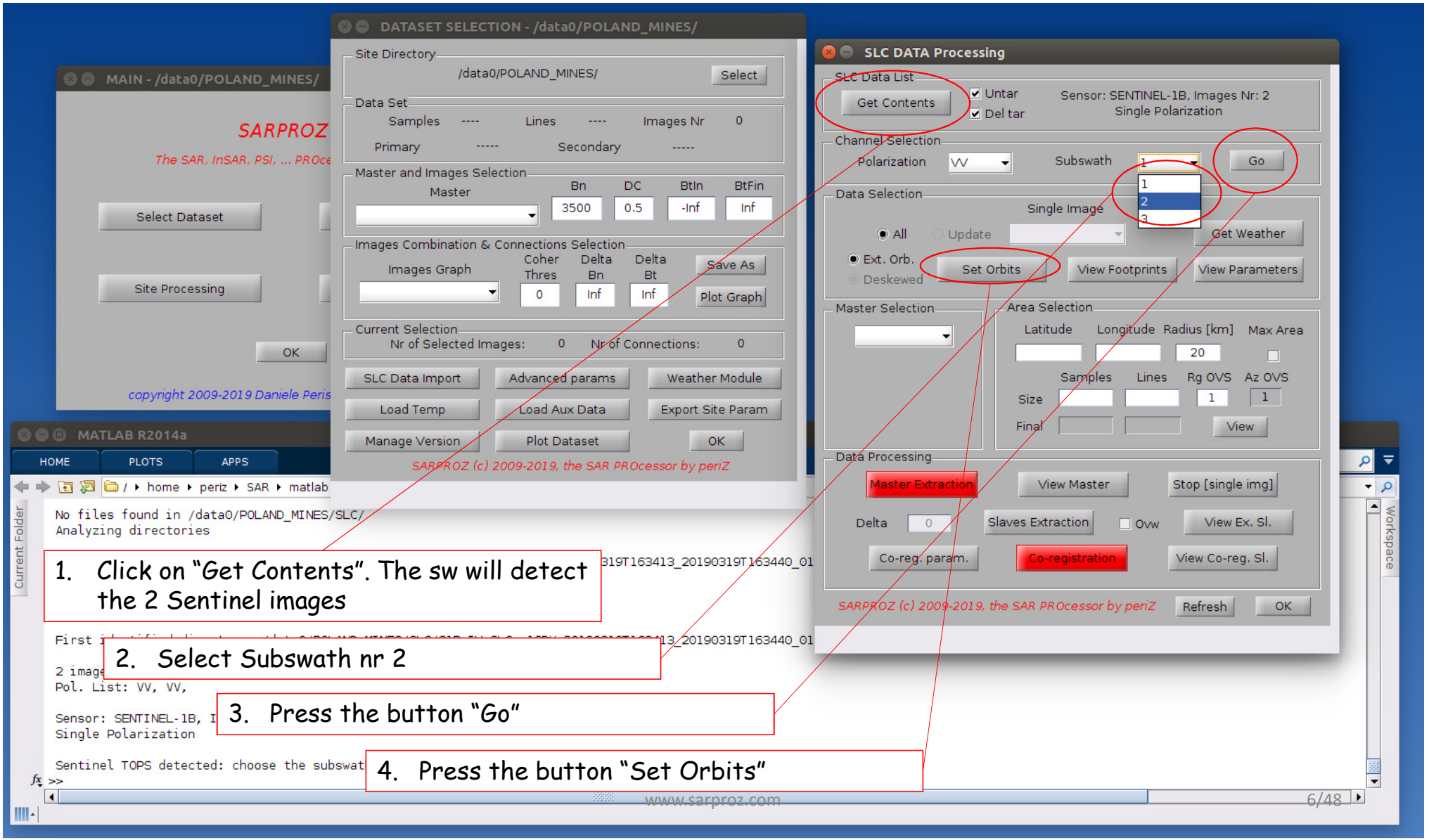
Note: Keep the command prompt visible and take the time to read the messages from the software. This will save you time.



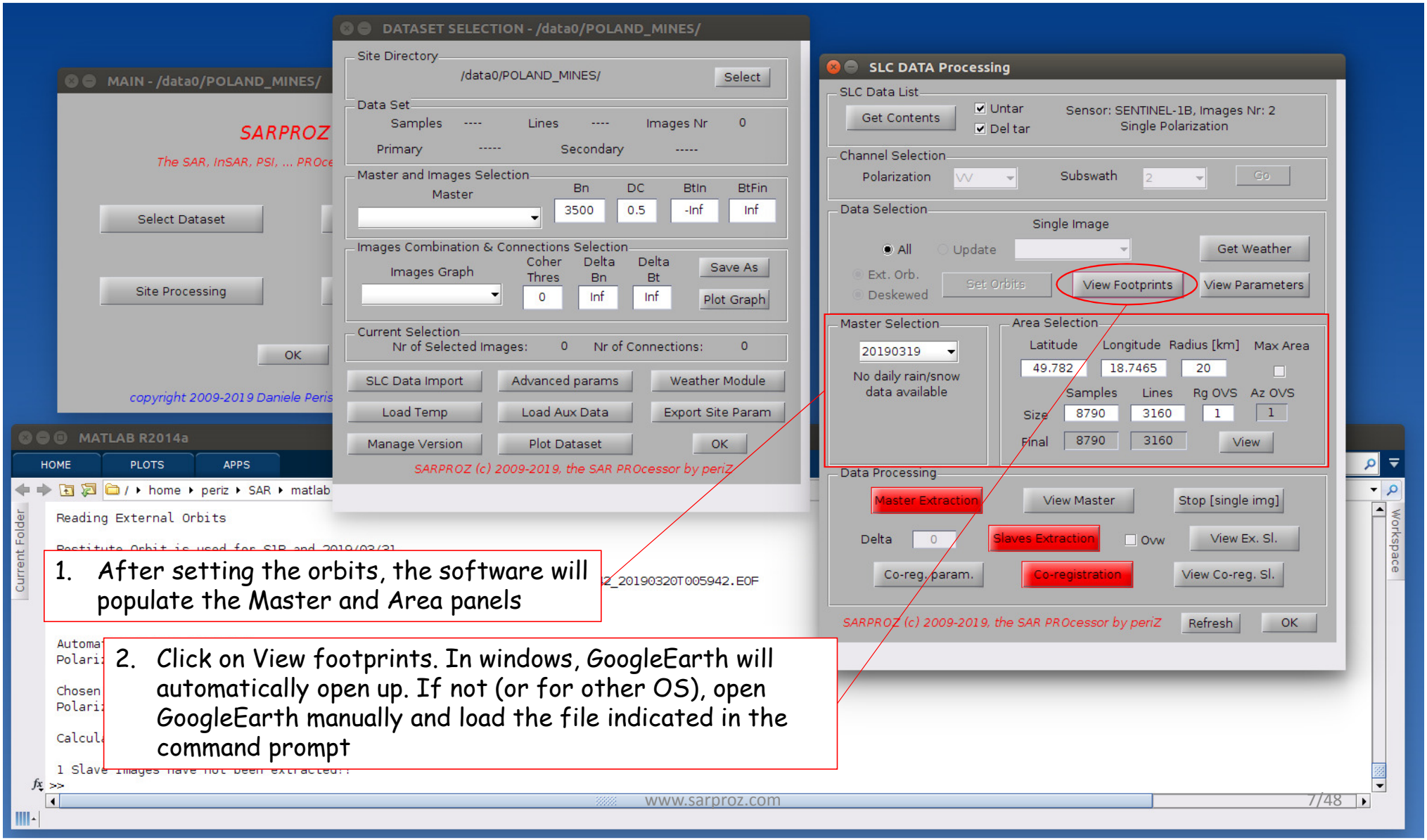

POLAND_MINES
data0
POLAND_MINES
SLC
Recent
Home
Desktop
Documents
Downloads
Music
Pictures
Videos
Trash
Network
Computer
Connect to Server
Name
Size
Type
Modified
SLC
2 items
Folder
Apr 9
• Create a project folder and a subfolder named "SLC"
Current Folder
Welcome to SARPROZ
by Daniele Perissin, copyright 2009-2019, www.sarproz.com
Messages from this session are written in file 12_Apr_2019_10_31_16_sarproz.log
directory /home/periz/SAR/matlab/pcodes
pcodes generated on: 12-Apr-2019 10:26:25, dtype: 0,
Configuration check... ...Done!
no parallel session will be opened
>>

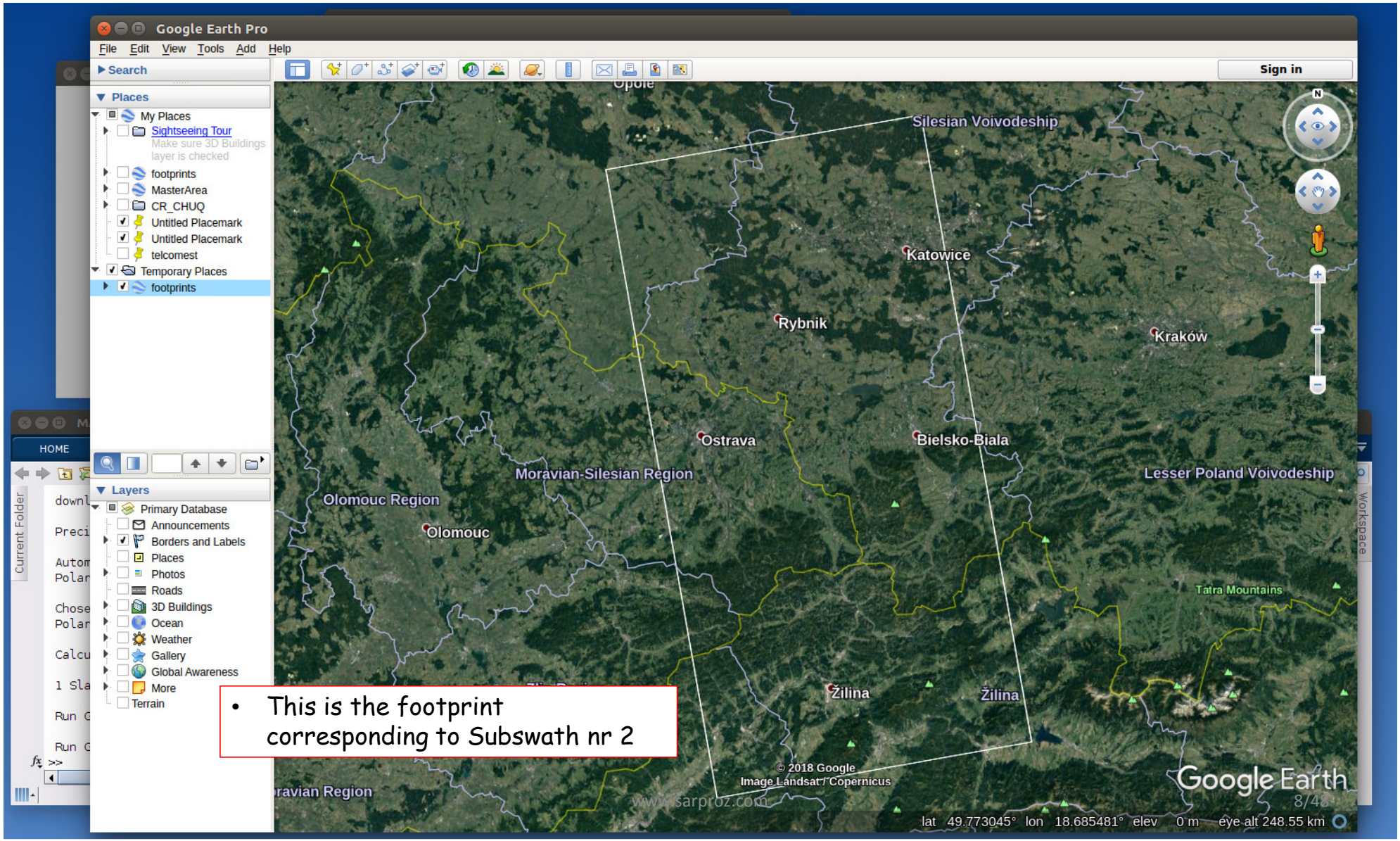

SLC
data0
POLAND_MINES
SLC
Recent
Home
Desktop
Documents
Downloads
Music
Pictures
Videos
Trash
Network
Computer
Connect to Server
Name
Size
Type
Modified
S1B_IW_SLC__1SDV_20190319T163413_20190319T163440_015426_01CE3E_459D.SAFE
6 items
Folder
Mar 20
S1B_IW_SLC__1SDV_20190331T163413_20190331T163440_015601_01D3F4_8920.SAFE
6 items
Folder
Mar 31
• Download the above Sentinel images and copy them in the SLC folder
Note: in Windows you have to manually unzip the data. In Unix Sarproz unpacks data automatically
Note: in this tutorial we will use only two Sentinel images. You could use more if you like with the same settings
Current Folder
Welcome to SARPROZ
by Daniele Perissin, copyright 2009-2019, www.sarproz.com
Messages from this session are written in file 12_Apr_2019_10_31_16_sarproz.log
directory /home/periz/SAR/matlab/pcodes
pcodes generated on: 12-Apr-2019 10:26:25, dtype: 0,
Configuration check... ...Done!
no parallel session will be opened
>>

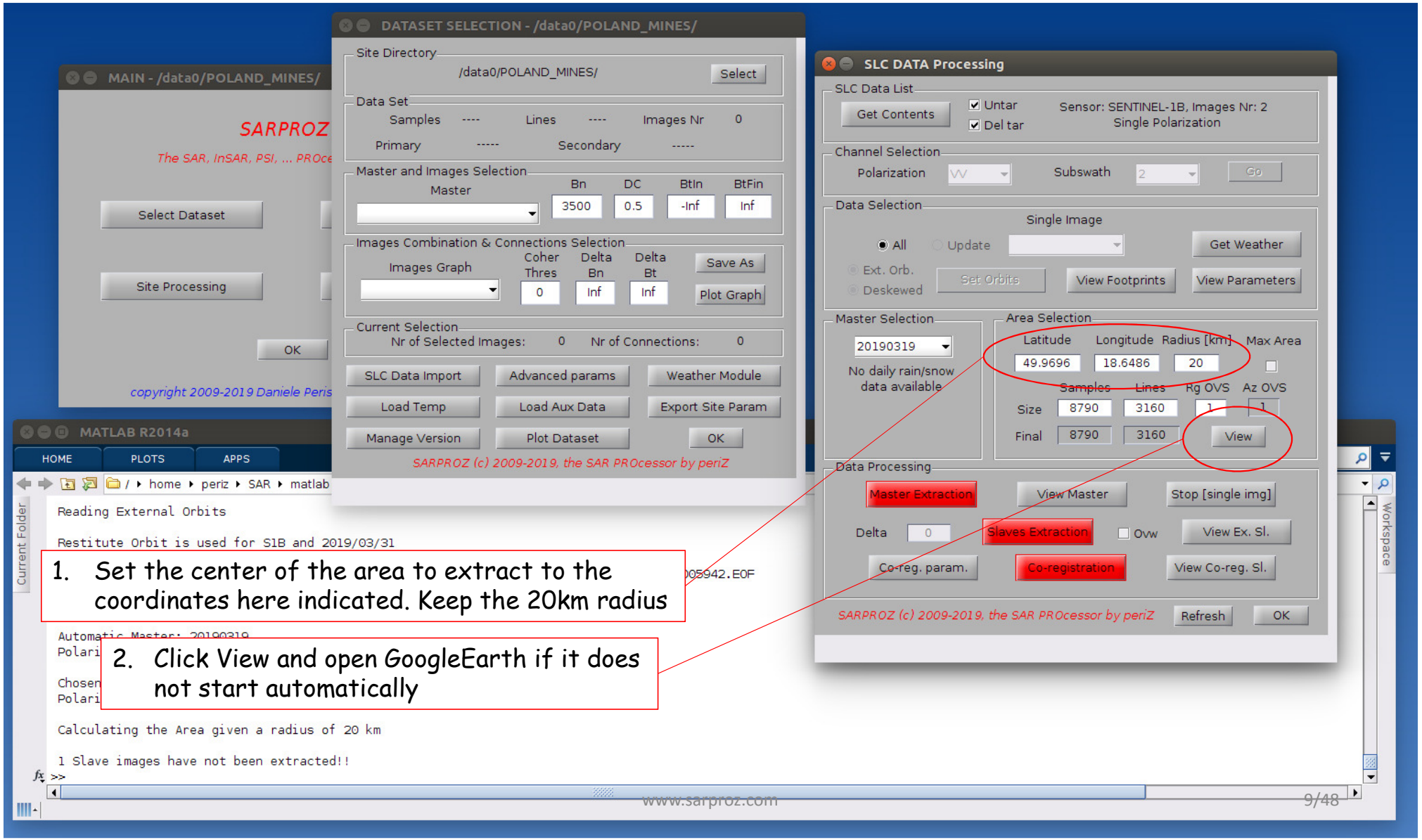

MAIN - /data0/POLAND_MINES/
SARPROZ
The SAR, InSAR, PSI, ... PROce
Select Dataset
Site Processing
OK
copyright 2009-2019 Daniele Peris
DATASET SELECTION - /data0/POLAND_MINES/
Site Directory
/data0/POLAND_MINES/
Select
Data Set
Samples ---- Lines ---- Images Nr 0
Primary ----- Secondary -----
Master and Images Selection
Master
Bn
DC
BtIn
BtFin
3500
0.5
-Inf
Inf
Images Combination & Connections Selection
Images Graph
Coher Thres
Delta Bn
Delta Bt
Save As
0
Inf
Inf
Plot Graph
Current Selection
Nr of Selected Images: 0 Nr of Connections: 0
SLC Data Import
Advanced params
Weather Module
Load Temp
Load Aux Data
Export Site Param
Manage Version
Plot Dataset
OK
SARPROZ (c) 2009-2019, the SAR PROcessor by periZ
SLC DATA Processing
SLC Data List
Get Contents
Untar
Del tar
Channel Selection
Polarization
Subswath
Go
Data Selection
Single Image
All
Update
Get Weather
Ext. Orb.
Deskewed
Set Orbits
View Footprints
View Parameters
Master Selection
Area Selection
Latitude
Longitude
Radius [km]
Max Area
20
Samples
Lines
Rg OVS
Az OVS
Size
1
1
Final
View
Data Processing
Master Extraction
View Master
Stop [single img]
Delta
30
Slaves Extraction
Ovw
View Ex. Sl.
Co-reg. param.
Co-registration
View Co-reg. Sl.
SARPROZ (c) 2009-2019, the SAR PROcessor by periZ
Refresh
OK
MATLAB R2014a
HOME
PLOTS
APPS
home ▸ periz ▸ SAR ▸ matlab
file /data0/POLAND_MINES/RESULTS/GEO/20190319-20190331_phase_1_1_mod_geo.kmz written
Welcome to SARPROZ
pcodes generated on: 12
Configuration check...
no parallel session wil
>>
Current Folder
Workspace
1. Click on "Select Dataset"
2. Click on "Select" and choose the project directory previously created
3. The SLC data processing window will open up (if not, click on SLC data import)



1. Click on "Get Contents". The sw will detect the 2 Sentinel images
2. Select Subswath nr 2
3. Press the button "Go"
4. Press the button "Set Orbits"

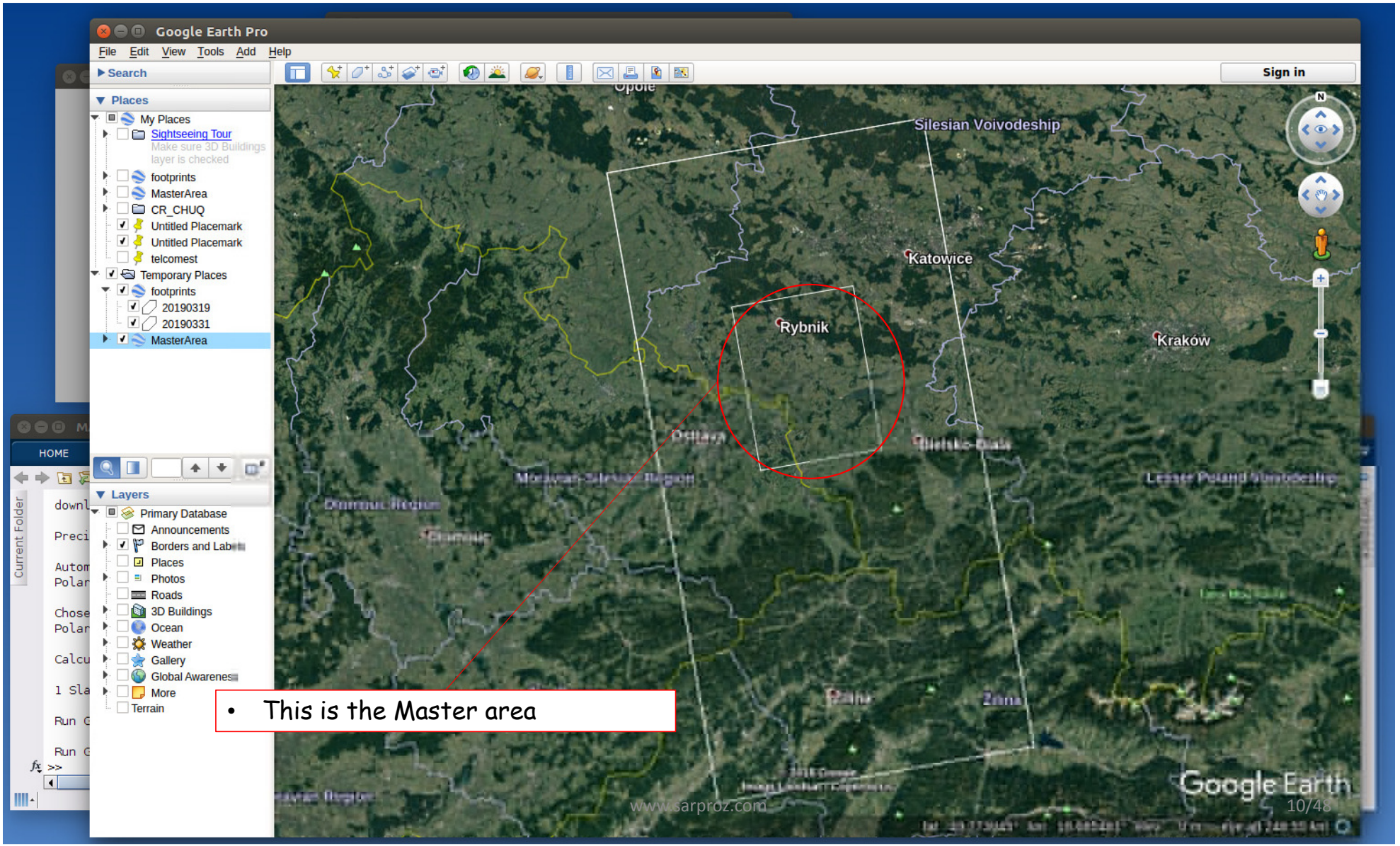

MAIN - /data0/POLAND_MINES/
SARPROZ
The SAR, InSAR, PSI, ... PROce
Select Dataset
Site Processing
OK
copyright 2009-2019 Daniele Peris
DATASET SELECTION - /data0/POLAND_MINES/
Site Directory
/data0/POLAND_MINES/
Select
Data Set
Samples ---- Lines ---- Images Nr 0
Primary ----- Secondary -----
Master and Images Selection
Master
Bn DC BtIn BtFin
3500 0.5 -Inf Inf
Images Combination & Connections Selection
Images Graph
Coher Thres
Delta Bn
Delta Bt
0 Inf Inf
Save As
Plot Graph
Current Selection
Nr of Selected Images: 0 Nr of Connections: 0
SLC Data Import
Advanced params
Weather Module
Load Temp
Load Aux Data
Export Site Param
Manage Version
Plot Dataset
OK
SARPROZ (c) 2009-2019, the SAR PROcessor by periZ
SLC DATA Processing
SLC Data List
Get Contents
Untar
Del tar
Sensor: SENTINEL-1B, Images Nr: 2
Single Polarization
Channel Selection
Polarization VV
Subswath 2
Go
Data Selection
Single Image
All
Update
Get Weather
Ext. Orb.
Deskewed
Set Orbits
View Footprints
View Parameters
Master Selection
20190319
No daily rain/snow data available
Area Selection
Latitude Longitude Radius [km] Max Area
49.782 18.7465 20
Samples Lines Rg OVS Az OVS
Size 8790 3160 1 1
Final 8790 3160
View
Data Processing
Master Extraction
View Master
Stop [single img]
Delta 0
Slaves Extraction
Ovw
View Ex. Sl.
Co-reg. param.
Co-registration
View Co-reg. Sl.
SARPROZ (c) 2009-2019, the SAR PROcessor by periZ
Refresh
OK
MATLAB R2014a
HOME
PLOTS
APPS
home periz SAR matlab
Current Folder
Workspace
Reading External Orbits
Restitute Orbit is used for S1B and 2019/03/3
2_20190320T005942.EOF
Automa
Polari
Chosen
Polari
Calcul
1 Slave images have not been extracted!
>>
1. After setting the orbits, the software will populate the Master and Area panels
2. Click on View footprints. In windows, GoogleEarth will automatically open up. If not (or for other OS), open GoogleEarth manually and load the file indicated in the command prompt
www.sarproz.com
7/48


Google Earth Pro
File Edit View Tools Add Help
Search
Places
My Places
Sightseeing Tour
Make sure 3D Buildings layer is checked
footprints
MasterArea
CR_CHUQ
Untitled Placemark
Untitled Placemark
telcomest
Temporary Places
footprints
Layers
Primary Database
Announcements
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Weather
Gallery
Global Awareness
More
Terrain
Sign in
Silesian Voivodeship
Katowice
Rybnik
Kraków
Ostrava
Bielsko-Biala
Moravian-Silesian Region
Lesser Poland Voivodeship
Olomouc Region
Olomouc
Tatra Mountains
Žilina
Žilina
© 2018 Google
Image Landsat / Copernicus
Google Earth
lat 49.773045° lon 18.685481° elev 0 m eye alt 248.55 km
• This is the footprint corresponding to Subswath nr 2

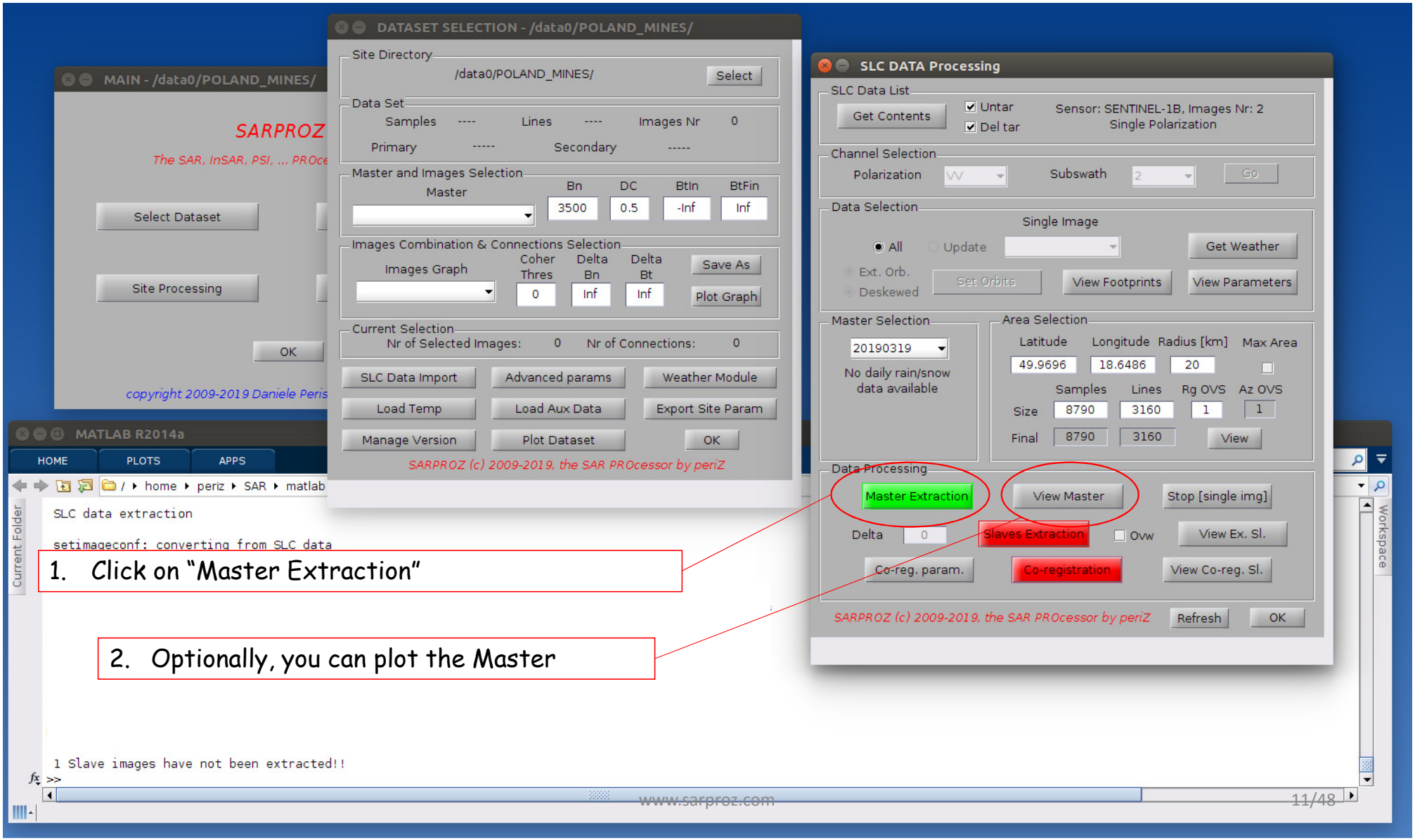


1. Set the center of the area to extract to the coordinates here indicated. Keep the 20km radius

2. Click View and open GoogleEarth if it does not start automatically

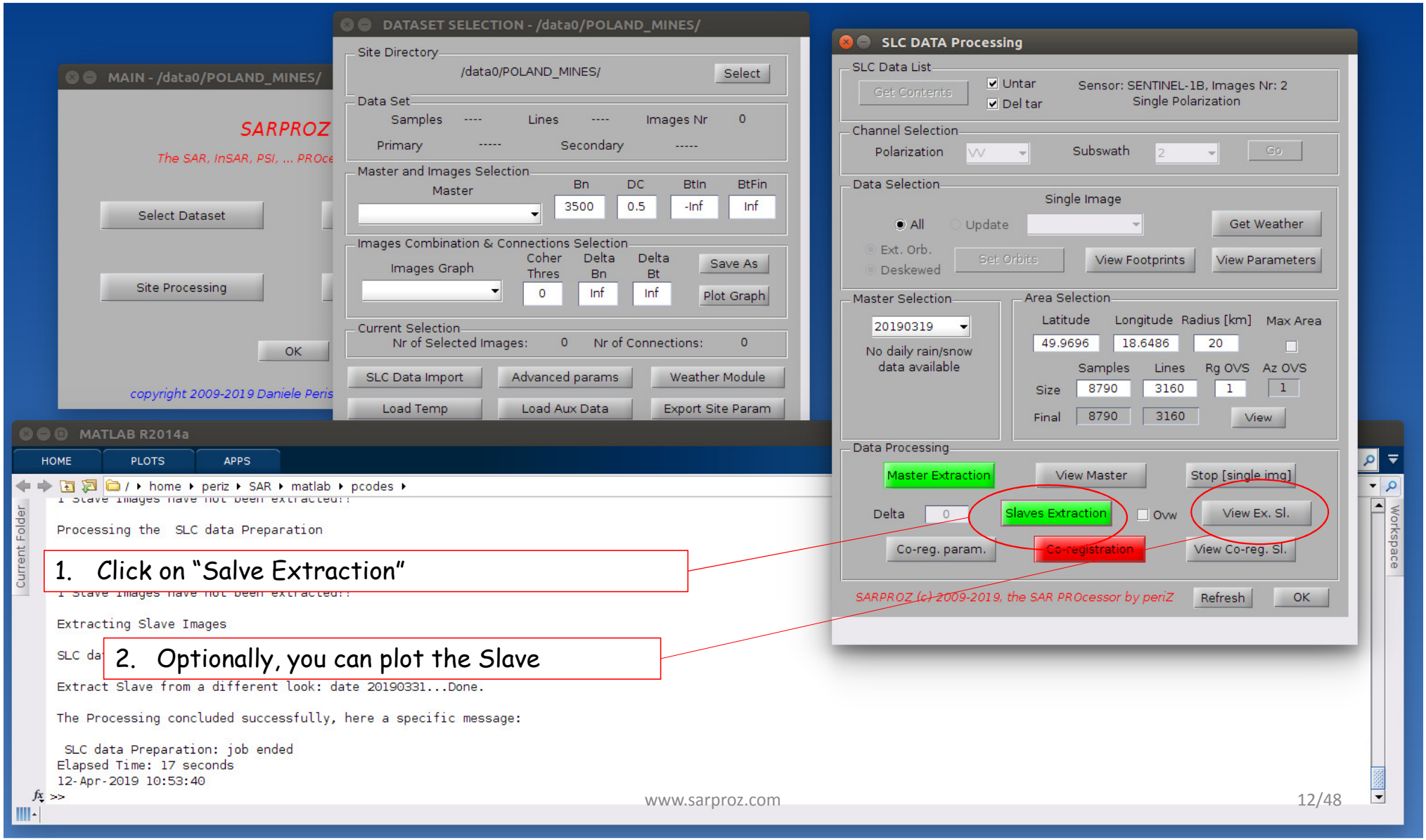


- This is the Master area



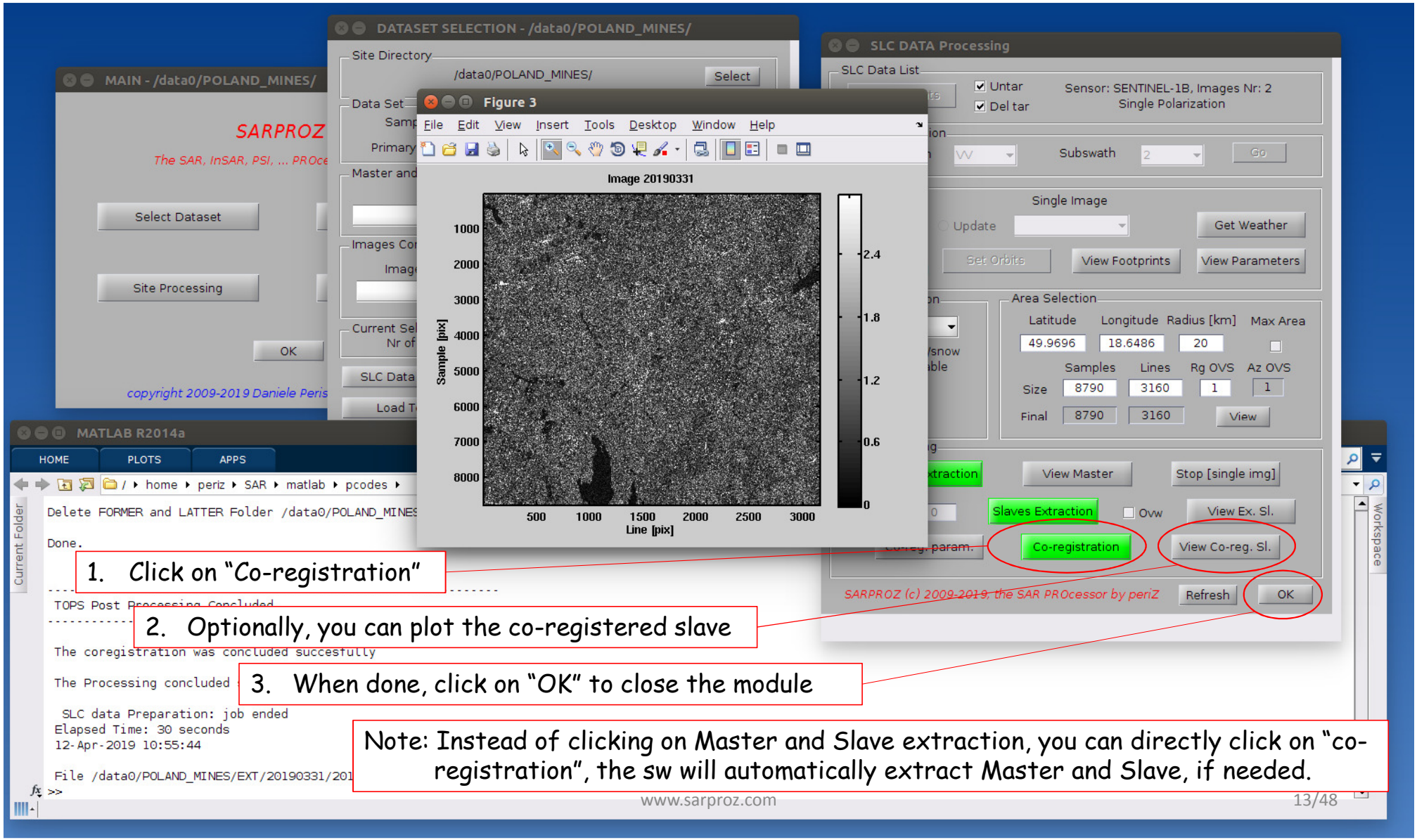
1. Click on "Master Extraction"

2. Optionally, you can plot the Master



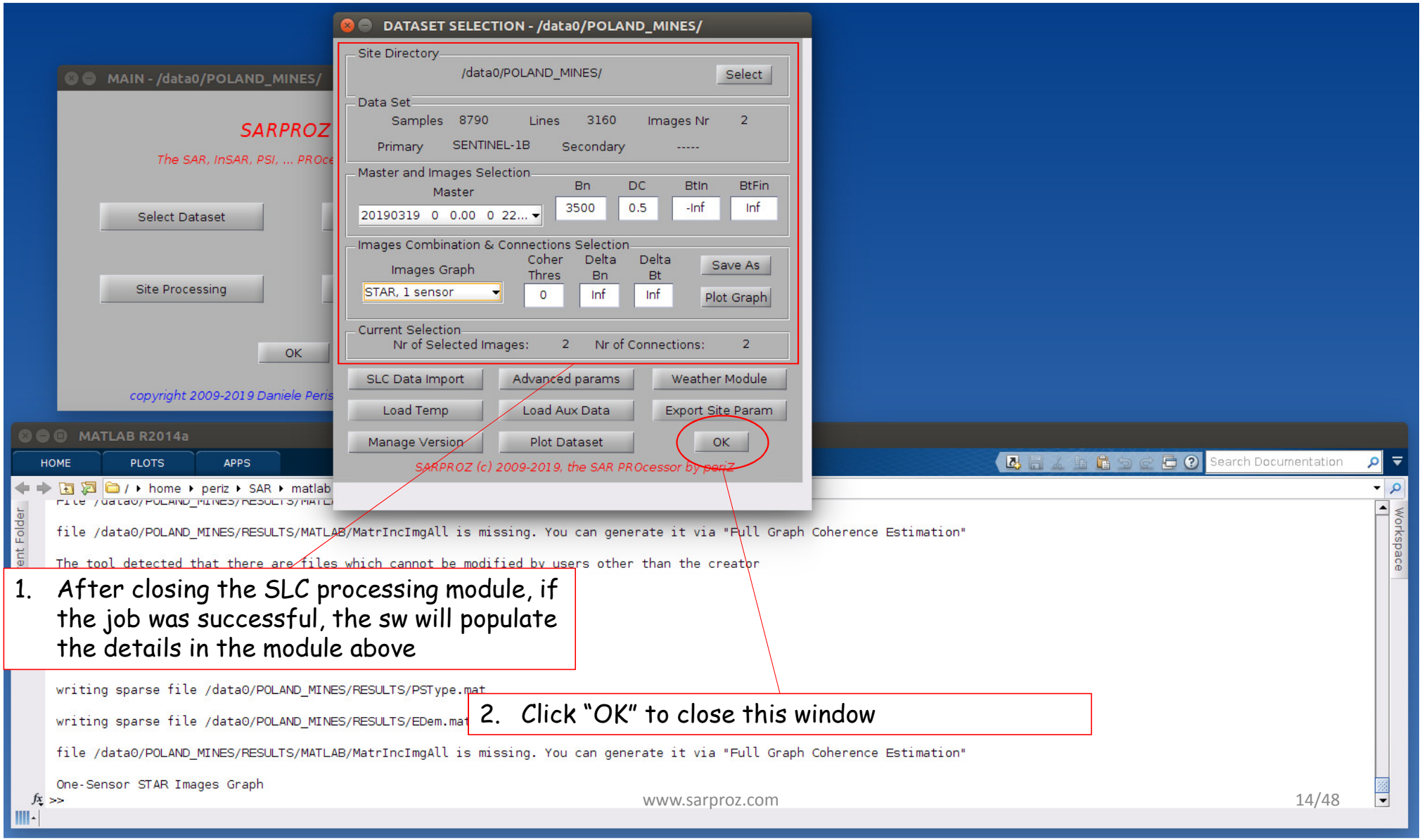
1. Click on "Salve Extraction"

2. Optionally, you can plot the Slave



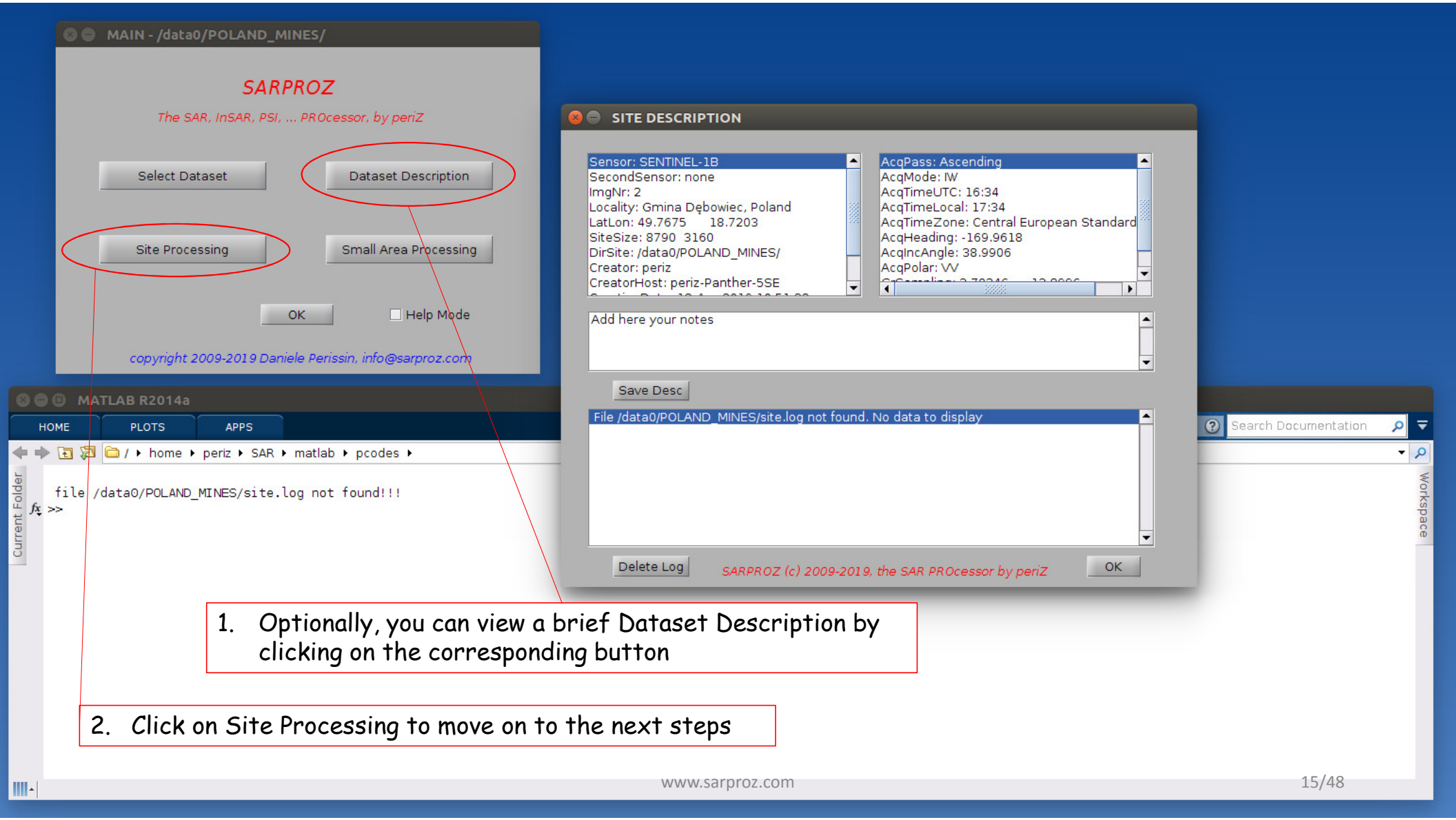
1. Click on "Co-registration"
2. Optionally, you can plot the co-registered slave
3. When done, click on "OK" to close the module

Note: Instead of clicking on Master and Slave extraction, you can directly click on "co-registration", the sw will automatically extract Master and Slave, if needed.



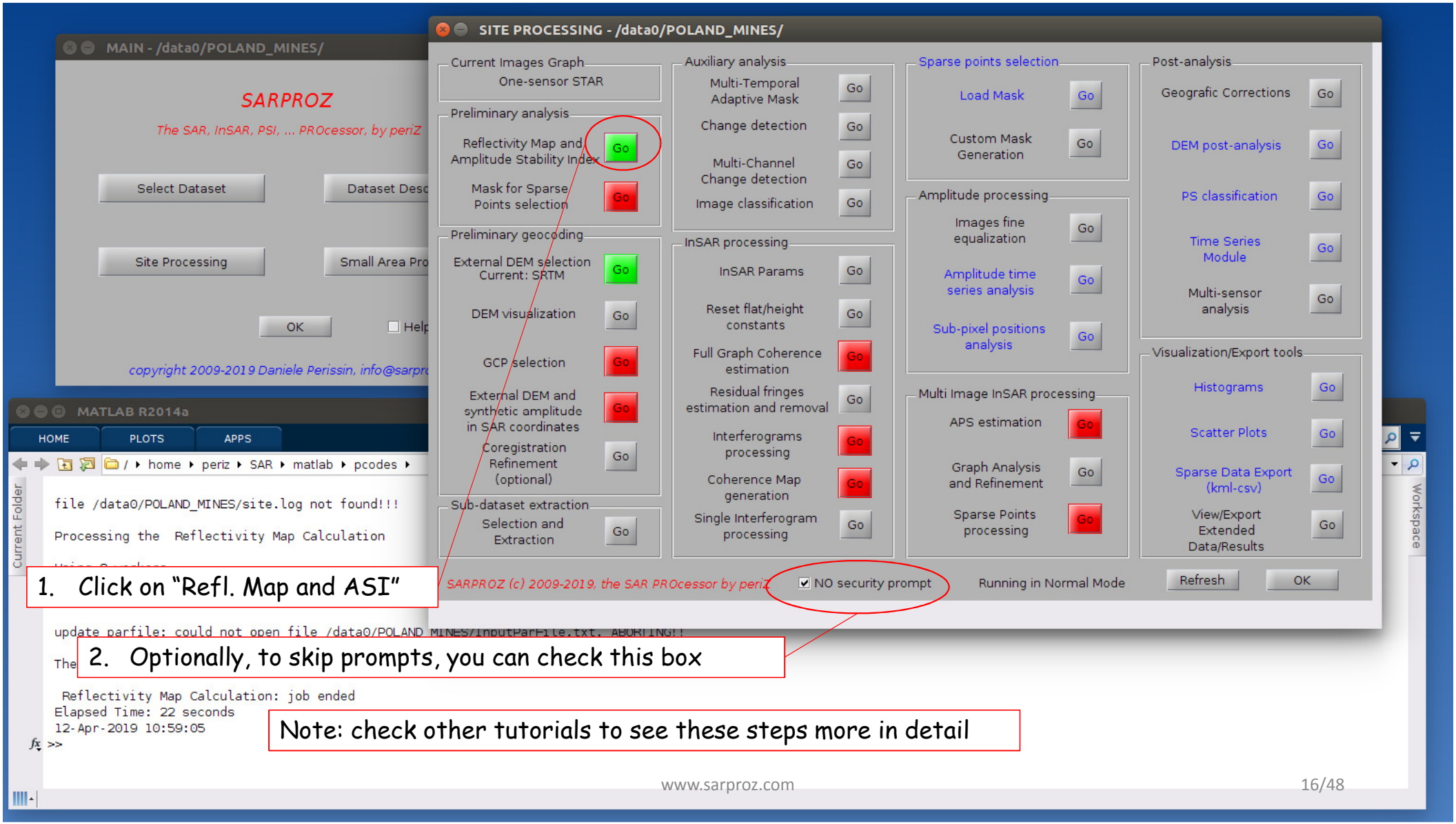
1. After closing the SLC processing module, if the job was successful, the sw will populate the details in the module above

2. Click "OK" to close this window



1. Optionally, you can view a brief Dataset Description by clicking on the corresponding button

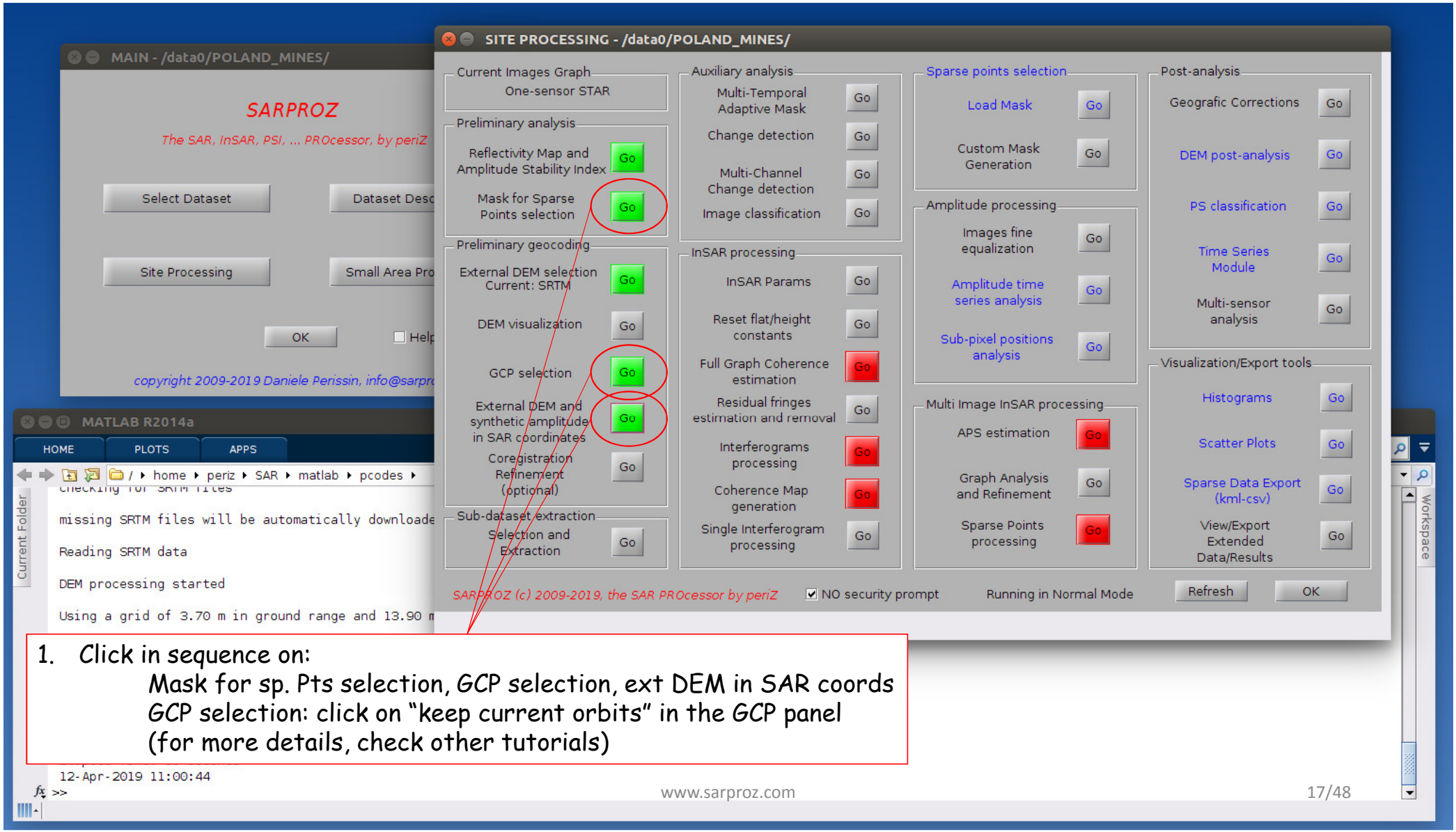
2. Click on Site Processing to move on to the next steps



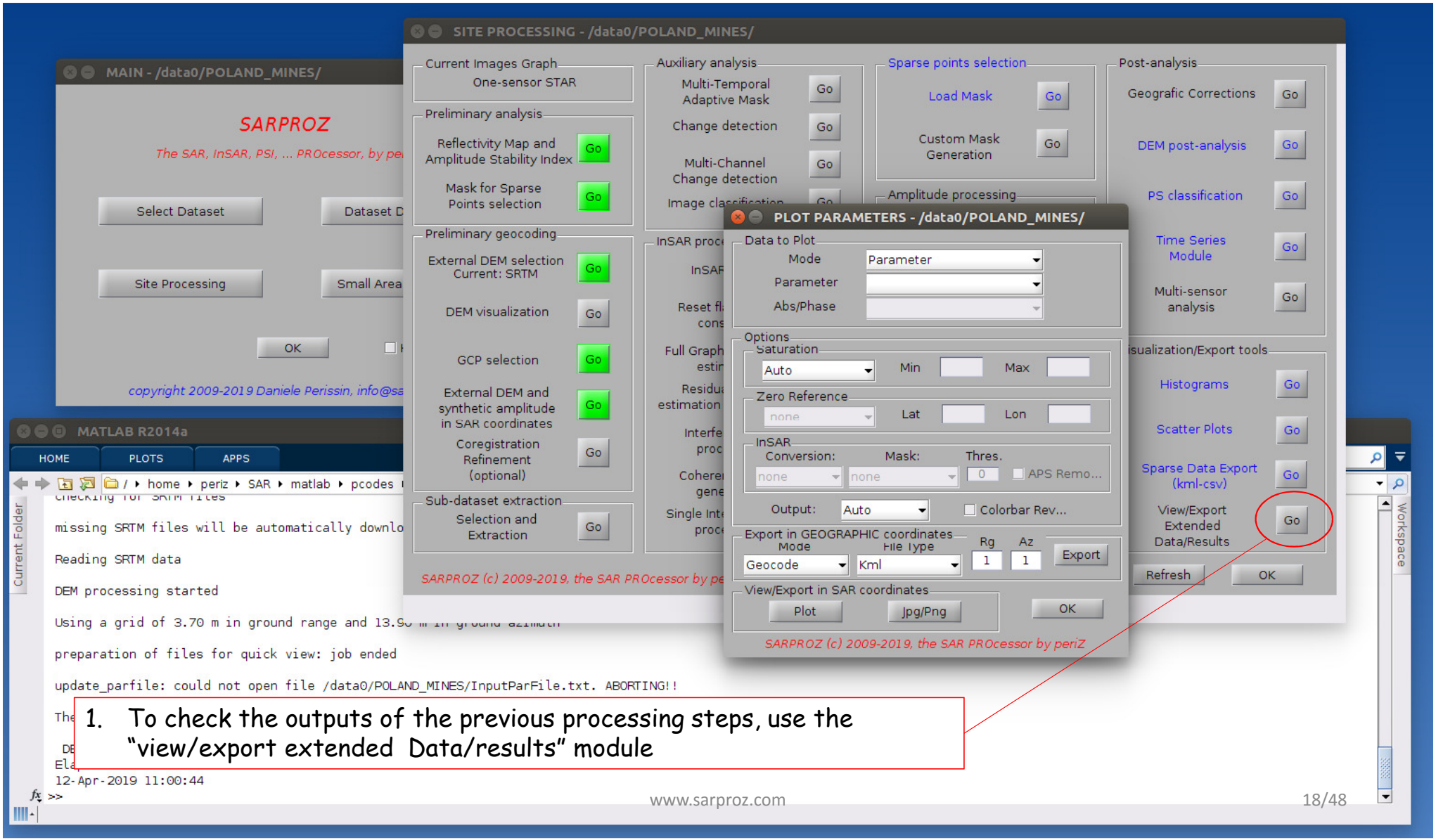
1. Click on "Refl. Map and ASI"

2. Optionally, to skip prompts, you can check this box

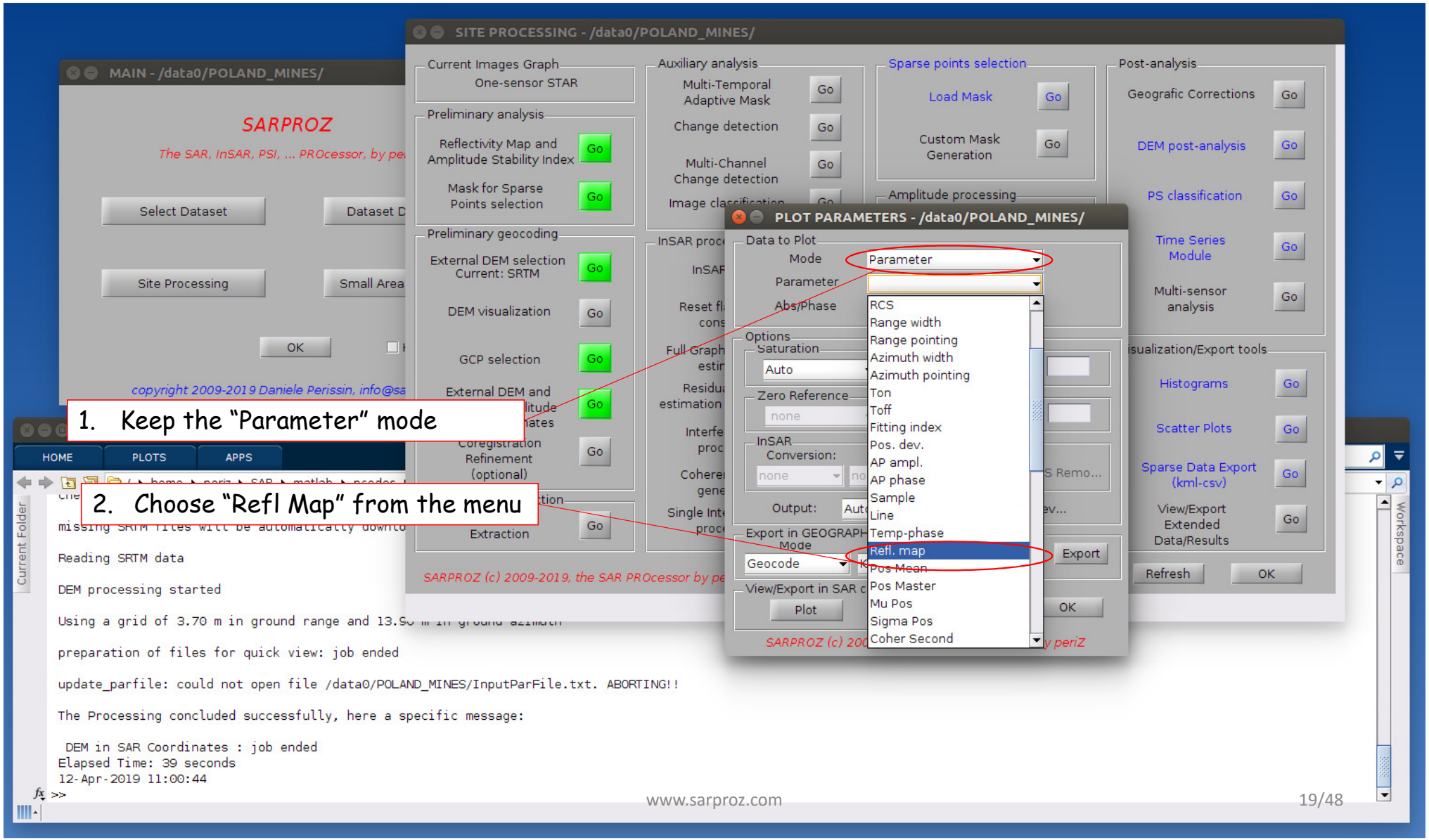
Note: check other tutorials to see these steps more in detail



1. Click in sequence on:
   Mask for sp. Pts selection, GCP selection, ext DEM in SAR coords
   GCP selection: click on "keep current orbits" in the GCP panel
   (for more details, check other tutorials)



1. To check the outputs of the previous processing steps, use the "view/export extended Data/results" module


MAIN - /data0/POLAND_MINES/
SARPROZ
The SAR, InSAR, PSI, ... PROcessor, by pe
Select Dataset
Dataset D
Site Processing
Small Area
OK
copyright 2009-2019 Daniele Perissin, info@sa
SITE PROCESSING - /data0/POLAND_MINES/
Current Images Graph
One-sensor STAR
Preliminary analysis
Reflectivity Map and Amplitude Stability Index
Mask for Sparse Points selection
Preliminary geocoding
External DEM selection Current: SRTM
DEM visualization
GCP selection
External DEM and
Coregistration Refinement (optional)
Extraction
Auxiliary analysis
Multi-Temporal Adaptive Mask
Change detection
Multi-Channel Change detection
Image classification
InSAR proce
InSAR
Reset fl
cons
Full Graph
estir
Residua
estimation
Interfe
proc
Coheren
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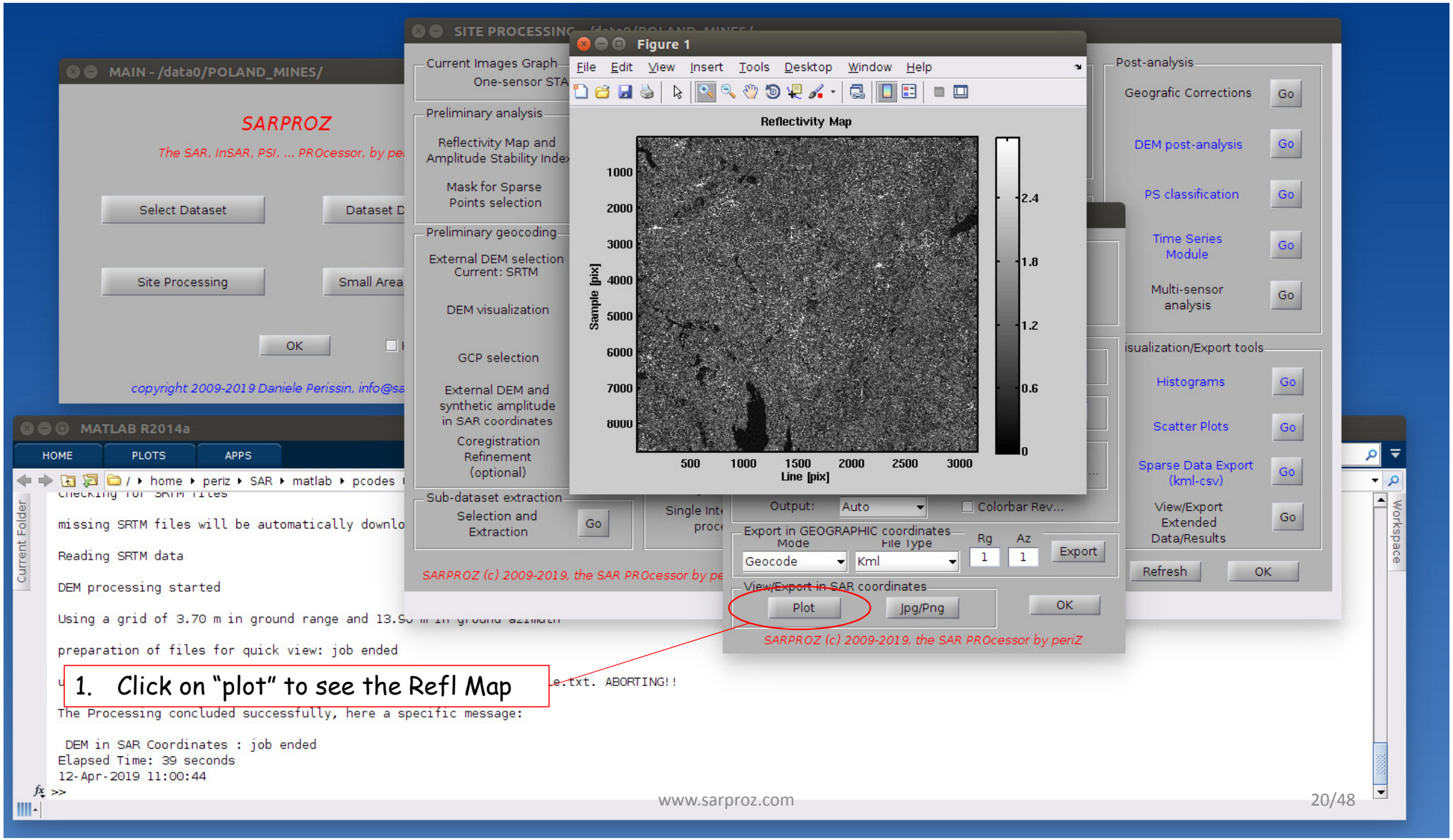
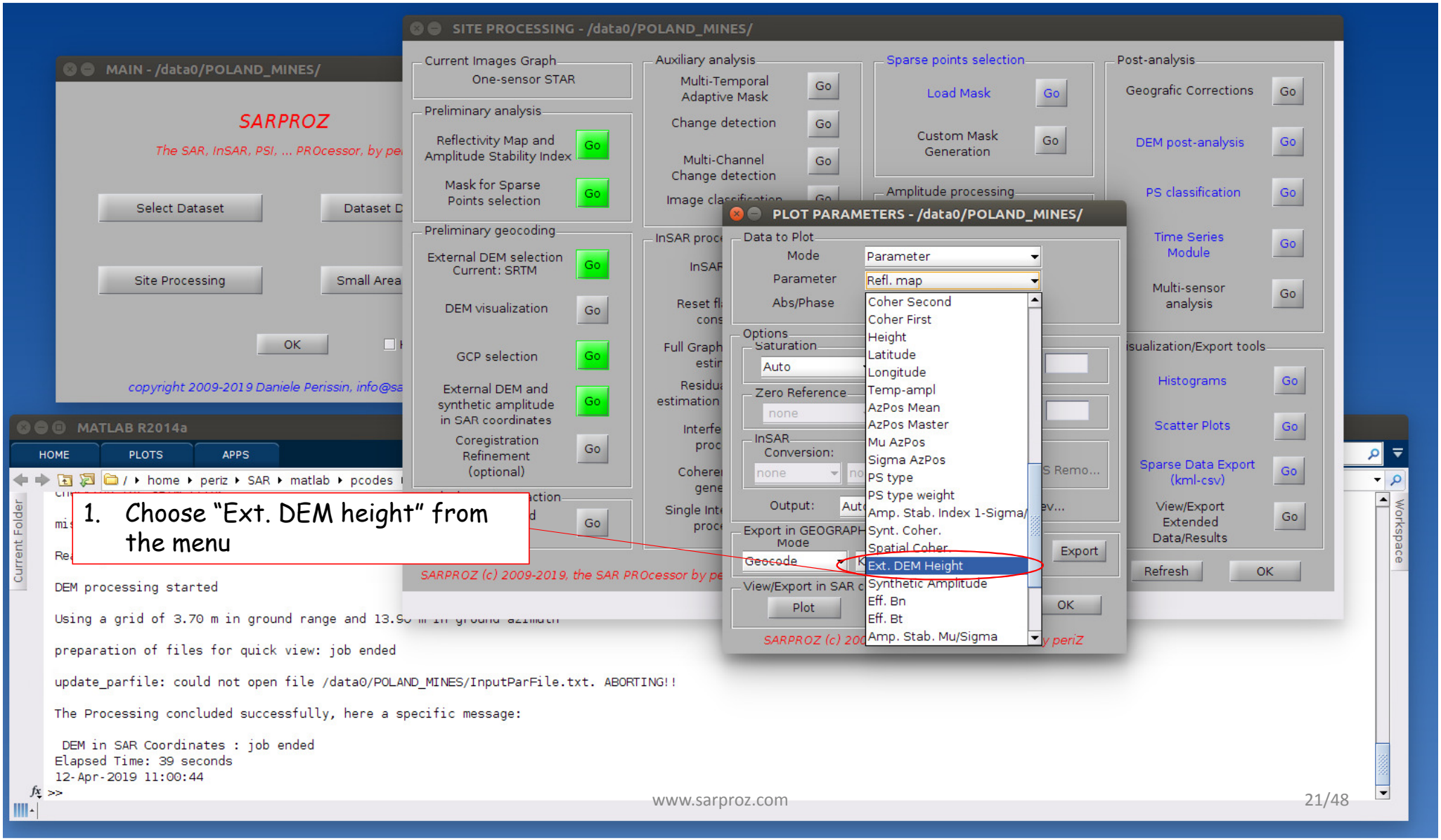
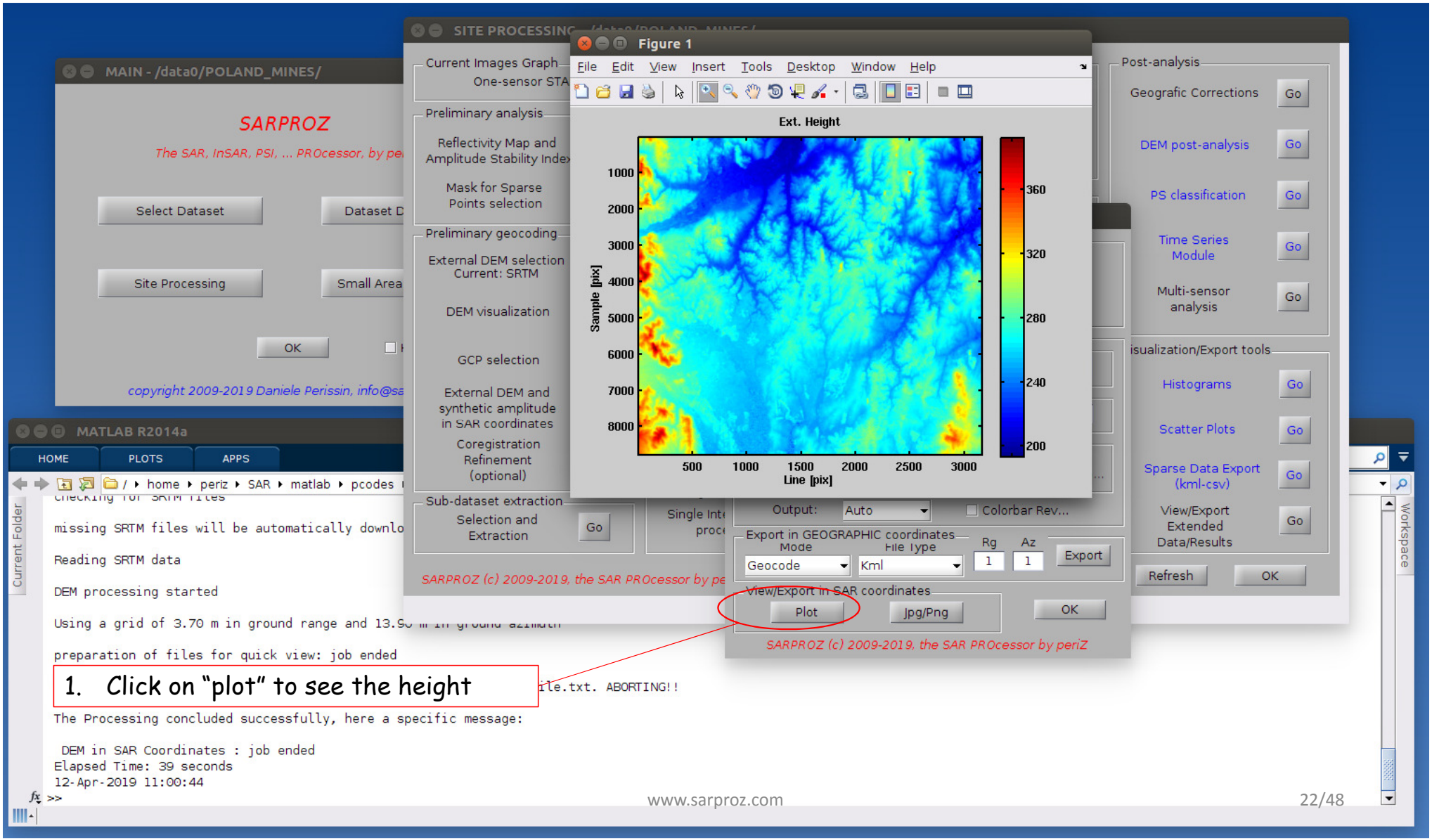
Single Inte
proce
Sparse points selection
Load Mask
Custom Mask Generation
Amplitude processing
Post-analysis
Geografic Corrections
DEM post-analysis
PS classification
Time Series Module
Multi-sensor analysis
isualization/Export tools
Histograms
Scatter Plots
Sparse Data Export (kml-csv)
View/Export Extended Data/Results
Refresh
OK
Go
SARPROZ (c) 2009-2019, the SAR PROcessor by pe
PLOT PARAMETERS - /data0/POLAND_MINES/
Data to Plot
Mode
Parameter
Parameter
Abs/Phase
Options
Saturation
Auto
Zero Reference
none
InSAR Conversion:
none
Output:
Export in GEOGRAPH
Mode
Geocode
View/Export in SAR c
Plot
RCS
Range width
Range pointing
Azimuth width
Azimuth pointing
Ton
Toff
Fitting index
Pos. dev.
AP ampl.
AP phase
Sample
Line
Temp-phase
Refl. map
Pos Mean
Pos Master
Mu Pos
Sigma Pos
Coher Second
Export
OK
SARPROZ (c) 200
y periZ
1. Keep the "Parameter" mode
2. Choose "Refl Map" from the menu
HOME
PLOTS
APPS
Current Folder
Workspace
missing SRTM files will be automatically downlo
Reading SRTM data
DEM processing started
Using a grid of 3.70 m in ground range and 13.9
preparation of files for quick view: job ended
update_parfile: could not open file /data0/POLAND_MINES/InputParFile.txt. ABORTING!!
The Processing concluded successfully, here a specific message:
DEM in SAR Coordinates : job ended
Elapsed Time: 39 seconds
12-Apr-2019 11:00:44
>>



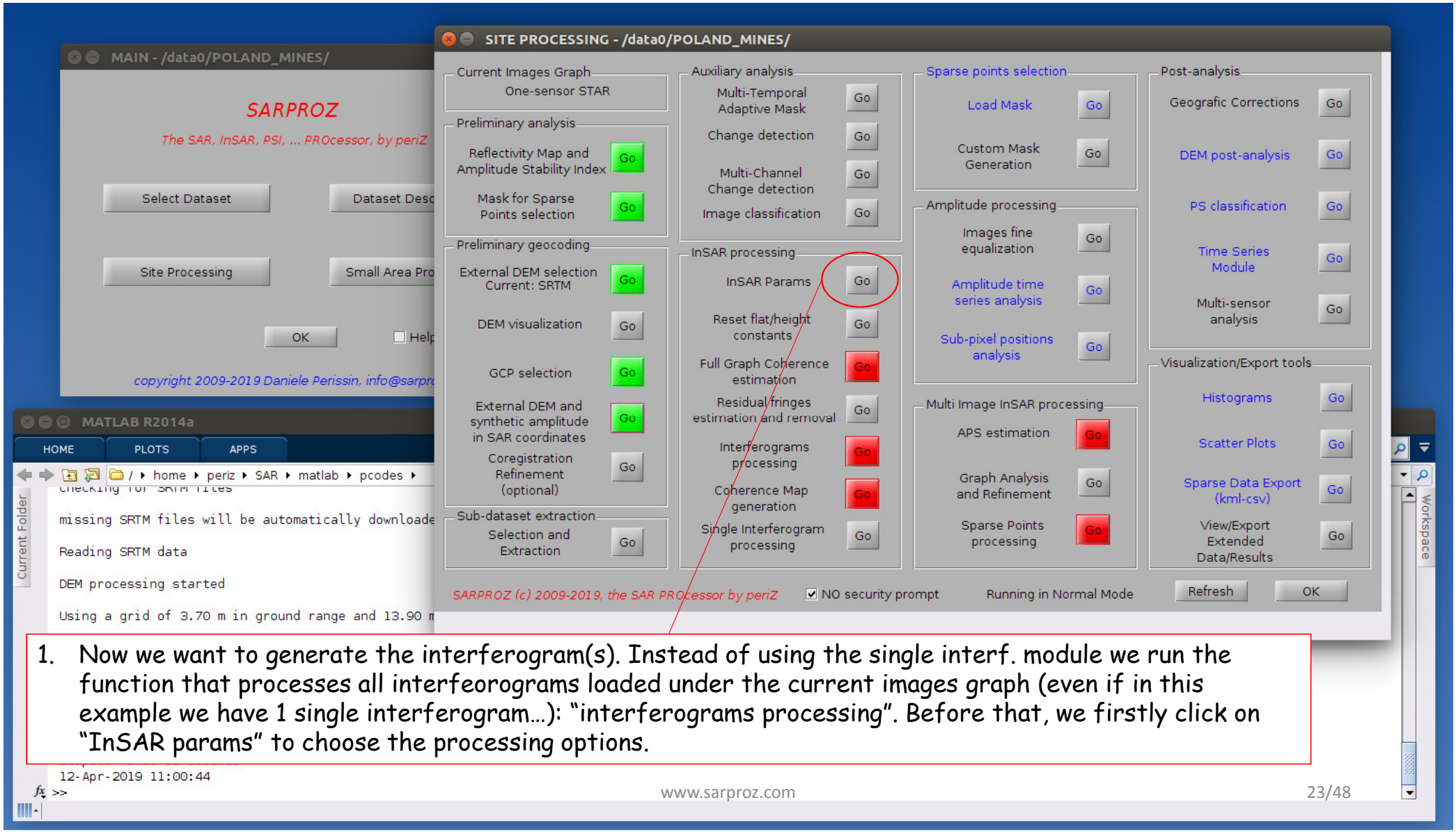
1. Click on "plot" to see the Refl Map



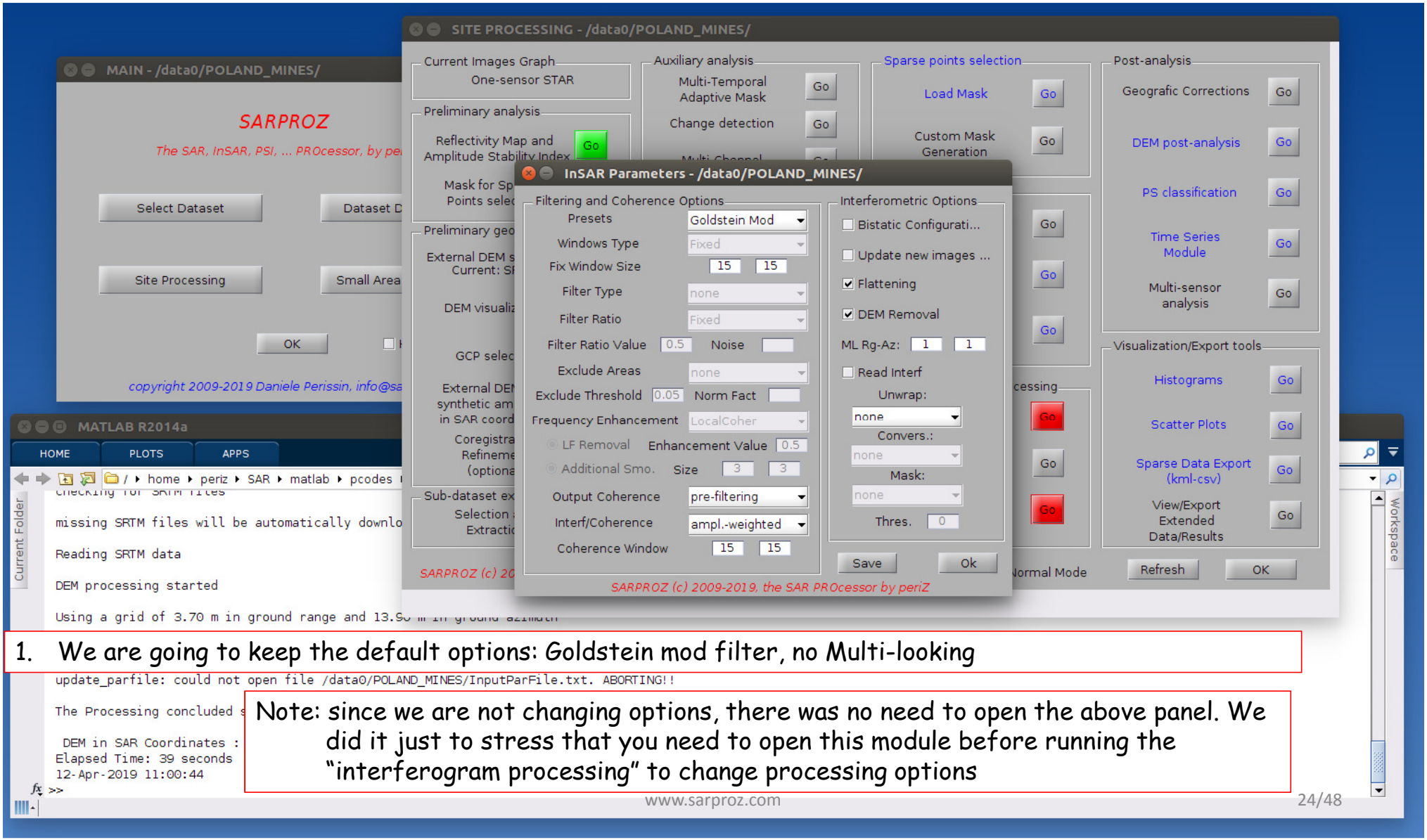
1. Choose "Ext. DEM height" from the menu



1. Click on "plot" to see the height

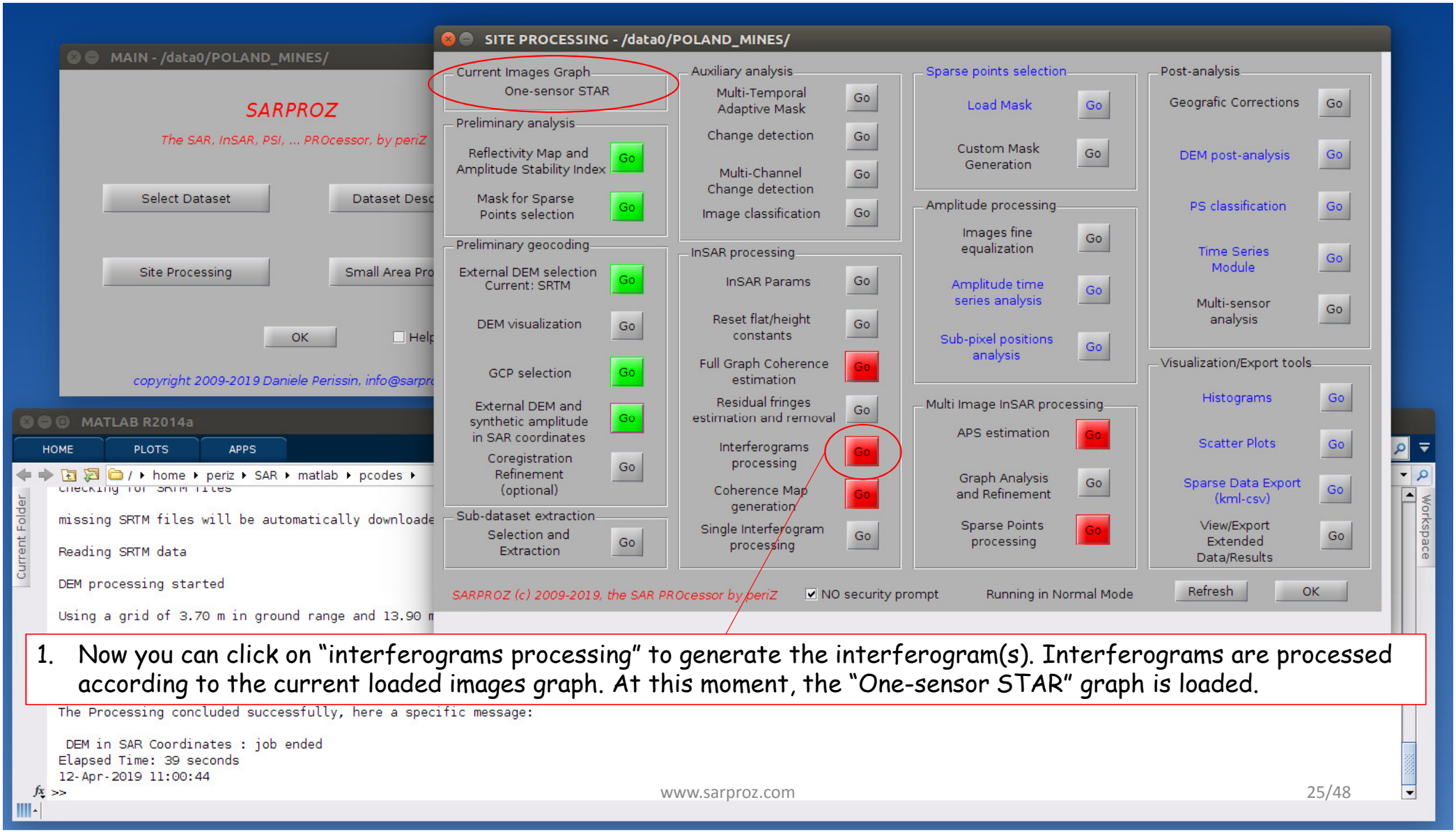


1. Now we want to generate the interferogram(s). Instead of using the single interf. module we run the function that processes all interfeorograms loaded under the current images graph (even if in this example we have 1 single interferogram…): "interferograms processing". Before that, we firstly click on "InSAR params" to choose the processing options.

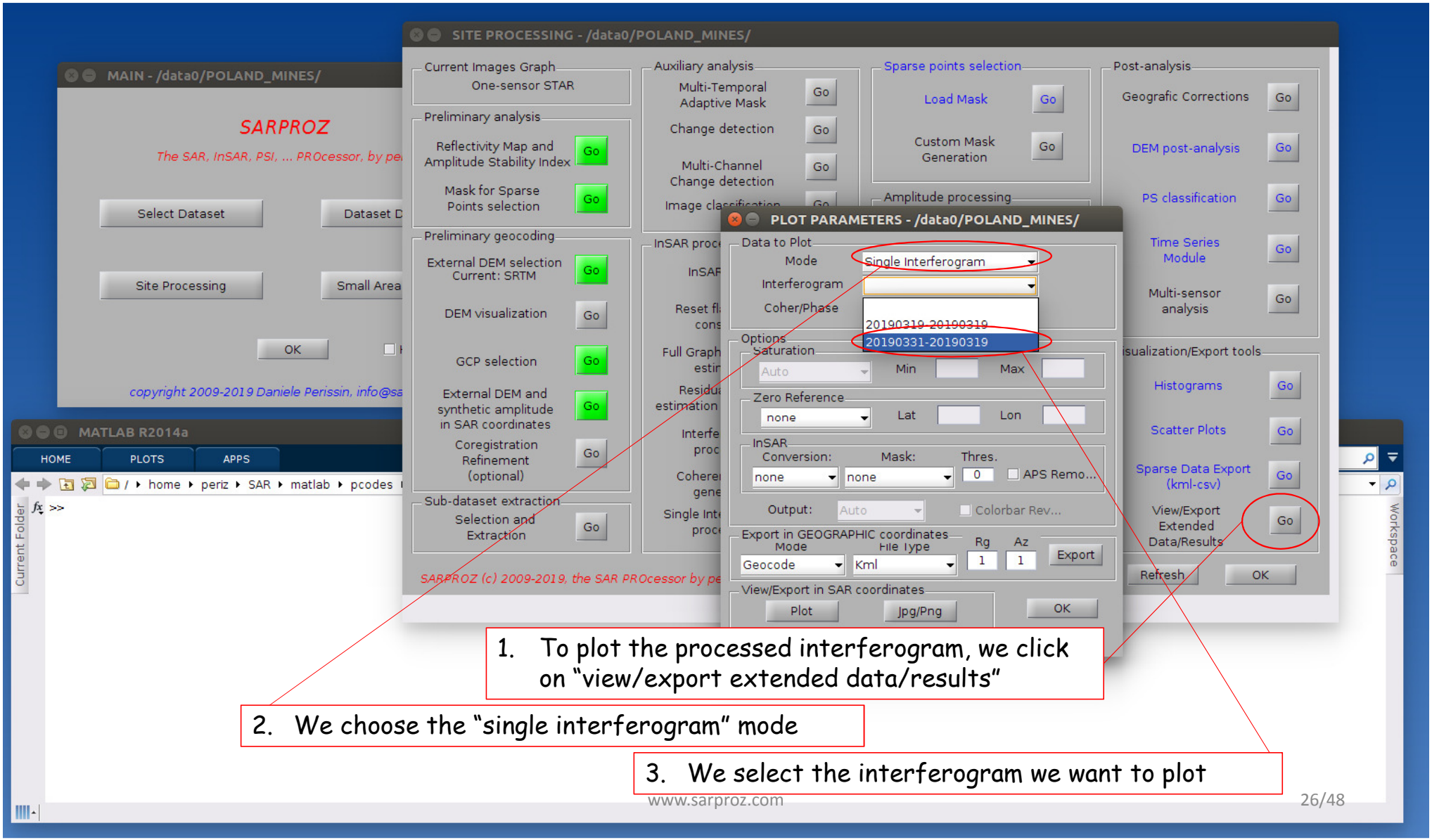


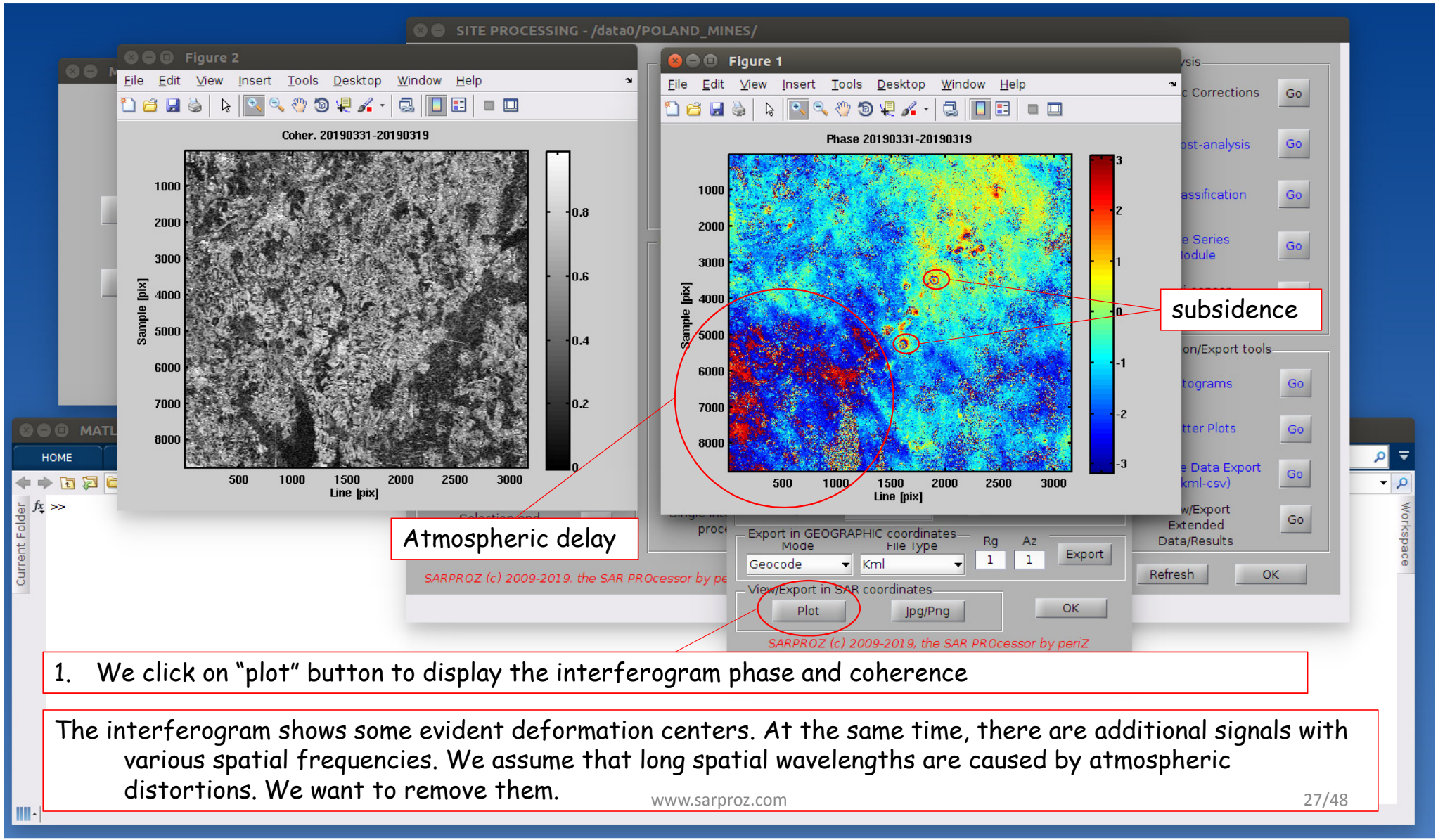
1. We are going to keep the default options: Goldstein mod filter, no Multi-looking

Note: since we are not changing options, there was no need to open the above panel. We did it just to stress that you need to open this module before running the "interferogram processing" to change processing options



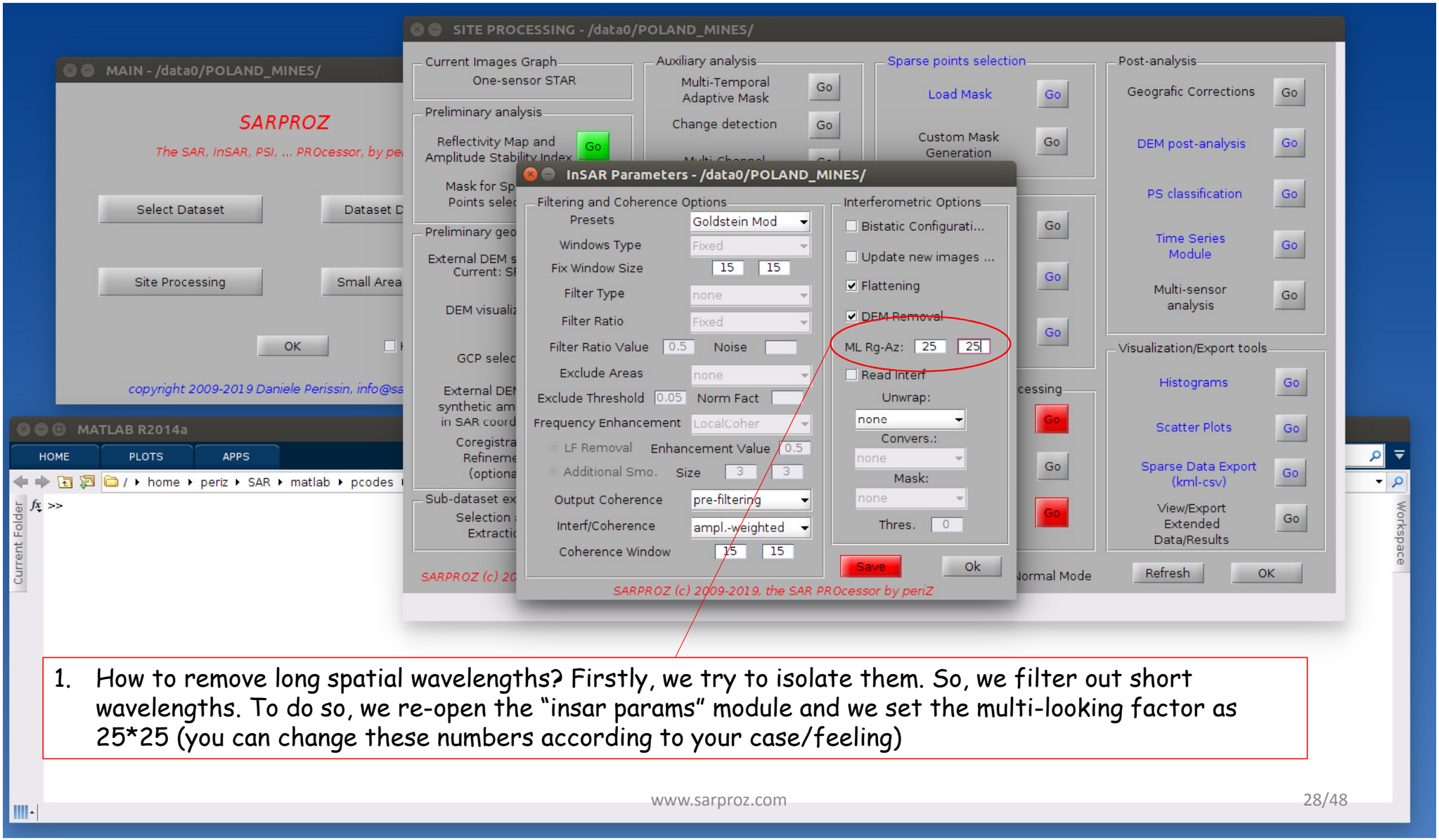
1. Now you can click on "interferograms processing" to generate the interferogram(s). Interferograms are processed according to the current loaded images graph. At this moment, the "One-sensor STAR" graph is loaded.


MAIN - /data0/POLAND_MINES/
SARPROZ
Select Dataset
Site Processing
OK
SITE PROCESSING - /data0/POLAND_MINES/
Current Images Graph
One-sensor STAR
Preliminary analysis
Reflectivity Map and Amplitude Stability Index
Mask for Sparse Points selection
Preliminary geocoding
External DEM selection Current: SRTM
DEM visualization
GCP selection
External DEM and synthetic amplitude in SAR coordinates
Coregistration Refinement (optional)
Sub-dataset extraction
Selection and Extraction
Auxiliary analysis
Multi-Temporal Adaptive Mask
Change detection
Multi-Channel Change detection
Sparse points selection
Load Mask
Custom Mask Generation
Amplitude processing
Post-analysis
Geografic Corrections
DEM post-analysis
PS classification
Time Series Module
Multi-sensor analysis
Histograms
Scatter Plots
Sparse Data Export (kml-csv)
View/Export Extended Data/Results
Refresh
OK
PLOT PARAMETERS - /data0/POLAND_MINES/
Data to Plot
Mode
Single Interferogram
Interferogram
Coher/Phase
20190319-20190319
20190331-20190319
Options
Saturation
Auto
Min
Max
Zero Reference
none
Lat
Lon
InSAR
Conversion:
Mask:
Thres.
APS Remo...
Output:
Colorbar Rev...
Export in GEOGRAPHIC coordinates
Mode
File Type
Rg
Az
Geocode
Kml
Export
View/Export in SAR coordinates
Plot
Jpg/Png
OK
MATLAB R2014a
HOME
PLOTS
APPS
Current Folder
Workspace
1. To plot the processed interferogram, we click on "view/export extended data/results"
2. We choose the "single interferogram" mode
3. We select the interferogram we want to plot

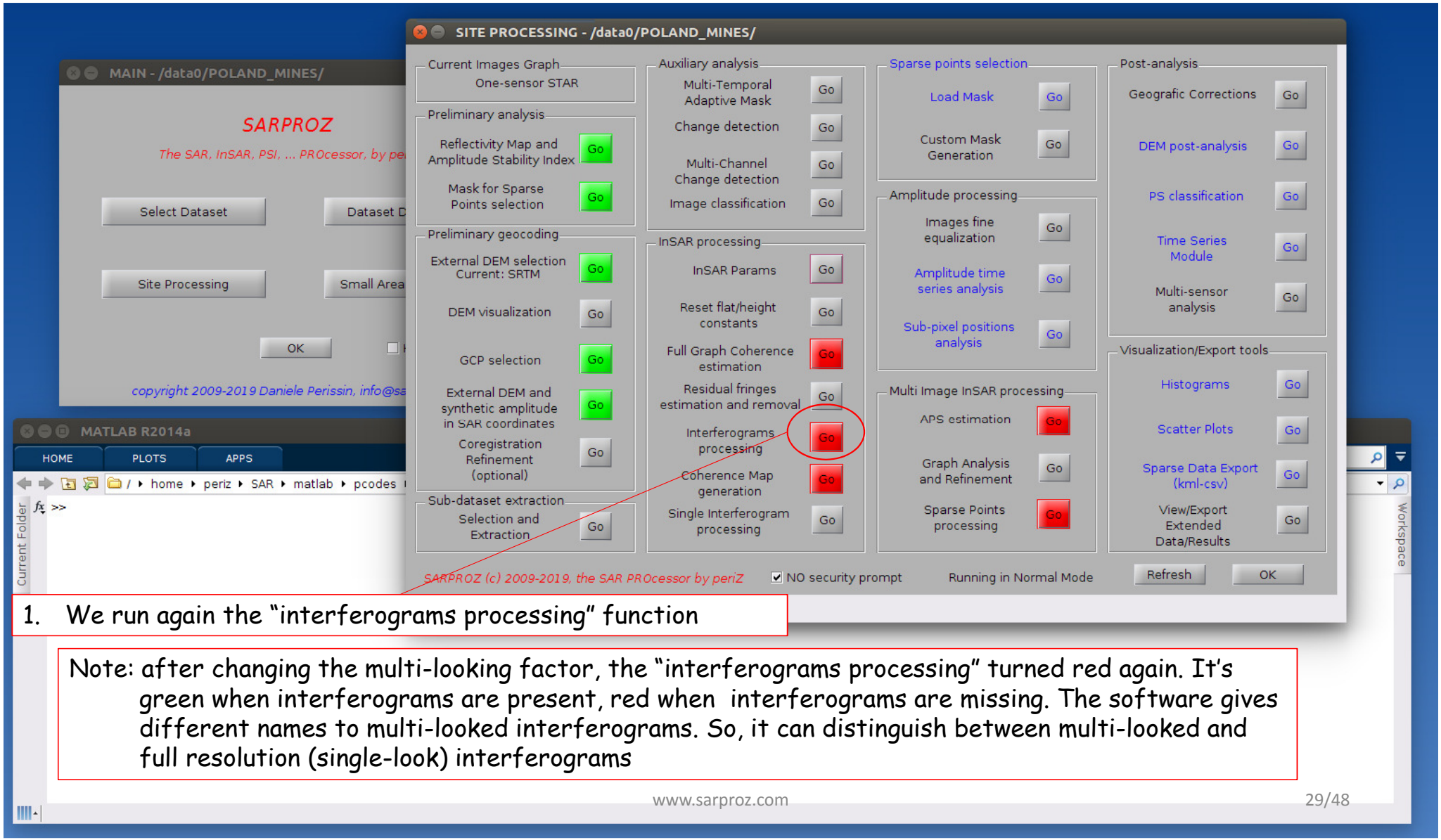


1. We click on "plot" button to display the interferogram phase and coherence

The interferogram shows some evident deformation centers. At the same time, there are additional signals with various spatial frequencies. We assume that long spatial wavelengths are caused by atmospheric distortions. We want to remove them.

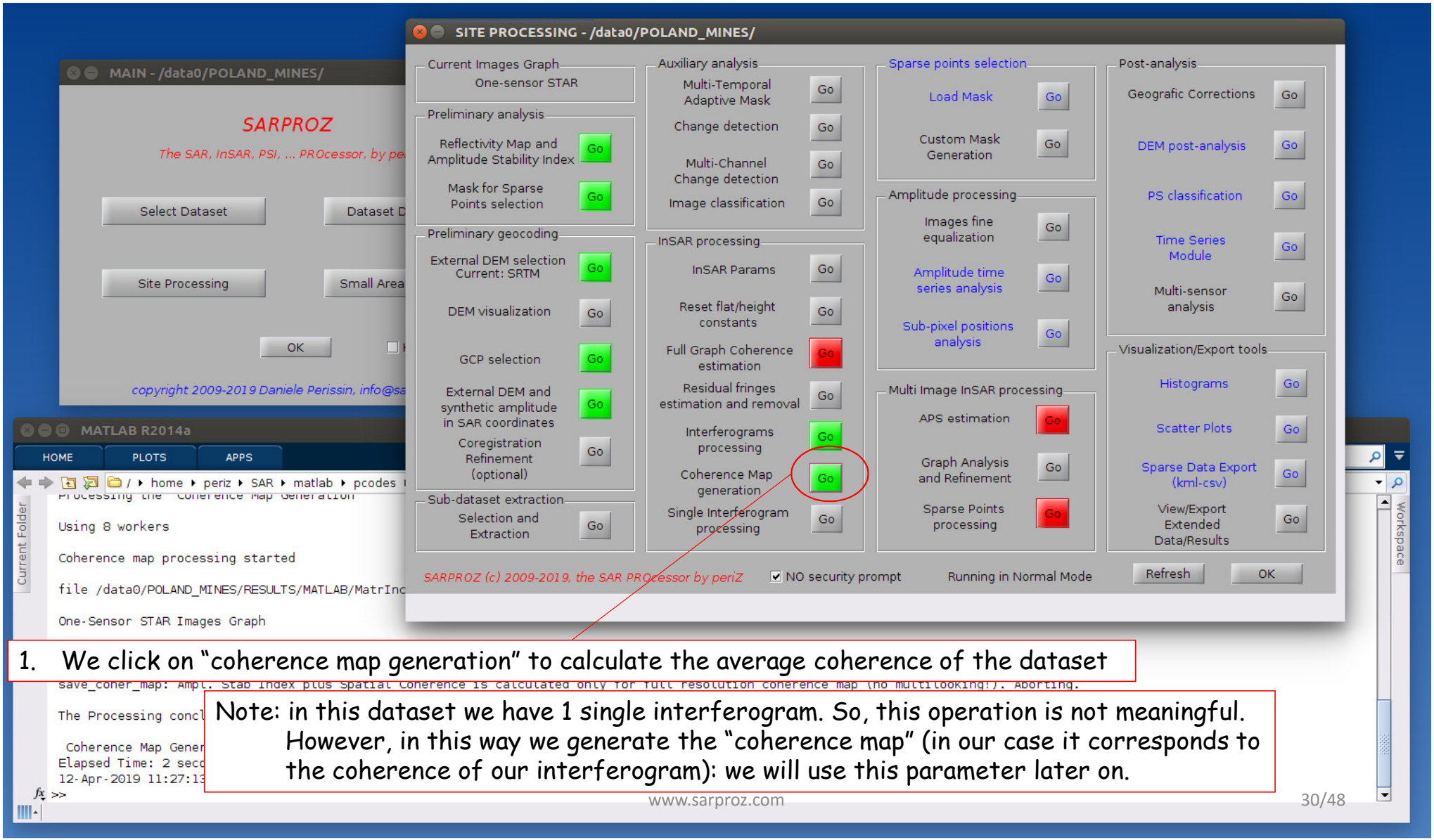


1. How to remove long spatial wavelengths? Firstly, we try to isolate them. So, we filter out short wavelengths. To do so, we re-open the "insar params" module and we set the multi-looking factor as 25*25 (you can change these numbers according to your case/feeling)



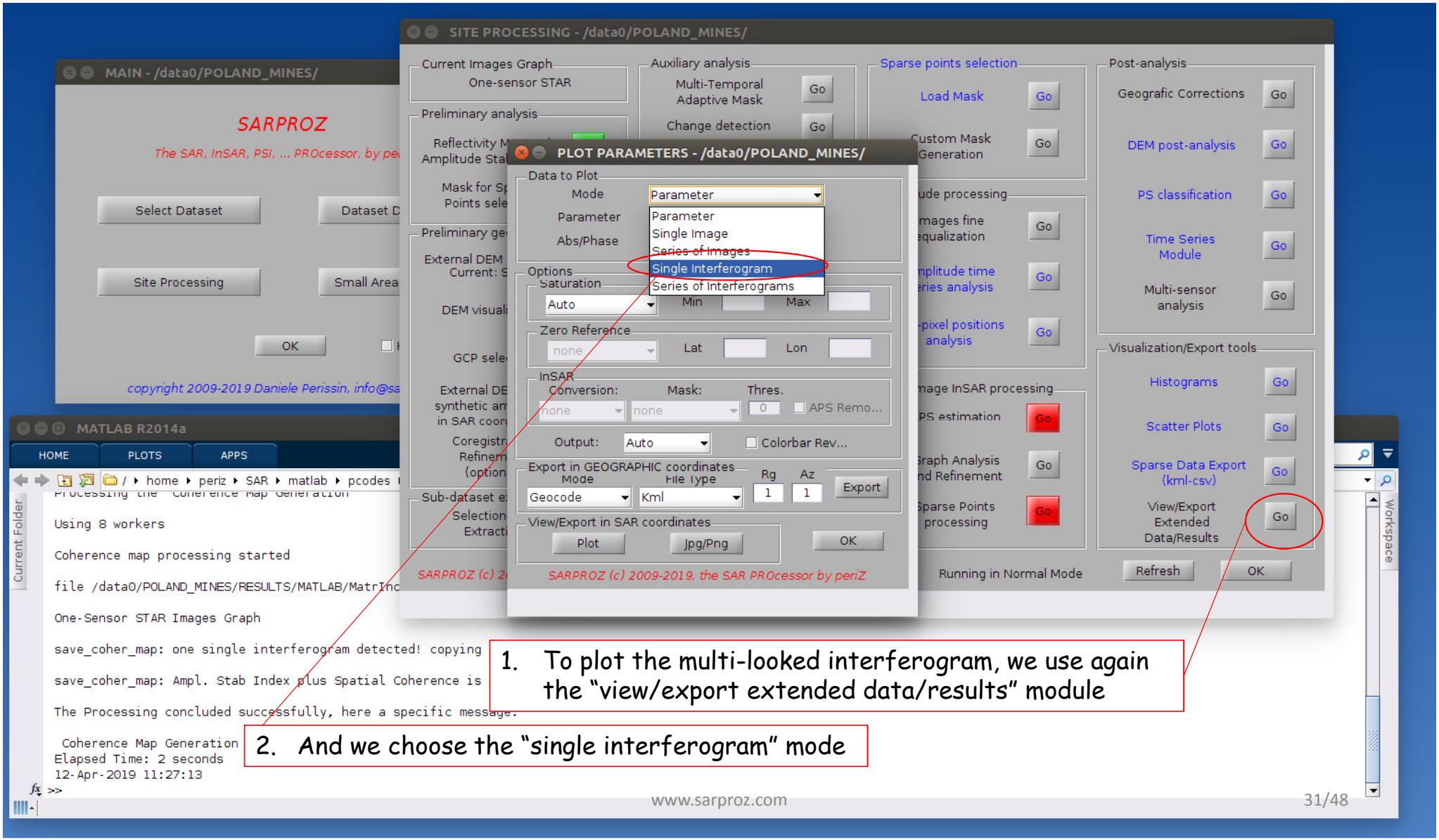
1. We run again the "interferograms processing" function

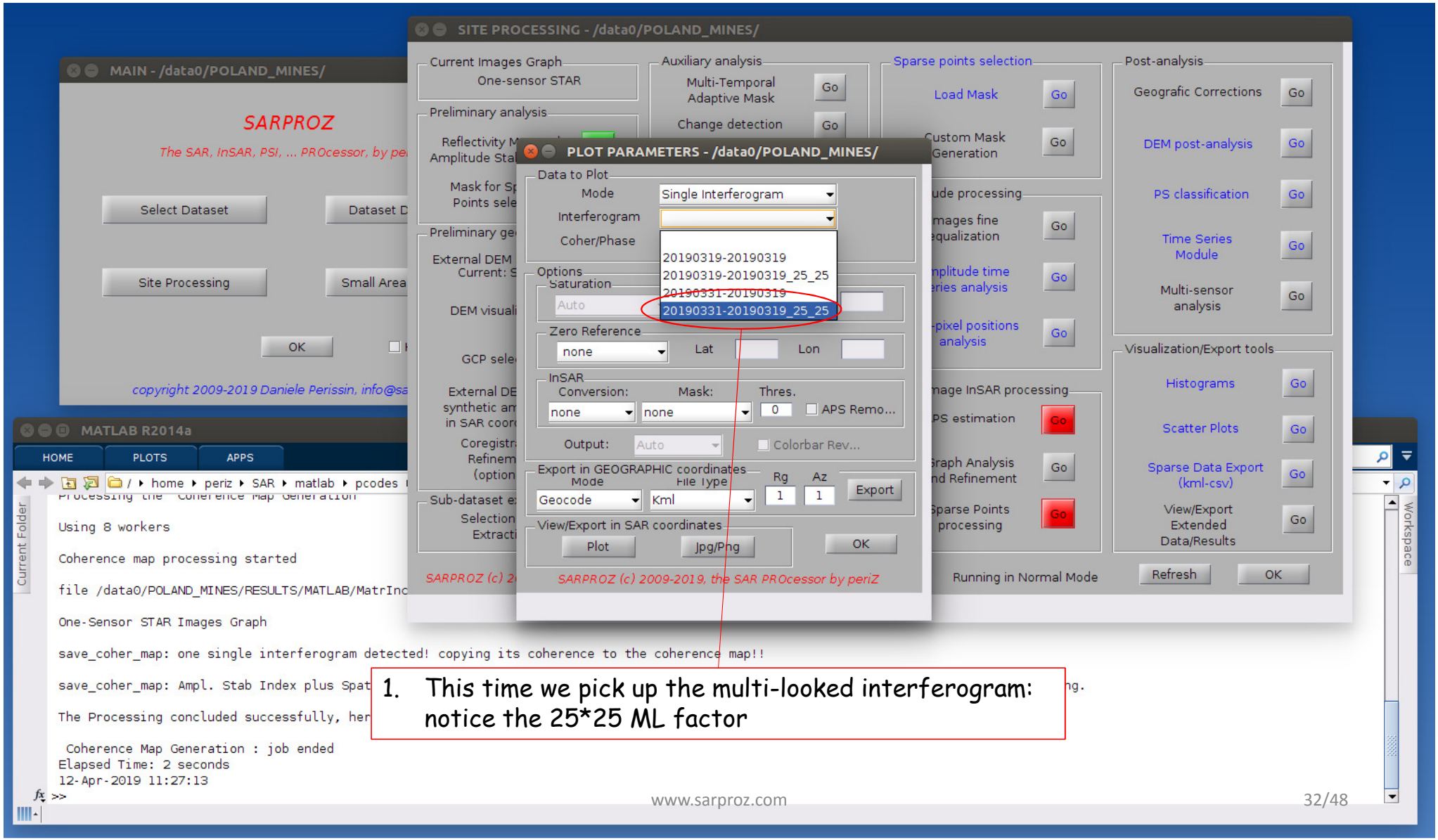
Note: after changing the multi-looking factor, the "interferograms processing" turned red again. It's green when interferograms are present, red when interferograms are missing. The software gives different names to multi-looked interferograms. So, it can distinguish between multi-looked and full resolution (single-look) interferograms



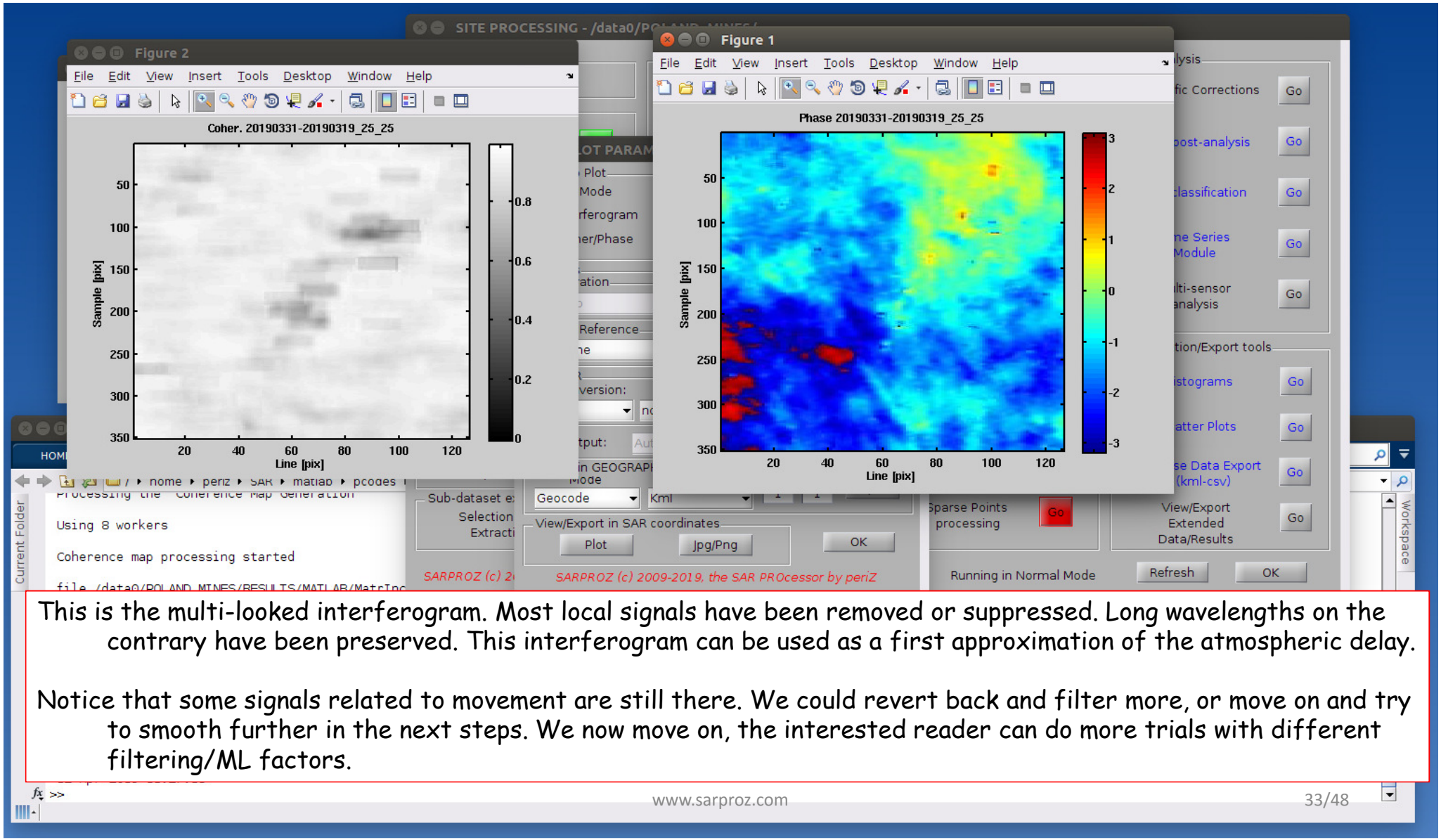
1. We click on "coherence map generation" to calculate the average coherence of the dataset

Note: in this dataset we have 1 single interferogram. So, this operation is not meaningful. However, in this way we generate the "coherence map" (in our case it corresponds to the coherence of our interferogram): we will use this parameter later on.


MAIN - /data0/POLAND_MINES/
SARPROZ
Select Dataset
Site Processing
OK
SITE PROCESSING - /data0/POLAND_MINES/
Current Images Graph
One-sensor STAR
Auxiliary analysis
Multi-Temporal Adaptive Mask
Change detection
Sparse points selection
Load Mask
Custom Mask Generation
Post-analysis
Geografic Corrections
DEM post-analysis
PS classification
Time Series Module
Multi-sensor analysis
Visualization/Export tools
Histograms
Scatter Plots
Sparse Data Export (kml-csv)
View/Export Extended Data/Results
Refresh
OK
Running in Normal Mode
PLOT PARAMETERS - /data0/POLAND_MINES/
Data to Plot
Mode
Parameter
Parameter
Single Image
Series of Images
Single Interferogram
Series of Interferograms
Abs/Phase
Options
Saturation
Auto
Min
Max
Zero Reference
none
Lat
Lon
InSAR
Conversion:
Mask:
Thres.
APS Remo...
Output:
Auto
Colorbar Rev...
Export in GEOGRAPHIC coordinates
Mode
File Type
Rg
Az
Geocode
Kml
1
1
Export
View/Export in SAR coordinates
Plot
Jpg/Png
OK
SARPROZ (c) 2009-2019, the SAR PROcessor by periZ
MATLAB R2014a
HOME
PLOTS
APPS
Using 8 workers
Coherence map processing started
One-Sensor STAR Images Graph
save_coher_map: one single interferogram detected! copying
save_coher_map: Ampl. Stab Index plus Spatial Coherence is
The Processing concluded successfully, here a specific message.
Coherence Map Generation
Elapsed Time: 2 seconds
12-Apr-2019 11:27:13
1. To plot the multi-looked interferogram, we use again the "view/export extended data/results" module
2. And we choose the "single interferogram" mode

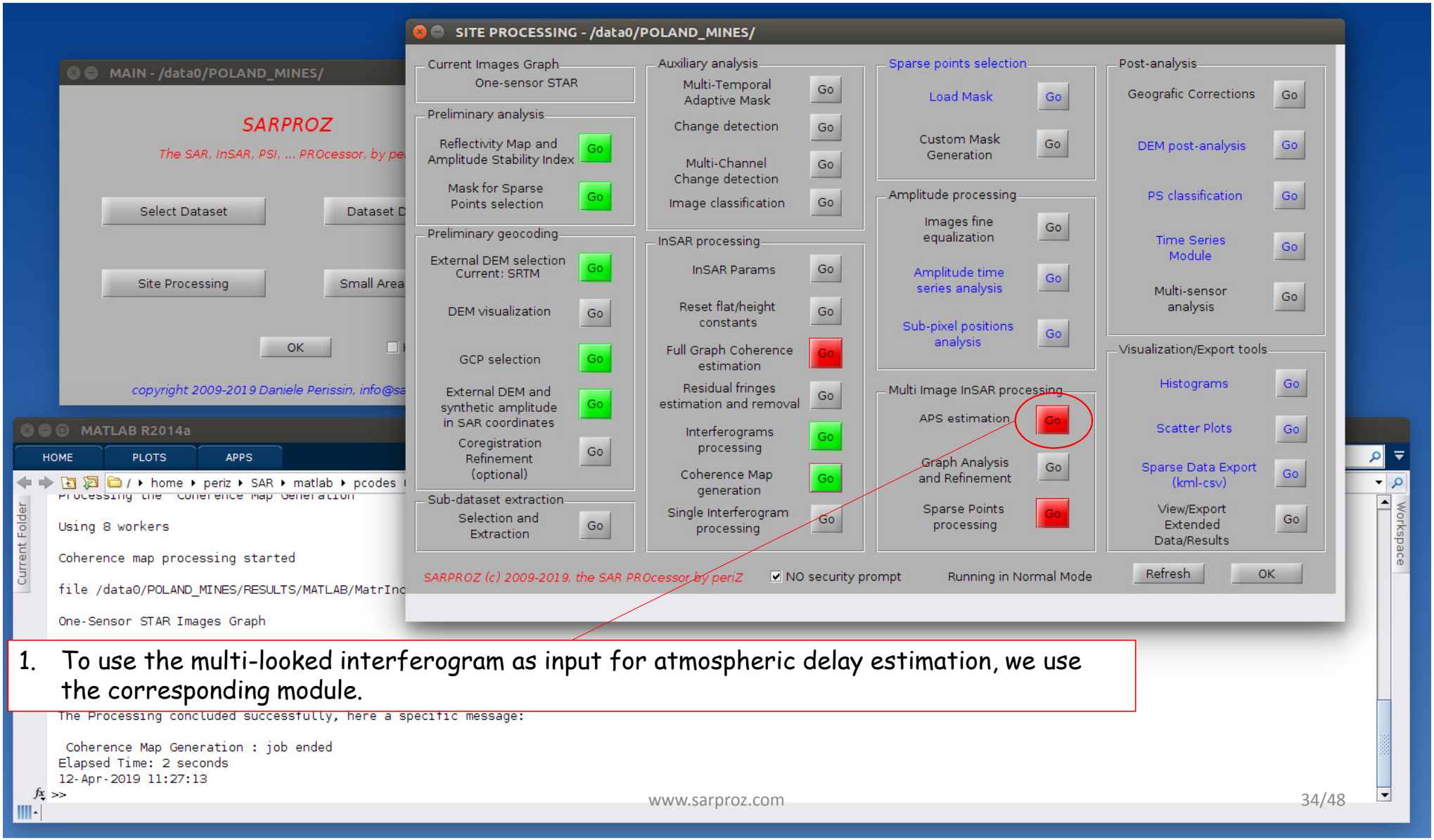


1. This time we pick up the multi-looked interferogram: notice the 25*25 ML factor

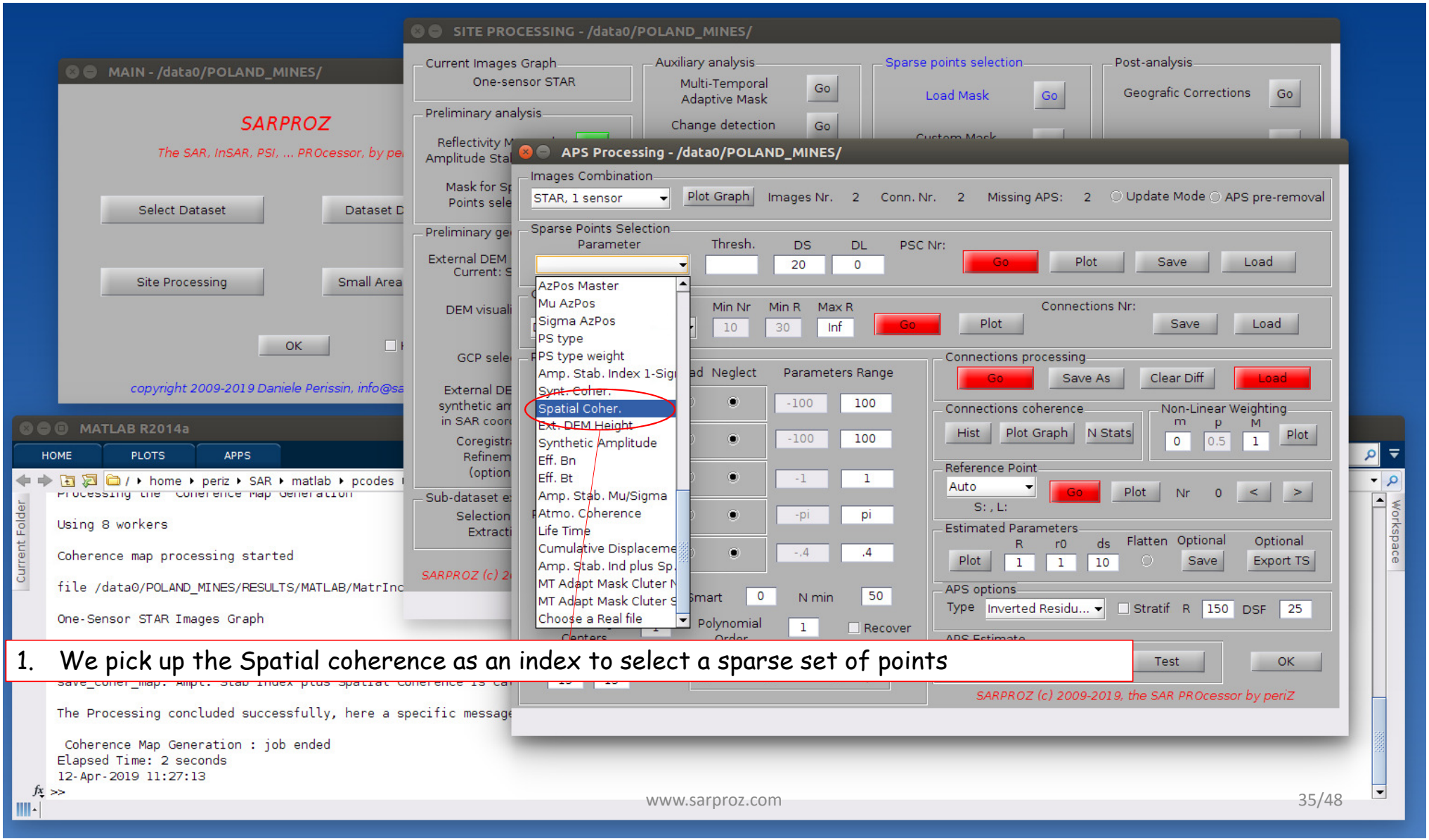


This is the multi-looked interferogram. Most local signals have been removed or suppressed. Long wavelengths on the contrary have been preserved. This interferogram can be used as a first approximation of the atmospheric delay.

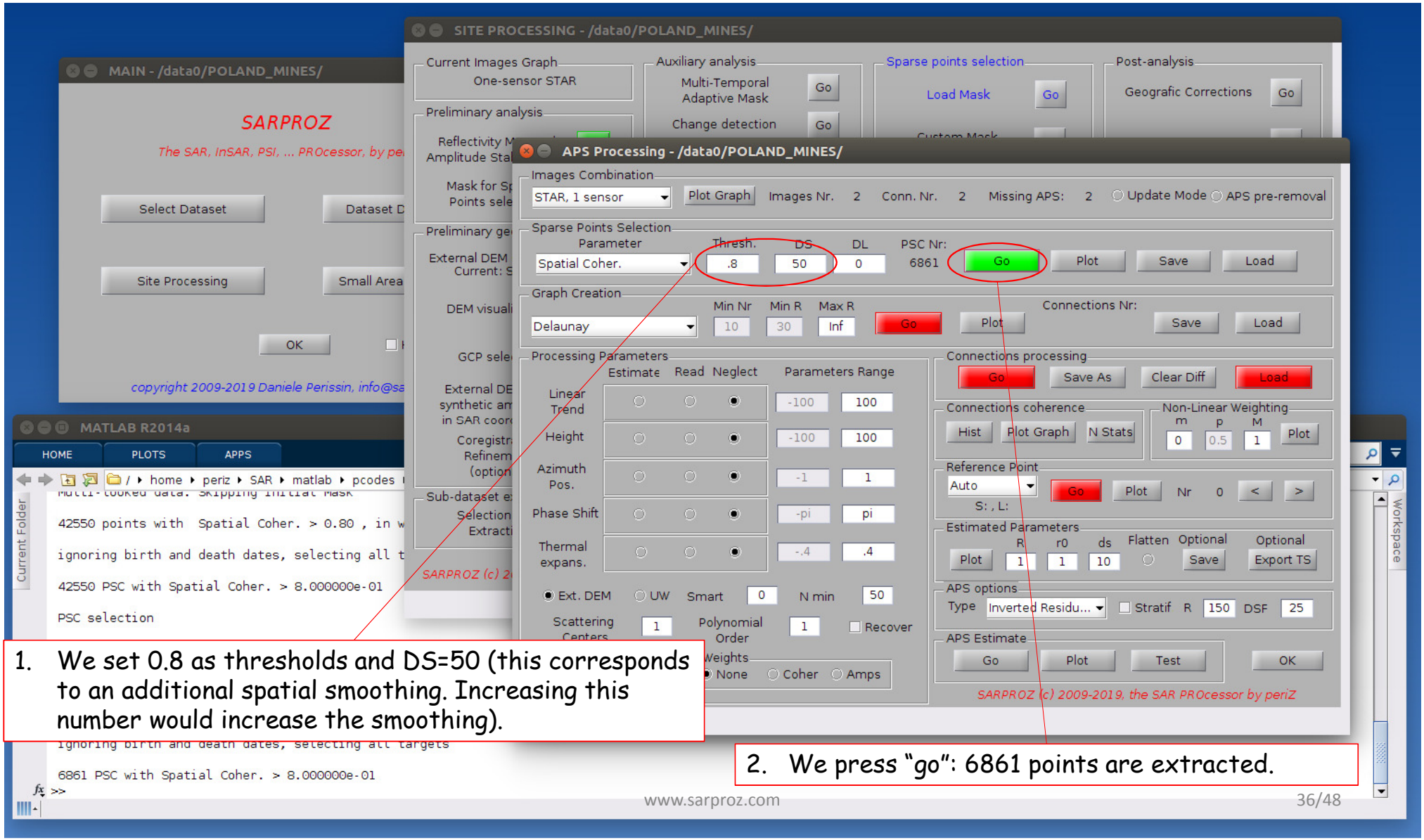
Notice that some signals related to movement are still there. We could revert back and filter more, or move on and try to smooth further in the next steps. We now move on, the interested reader can do more trials with different filtering/ML factors.



1. To use the multi-looked interferogram as input for atmospheric delay estimation, we use the corresponding module.

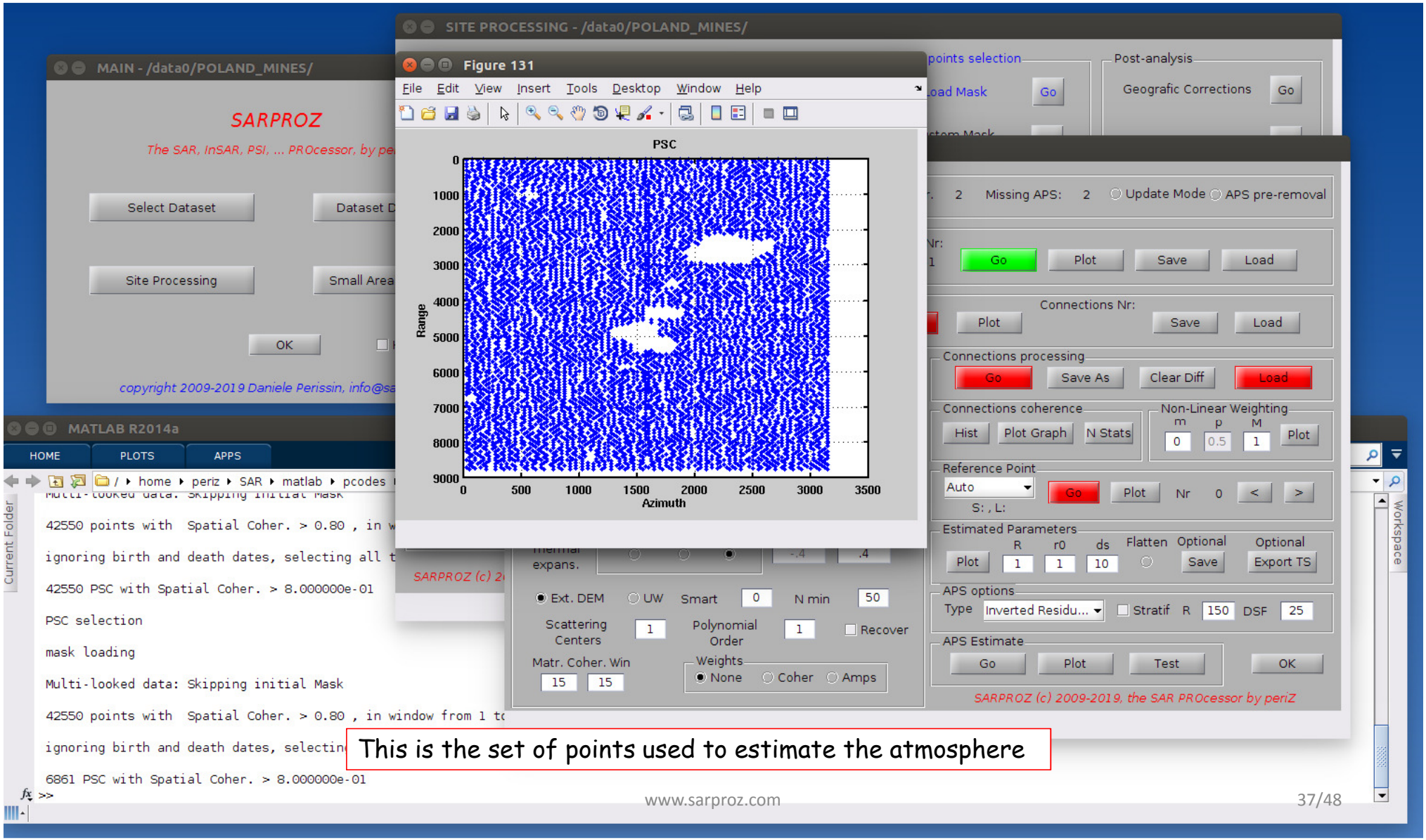


1. We pick up the Spatial coherence as an index to select a sparse set of points

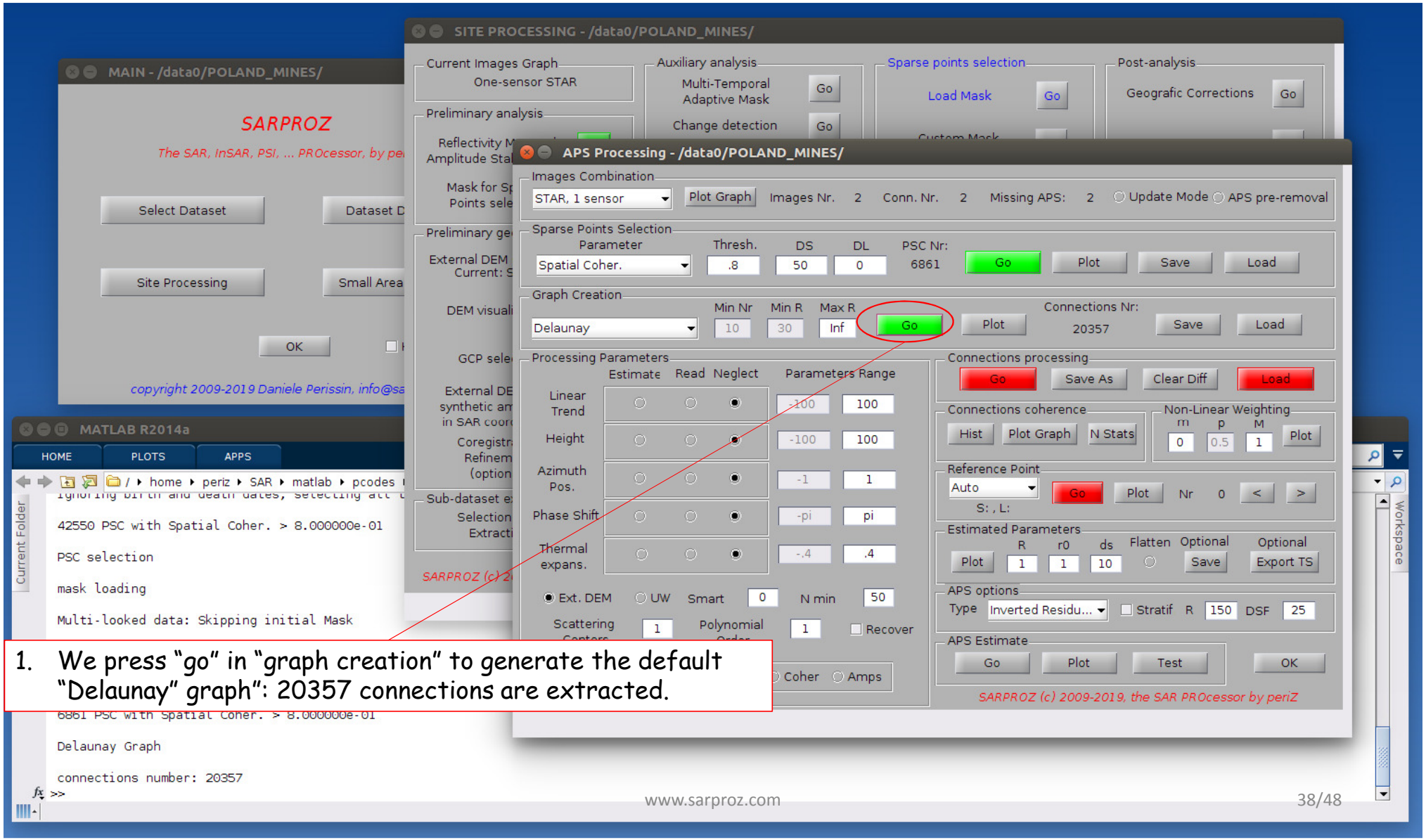


1. We set 0.8 as thresholds and DS=50 (this corresponds to an additional spatial smoothing. Increasing this number would increase the smoothing).

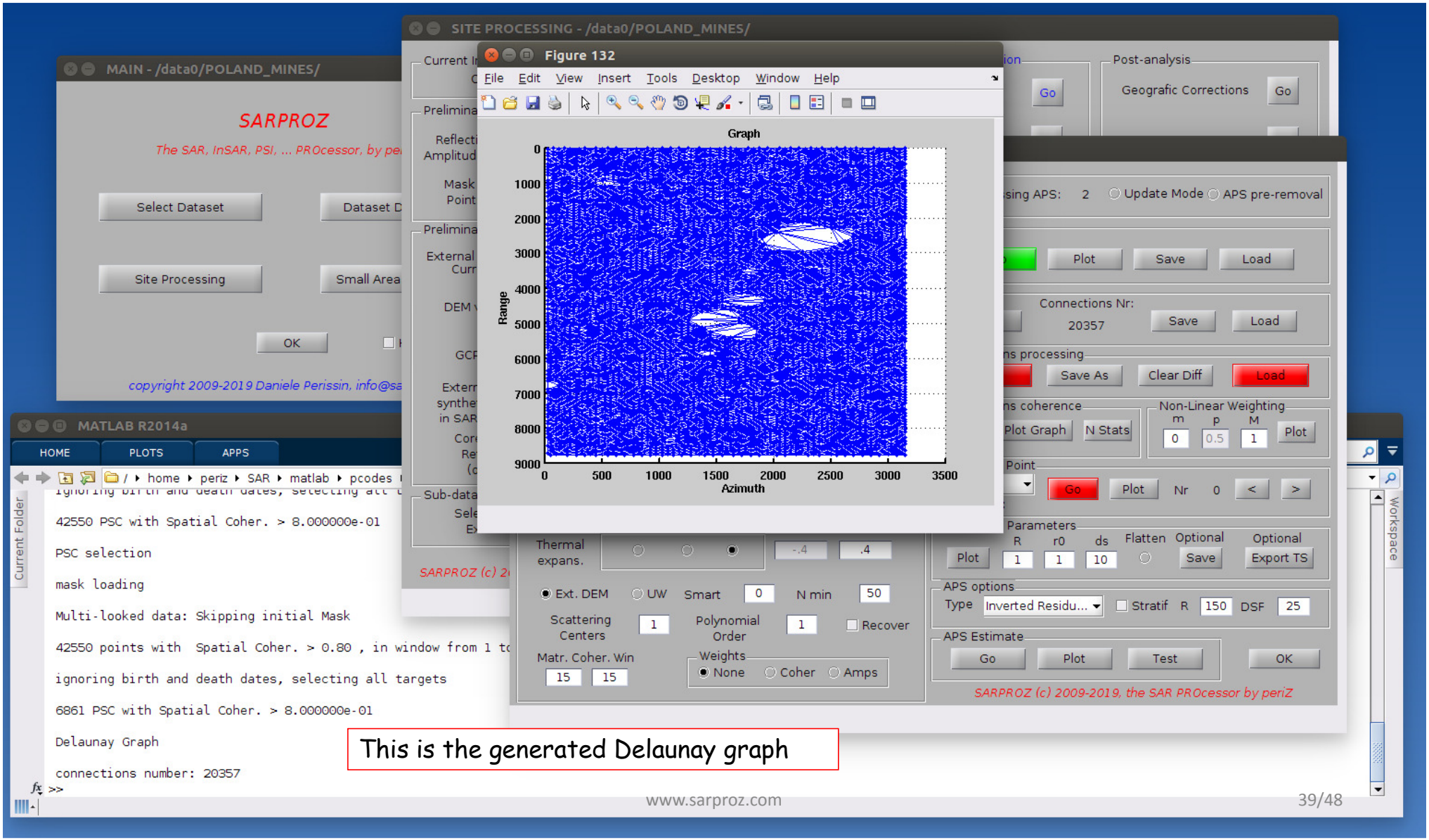
2. We press "go": 6861 points are extracted.



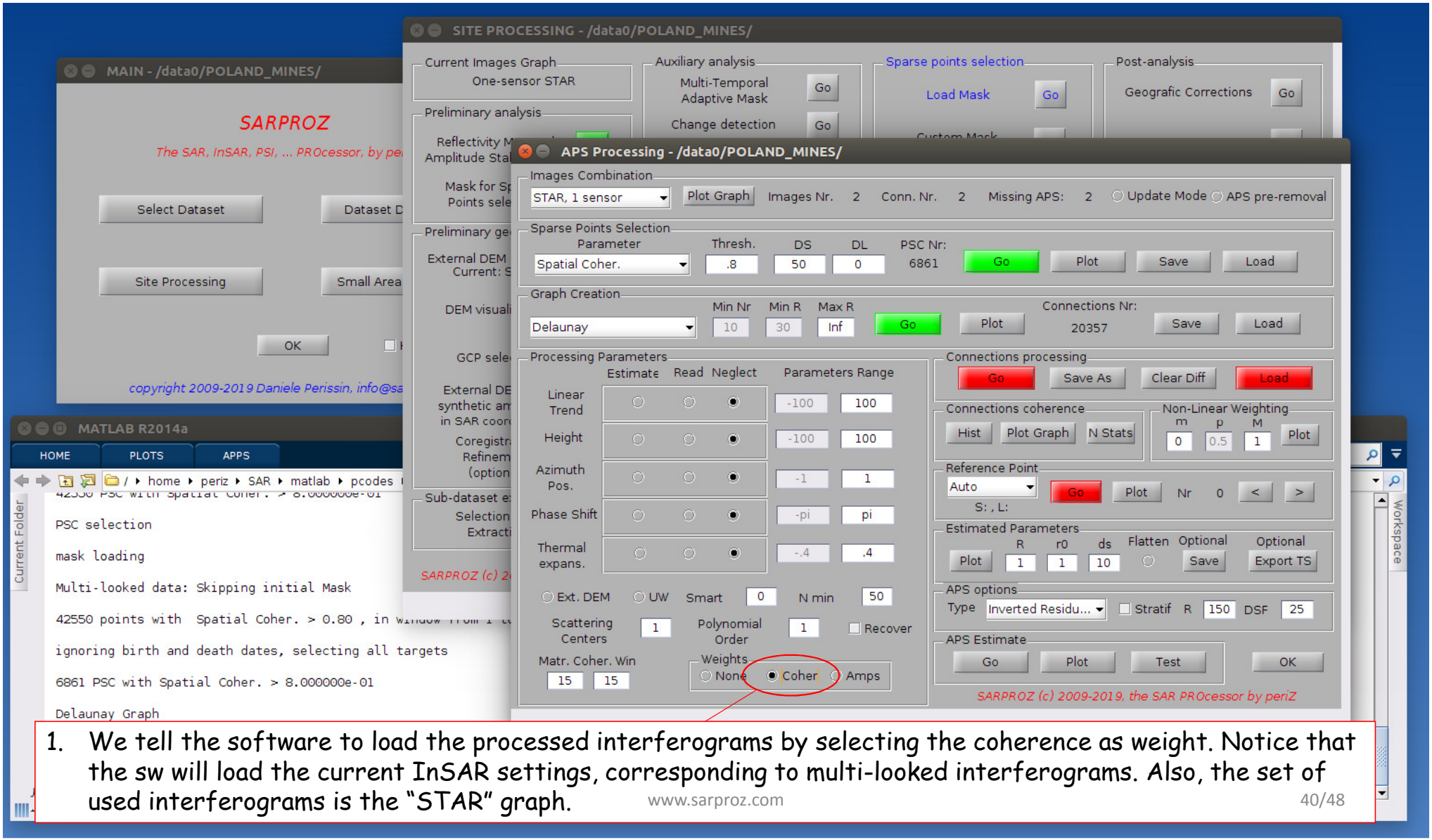
This is the set of points used to estimate the atmosphere



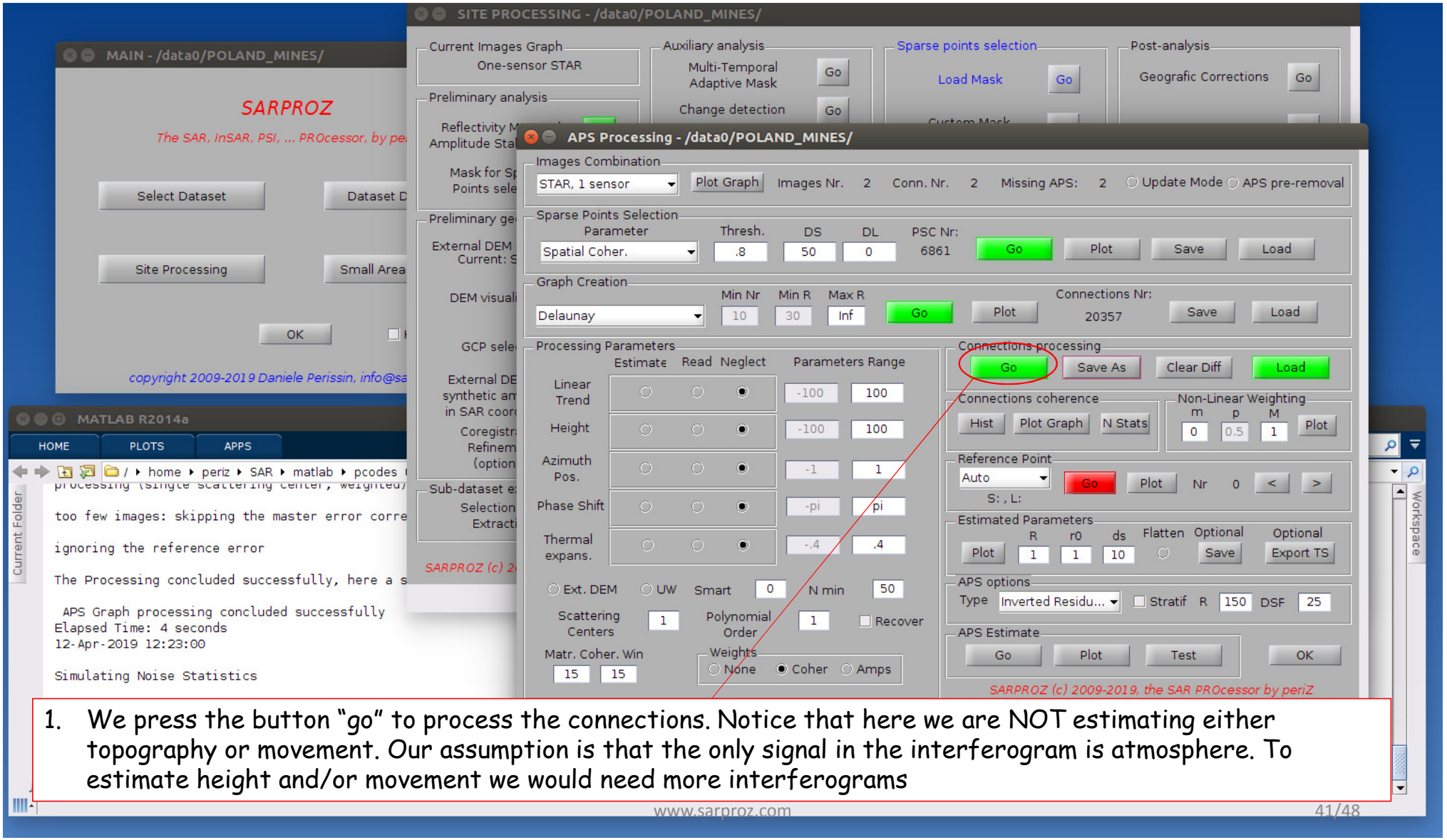
1. We press "go" in "graph creation" to generate the default "Delaunay" graph": 20357 connections are extracted.



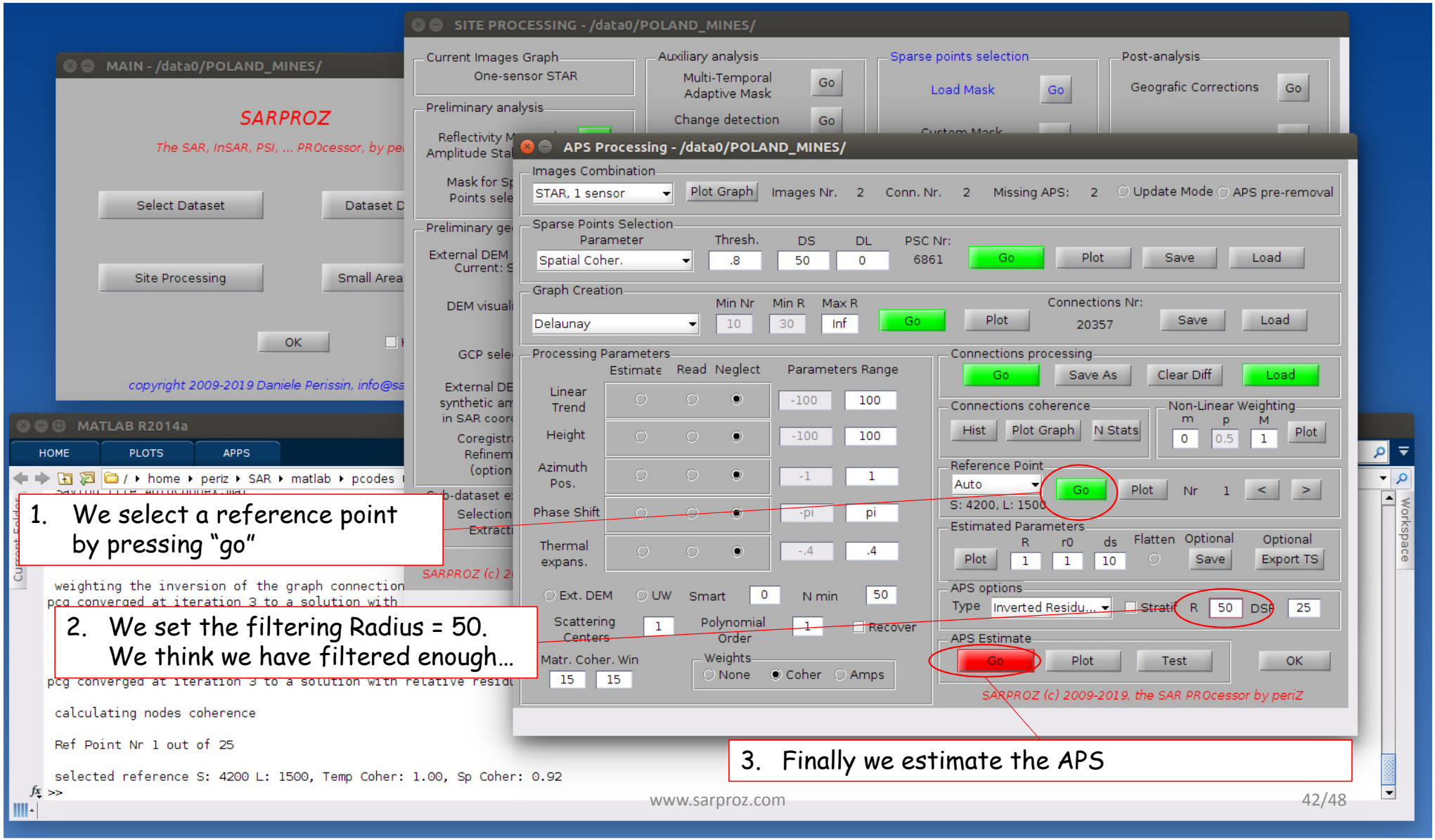
This is the generated Delaunay graph



1. We tell the software to load the processed interferograms by selecting the coherence as weight. Notice that the sw will load the current InSAR settings, corresponding to multi-looked interferograms. Also, the set of used interferograms is the "STAR" graph.



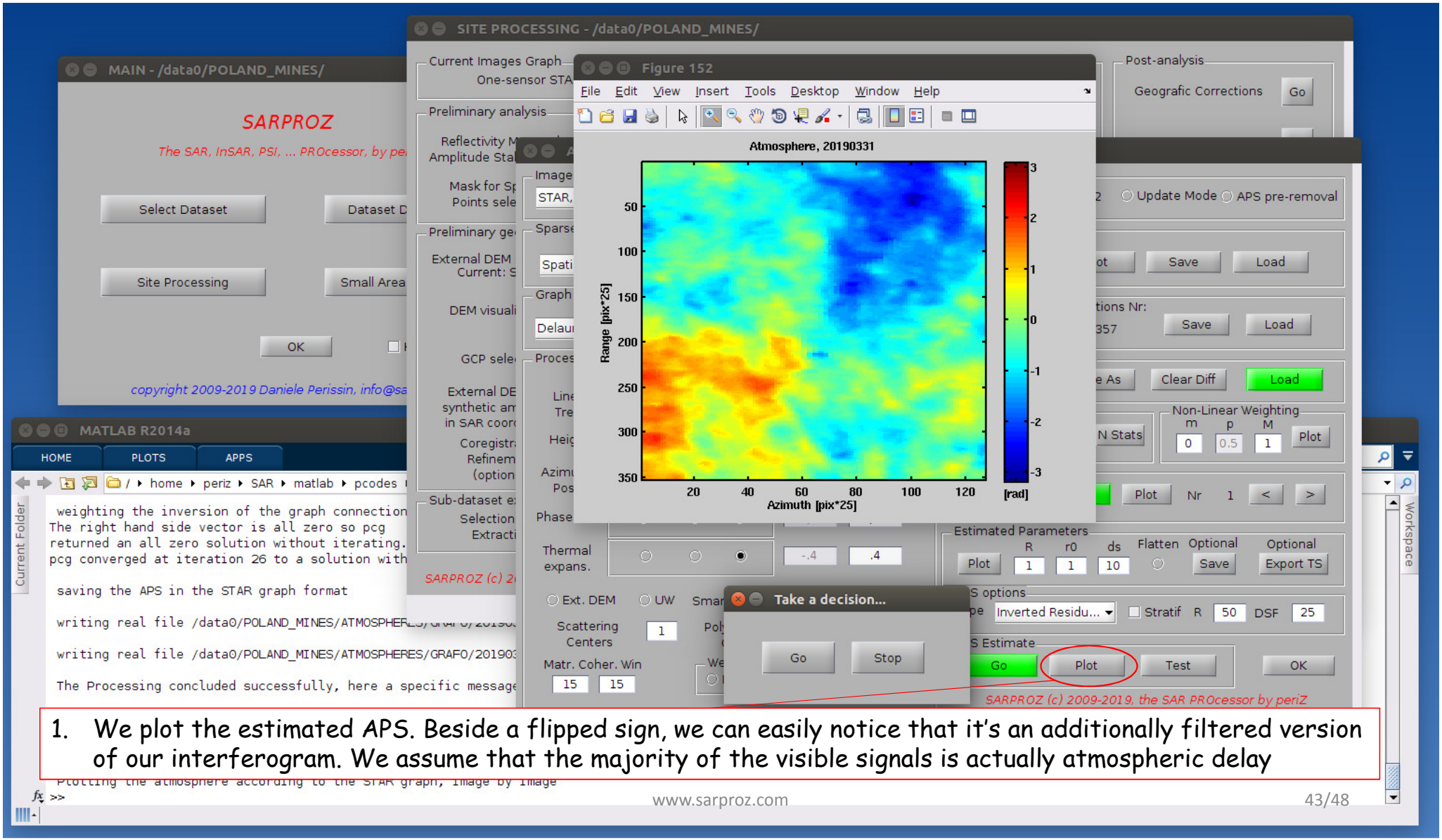
1. We press the button "go" to process the connections. Notice that here we are NOT estimating either topography or movement. Our assumption is that the only signal in the interferogram is atmosphere. To estimate height and/or movement we would need more interferograms



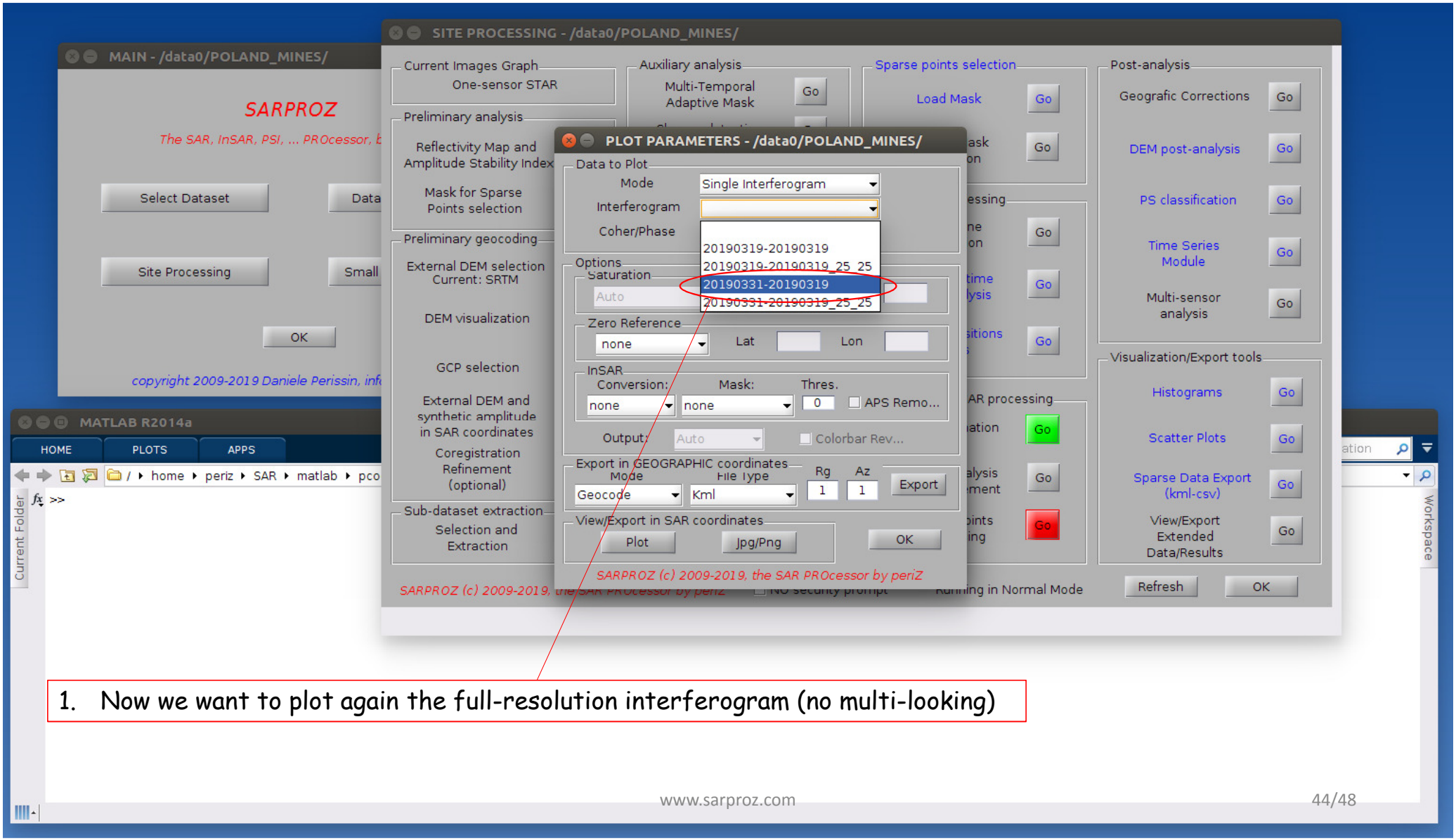
1. We select a reference point by pressing "go"

2. We set the filtering Radius = 50. We think we have filtered enough…

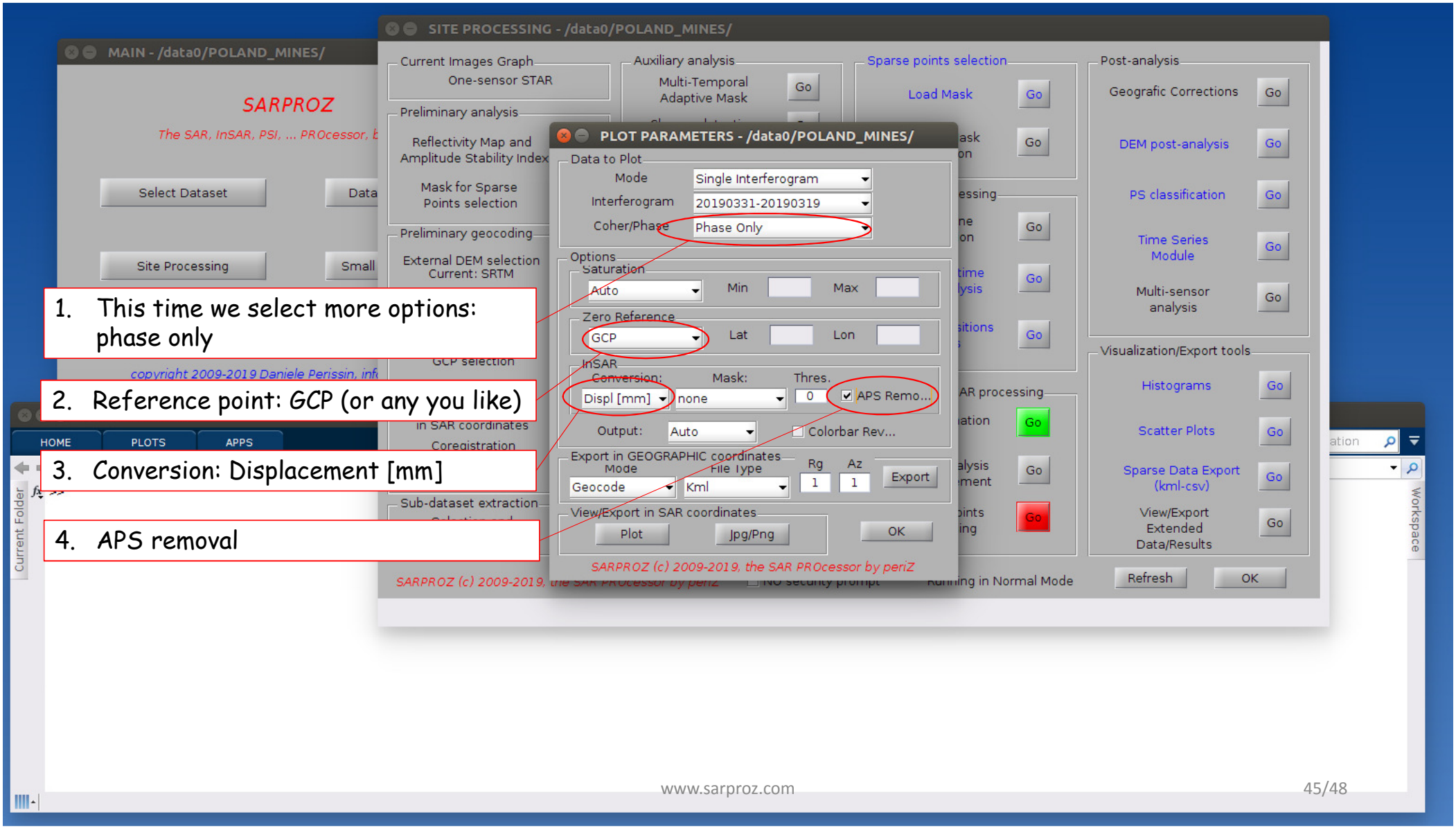
3. Finally we estimate the APS



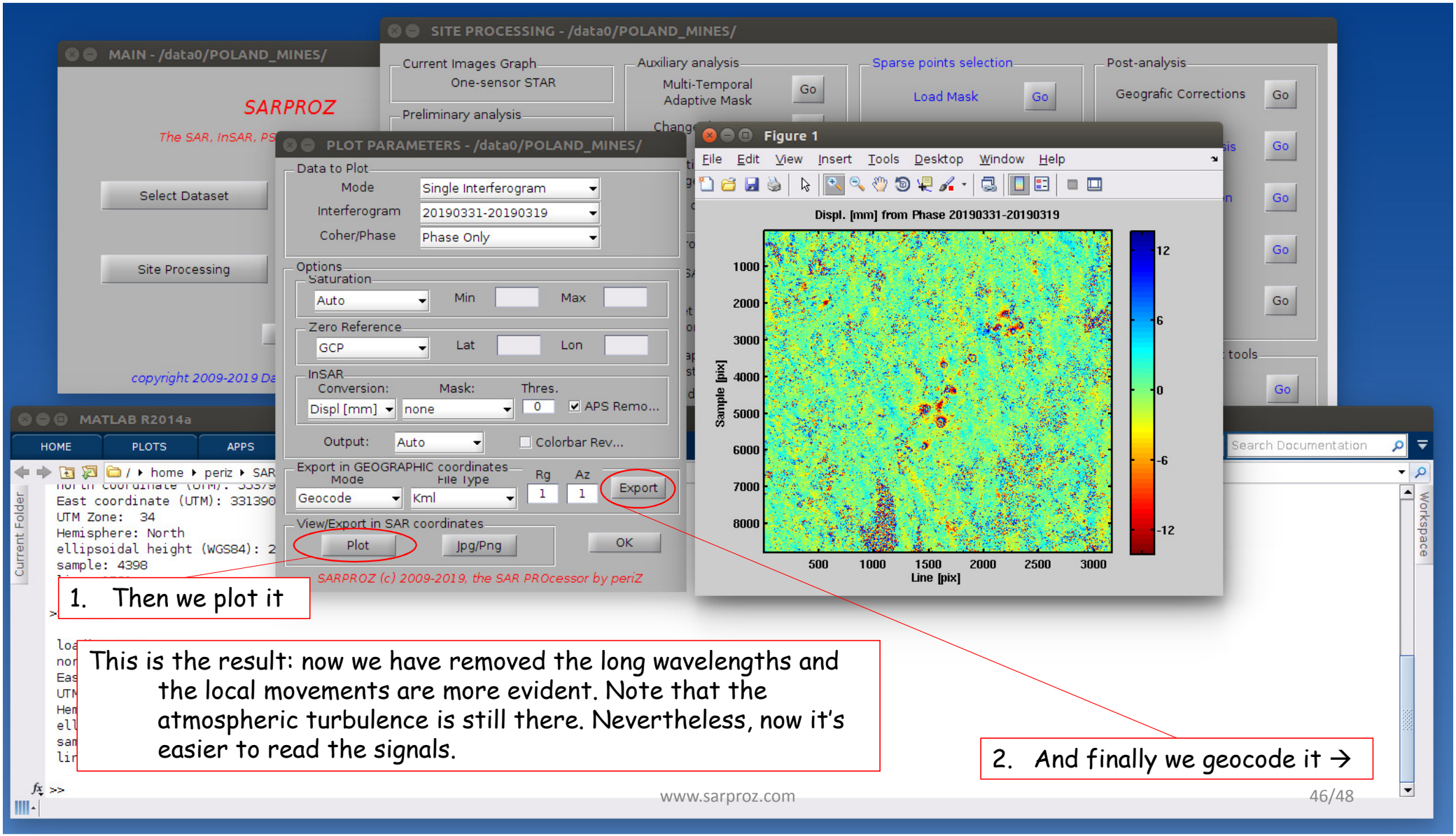
1. We plot the estimated APS. Beside a flipped sign, we can easily notice that it's an additionally filtered version of our interferogram. We assume that the majority of the visible signals is actually atmospheric delay

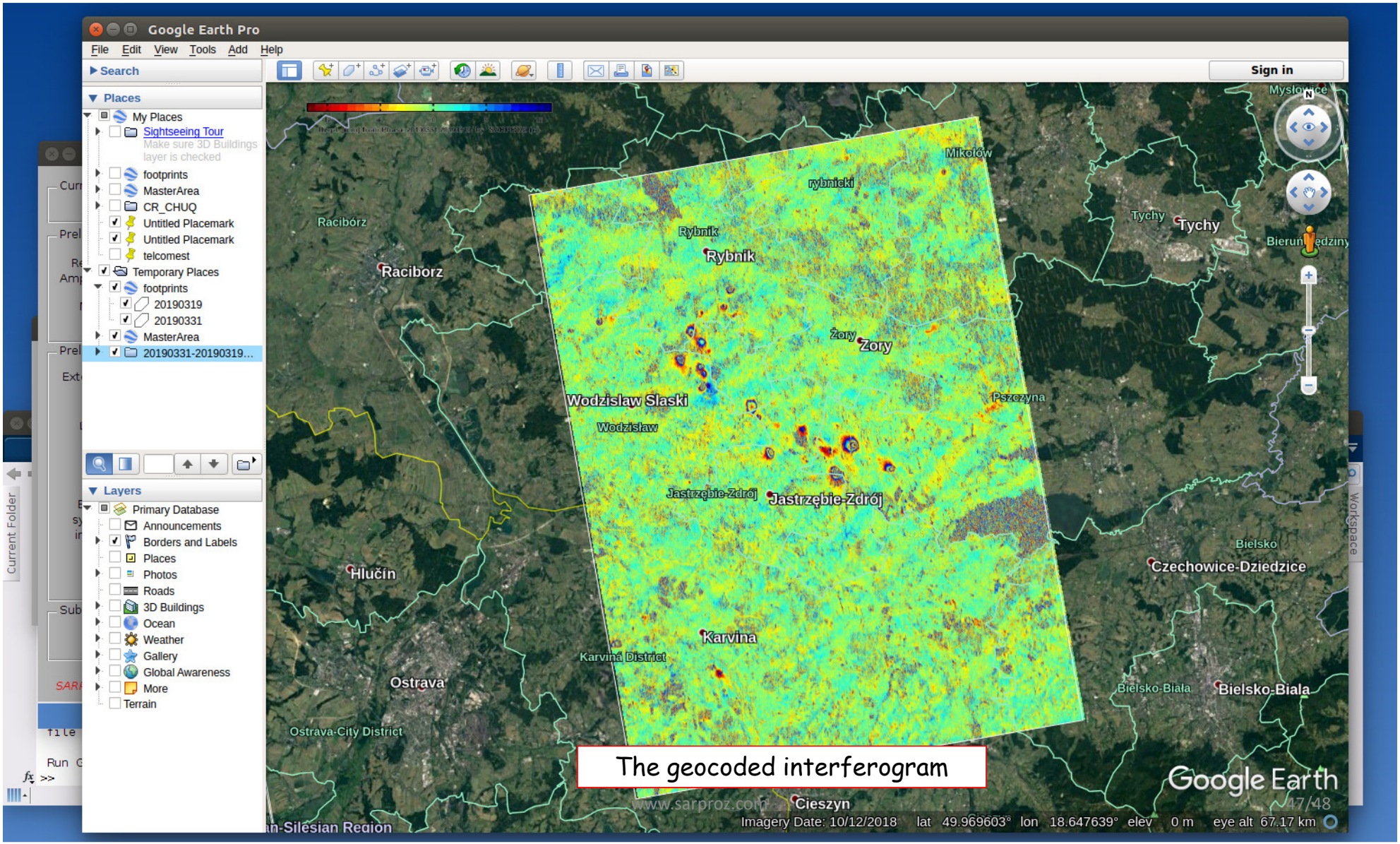


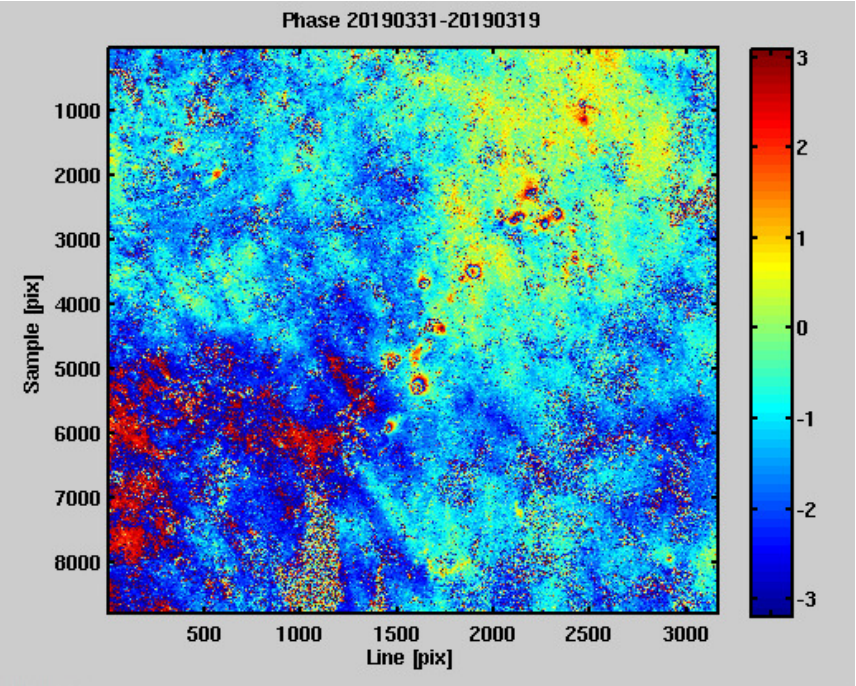
1. Now we want to plot again the full-resolution interferogram (no multi-looking)

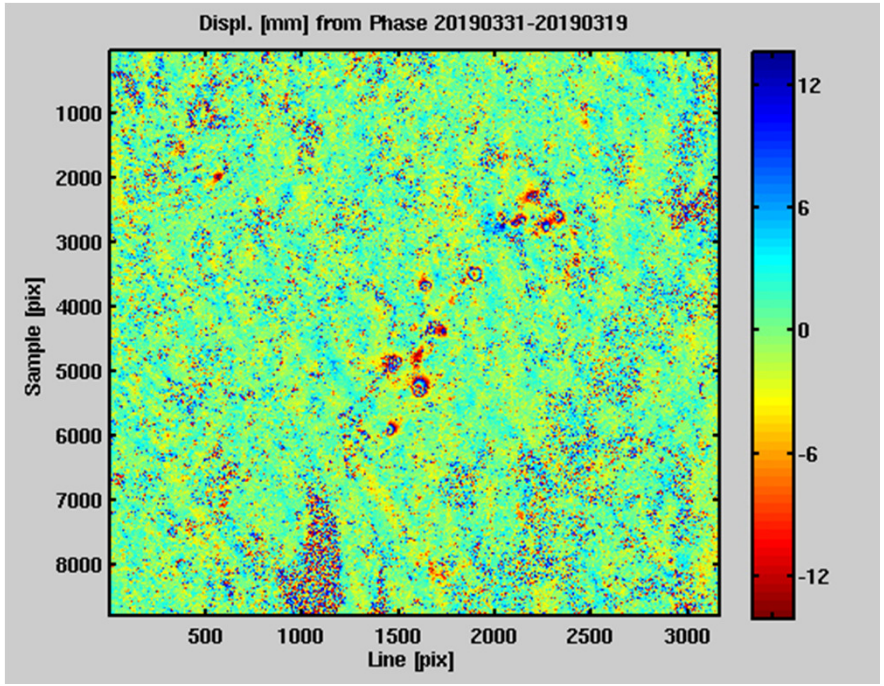


1. This time we select more options: phase only
2. Reference point: GCP (or any you like)
3. Conversion: Displacement [mm]
4. APS removal


MAIN - /data0/POLAND_MINES/
SARPROZ
Select Dataset
Site Processing
SITE PROCESSING - /data0/POLAND_MINES/
Current Images Graph
One-sensor STAR
Preliminary analysis
Auxiliary analysis
Multi-Temporal Adaptive Mask
Go
Sparse points selection
Load Mask
Post-analysis
Geografic Corrections
PLOT PARAMETERS - /data0/POLAND_MINES/
Data to Plot
Mode
Single Interferogram
Interferogram
20190331-20190319
Coher/Phase
Phase Only
Options
Saturation
Auto
Min
Max
Zero Reference
GCP
Lat
Lon
InSAR
Conversion:
Mask:
Thres.
Displ [mm]
none
0
APS Remo...
Output:
Auto
Colorbar Rev...
Export in GEOGRAPHIC coordinates
Mode
File Type
Rg
Az
Geocode
Kml
1
1
Export
View/Export in SAR coordinates
Plot
Jpg/Png
OK
SARPROZ (c) 2009-2019, the SAR PROcessor by periZ
Figure 1
File Edit View Insert Tools Desktop Window Help
Displ. [mm] from Phase 20190331-20190319
Sample [pix]
Line [pix]
MATLAB R2014a
HOME
PLOTS
APPS
Search Documentation
Current Folder
Workspace
East coordinate (UTM): 331390
UTM Zone: 34
Hemisphere: North
ellipsoidal height (WGS84): 2
sample: 4398
1. Then we plot it
This is the result: now we have removed the long wavelengths and the local movements are more evident. Note that the atmospheric turbulence is still there. Nevertheless, now it's easier to read the signals.
2. And finally we geocode it →







Before

After

Note: in this exercise we have removed some signals and left others. We removed long (spatial) wavelengths and we left short ones. Under the assumption that long wavelengths are atmospheric delay and short ones are subsidence, we have improved signal readability. However, you have to make sure the assumption is correct in your case study. If you have multiple images, use common time series analysis to estimate movement and topography. The time series approach is more robust. Use the technique described here only when you have few coherent images.