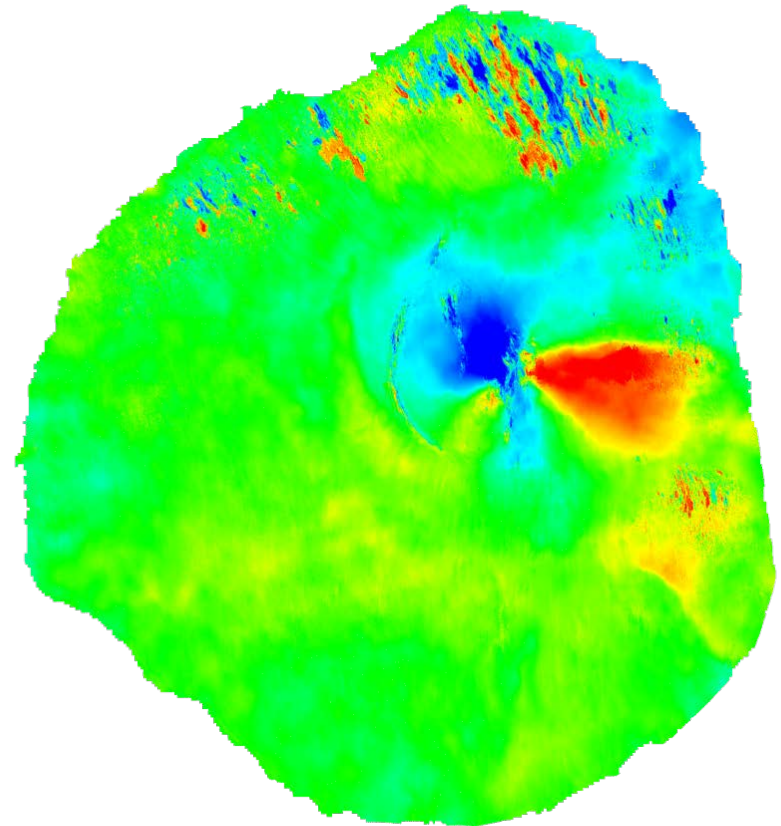


Practical Exercise

Measuring Ground Deformation

November 2016

- Familiarize with open source ESA SNAP/Sentinel-1 Toolbox
- Training on TOPS Differential SAR Interferometry (DInSAR) for measuring ground deformation
- Provide instruction on step-by-step interferometric processing of Sentinel-1 TOPS data (incl. parameters, tips etc.)
- End-to-end show case (Fogo Volcano eruption)



Contains modified
Copernicus Sentinel data [2014]

- A set of **Sentinel-1A SLCs** YYYYMMDDTHHMMSS
S1A_IW_SLC__1SSV_20141103T195043_20141103T195057_003122_00395A_F396.zip
S1A_IW_SLC__1SSV_20141127T195042_20141127T195056_003472_004117_2B48.zip
[downloadable @ <https://scihub.esa.int>]
- Sentinel-1 **Precise Orbits** (PODs) for the corresponding S1A dates (auxiliary data)
S1A_OPER_AUX_POEORB_OPOD_*.EOF.zip
[downloadable @ <https://qc.sentinel1.eo.esa.int>]
[stored locally @ C:\Users\#username#\snap\auxdata\Orbits\Sentinel-1\POEORB\2014]
- **Digital Elevation Model** (DEM) dataset from SRTM 3 arc-sec covering the Area of Interest (auxiliary data)
srtm_32_09.zip & srtm_32_10.zip
[stored locally @ C:\Users\#username#\snap\auxdata\dem\SRTM 3Sec]



EXERCISE

Sentinel-1 TOPS

Interferometry with S1TBX

PART 1

TOPS InSAR Processing

PART 2

Phase Unwrapping using SNAPHU

PART 3

Displacement Measurements &
Terrain Geocoding



Geocoded Terrain Corrected
S1 TOPS Ground Displacement Map

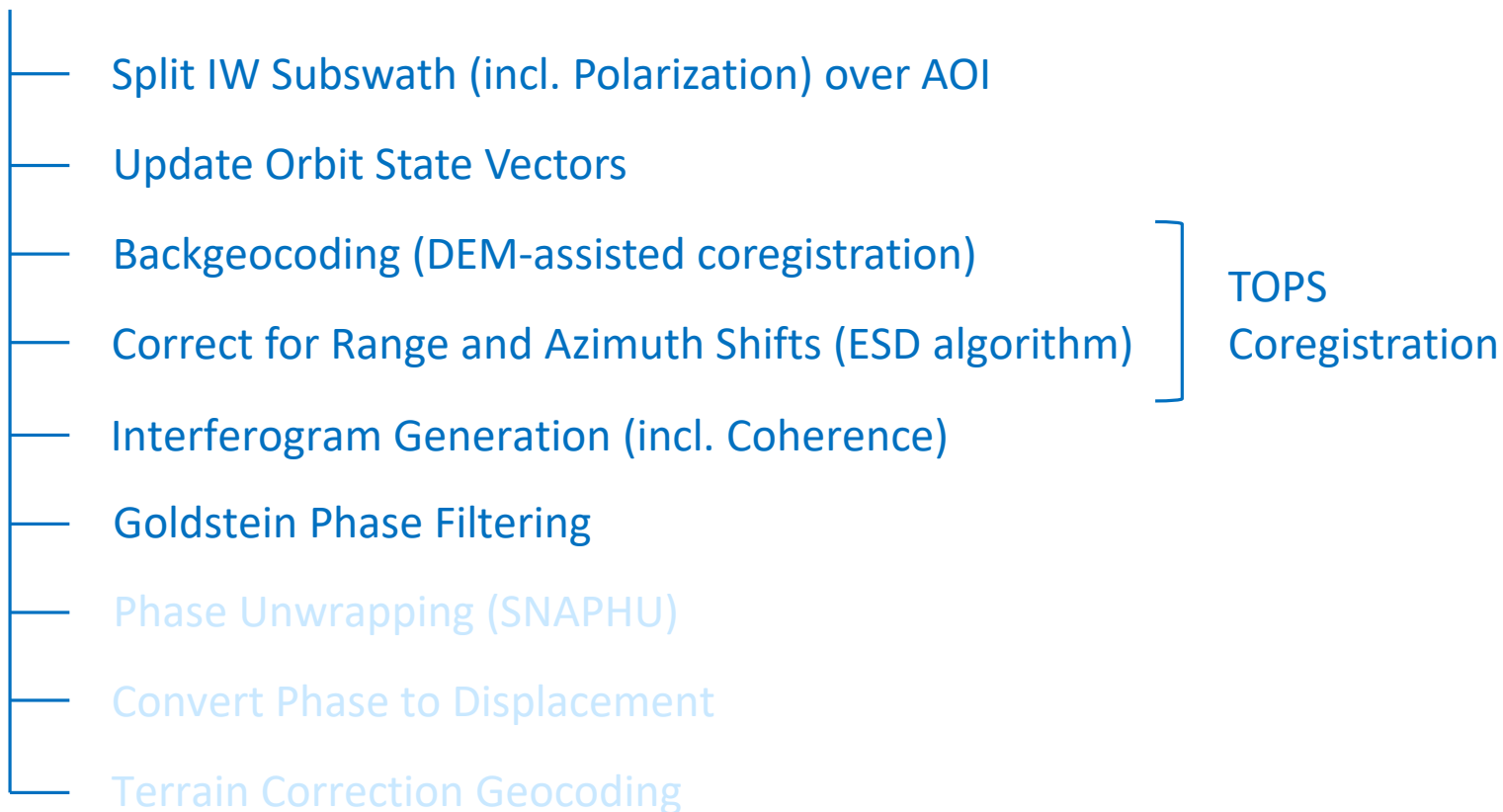
EXERCISE

PART 1

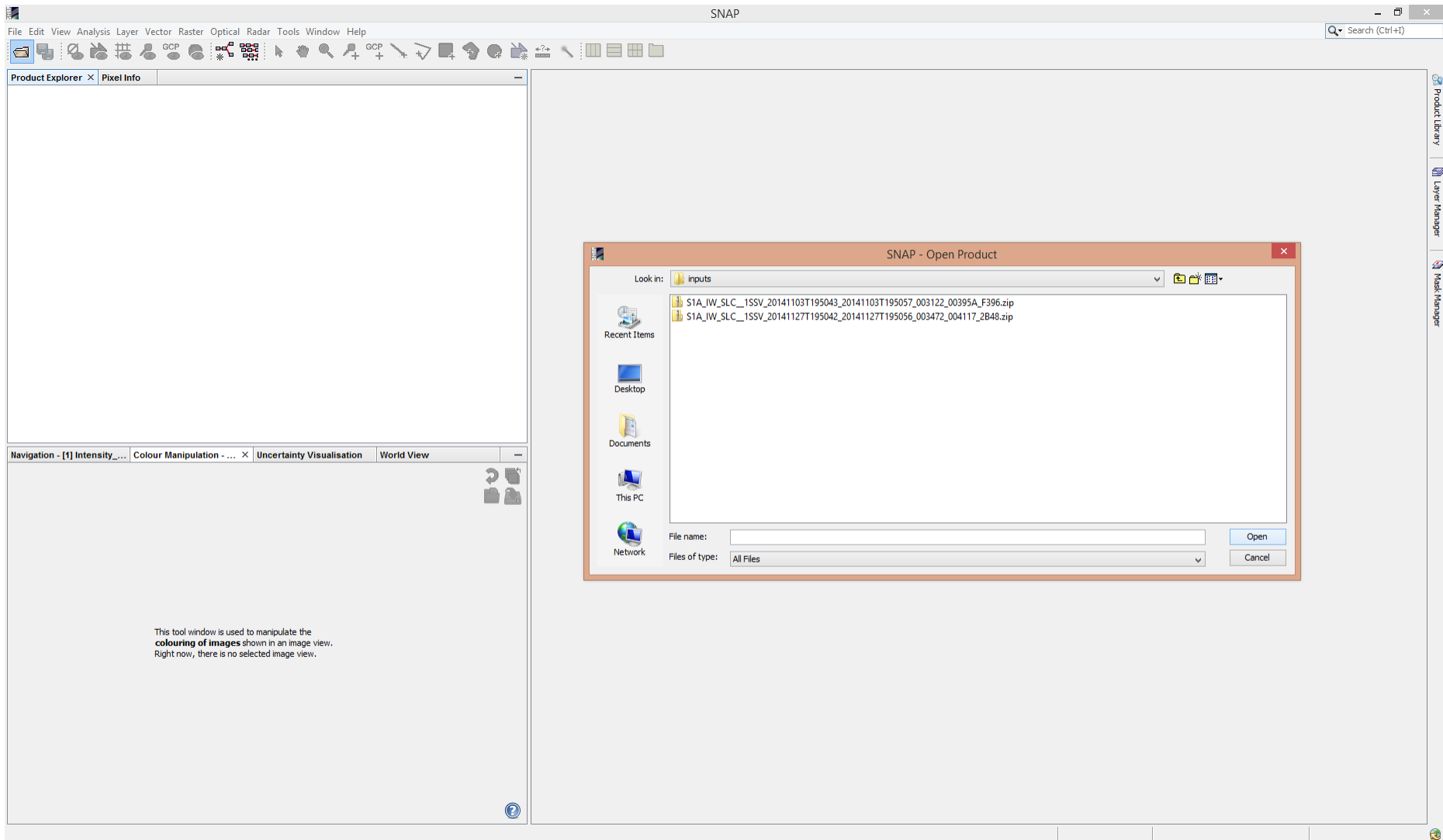
Sentinel-1 TOPS InSAR Processing



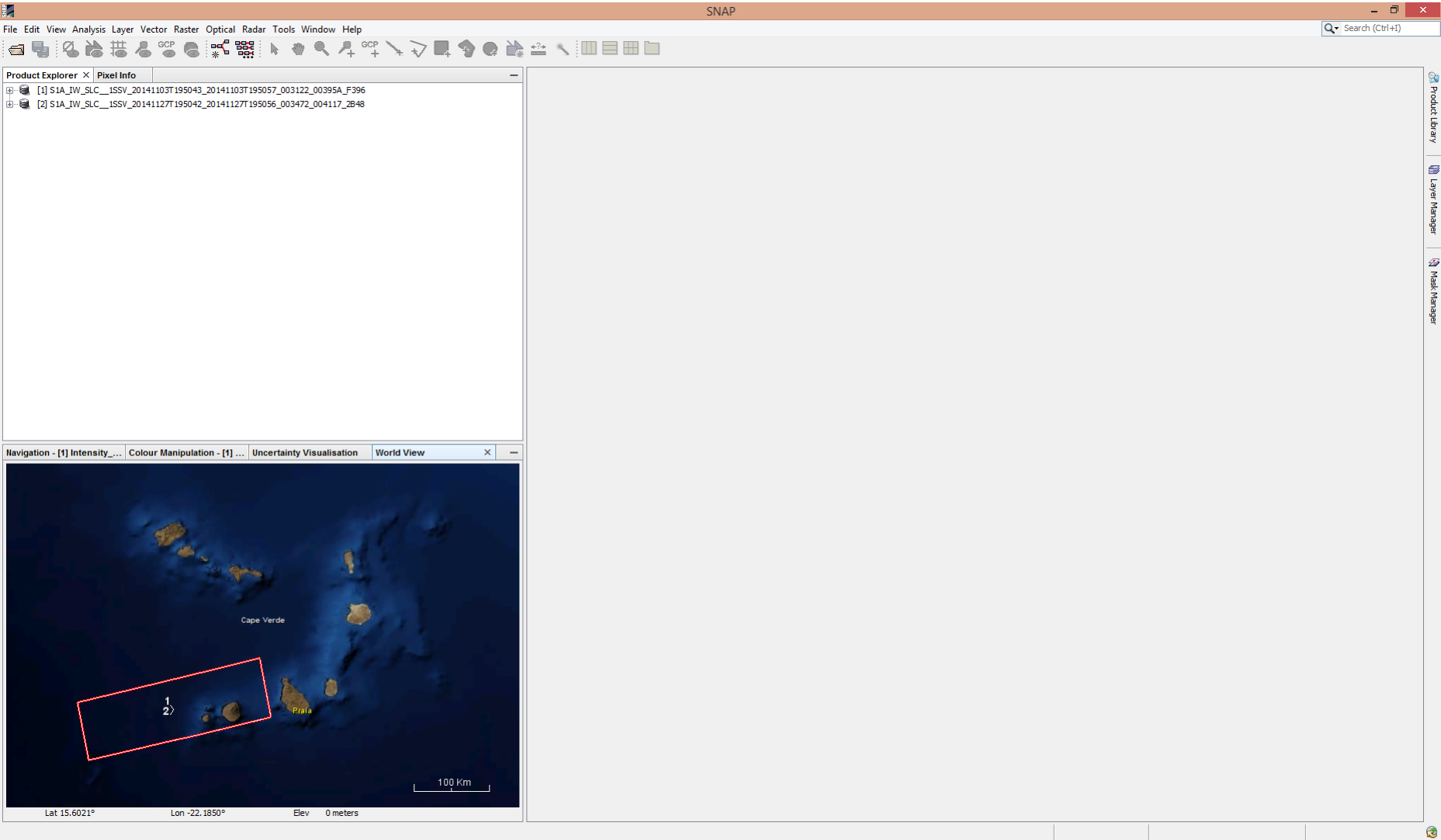
EXERCISE Processing Steps (PART 1)



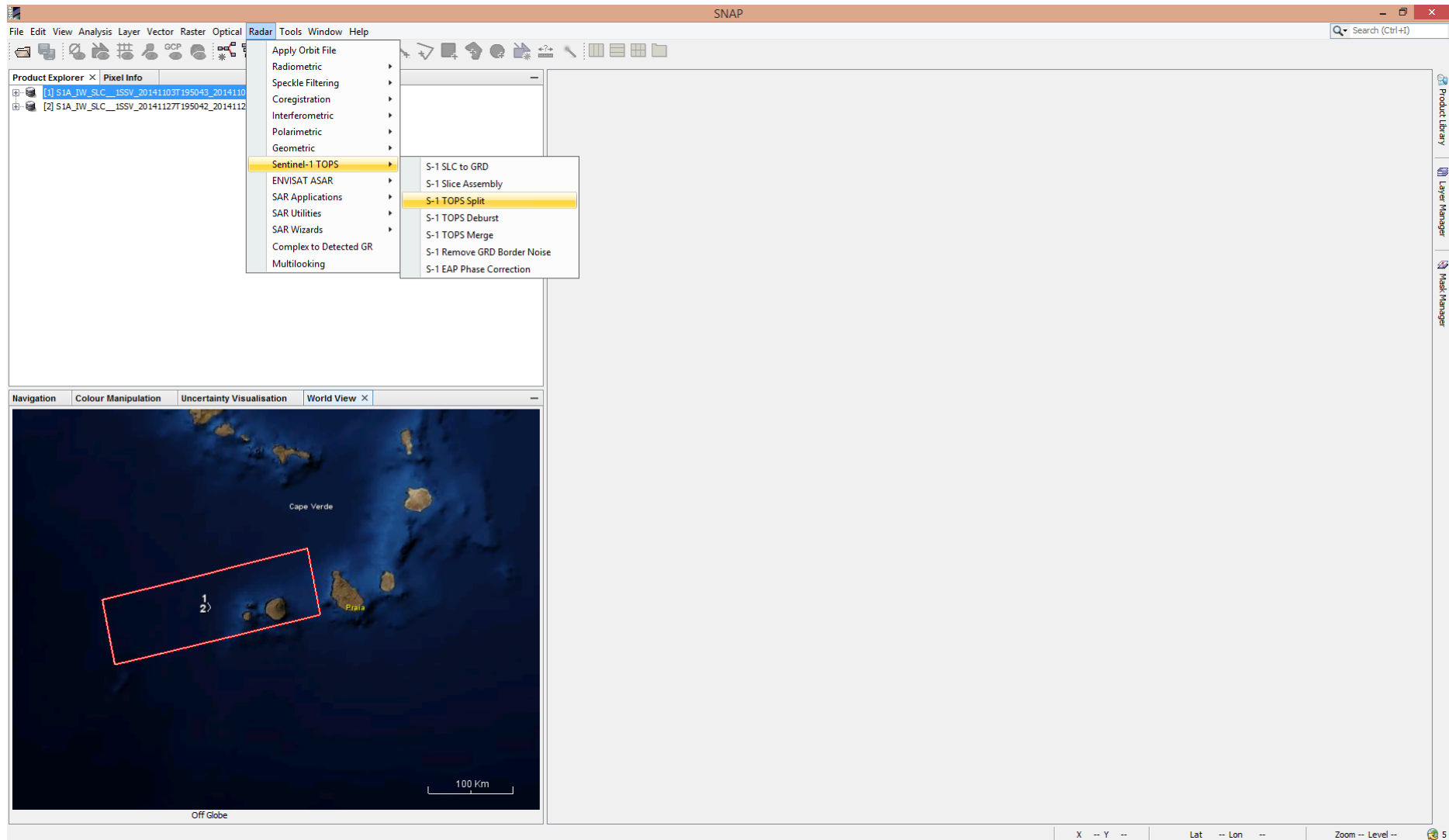
Read Sentinel-1 SLC Products (directly *.zip files)



Sentinel-1 IW TOPS (Swath of 250km)

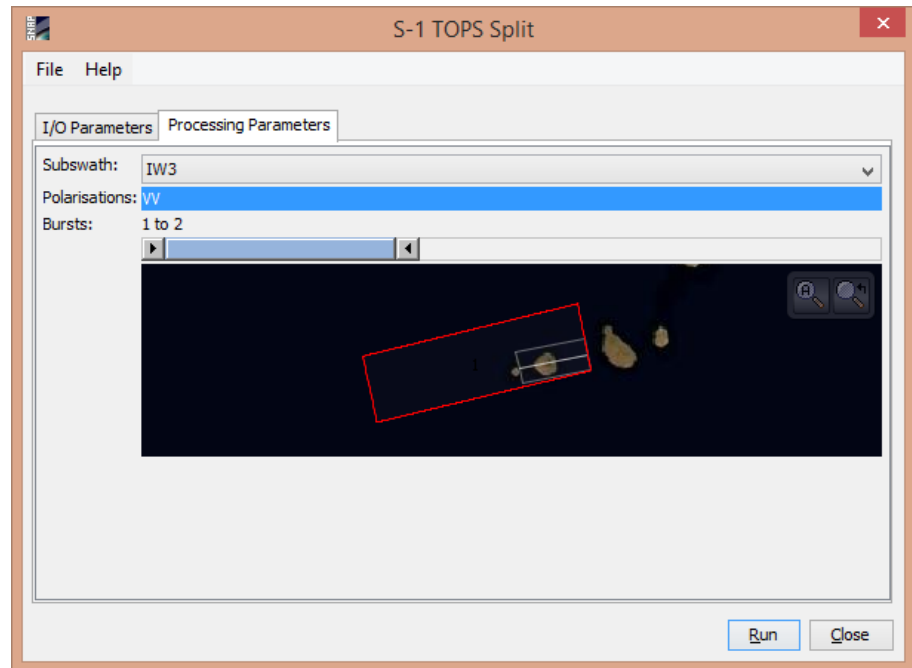
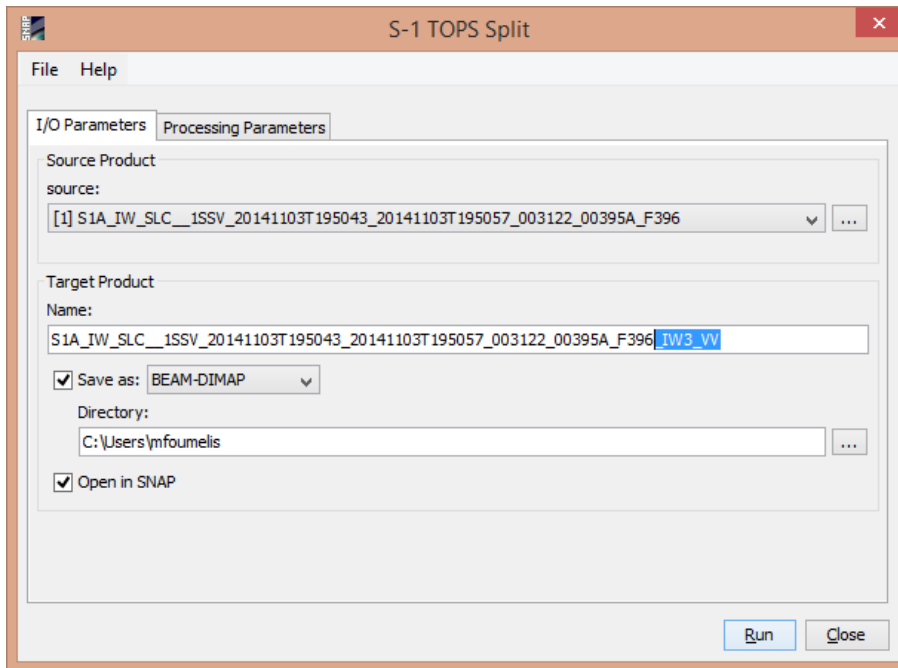


Splitting S1 SLC Products (@Subswath and Burst level)

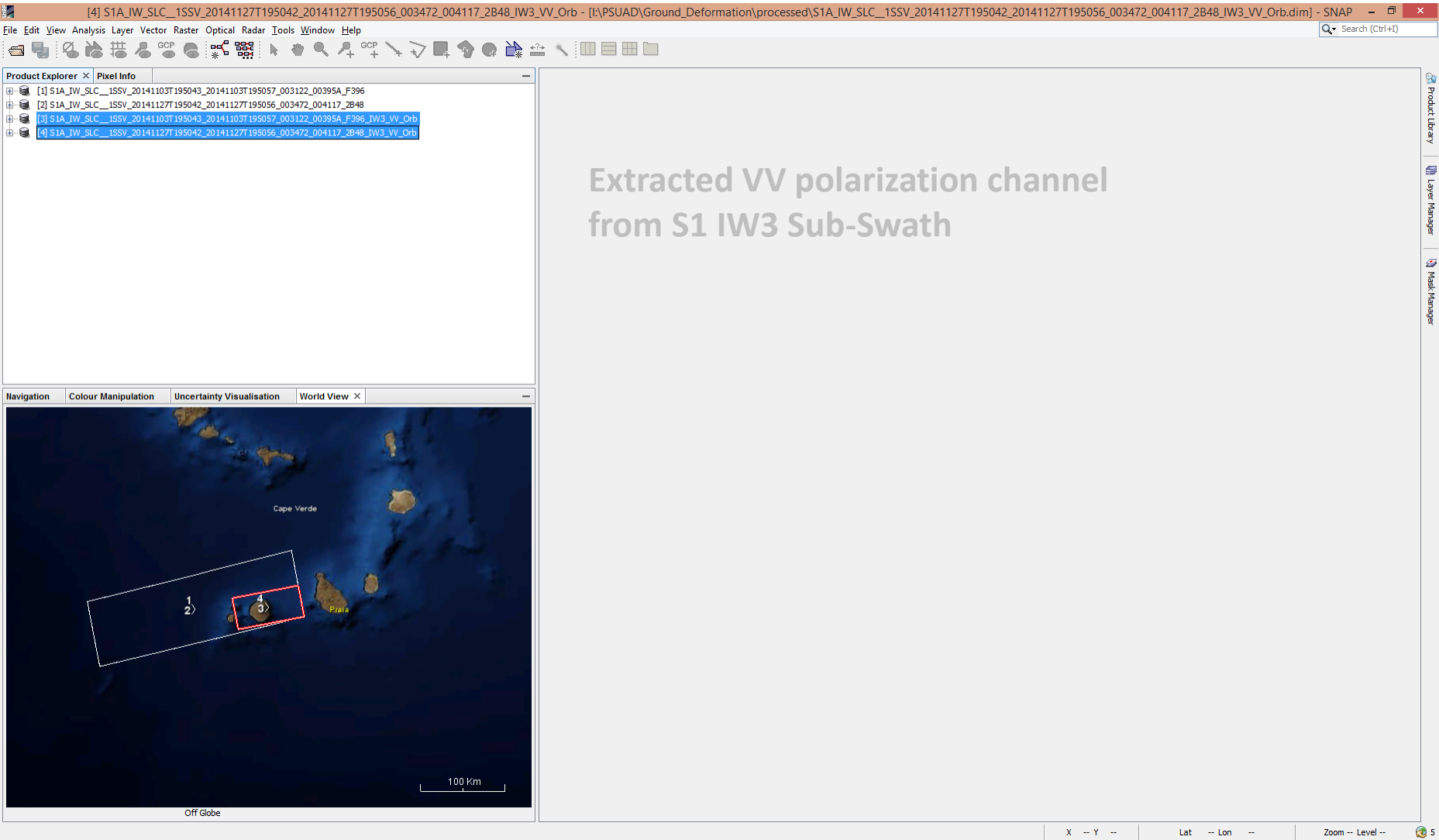


Splitting S1 SLC Products (@ Subswath and Burst level)

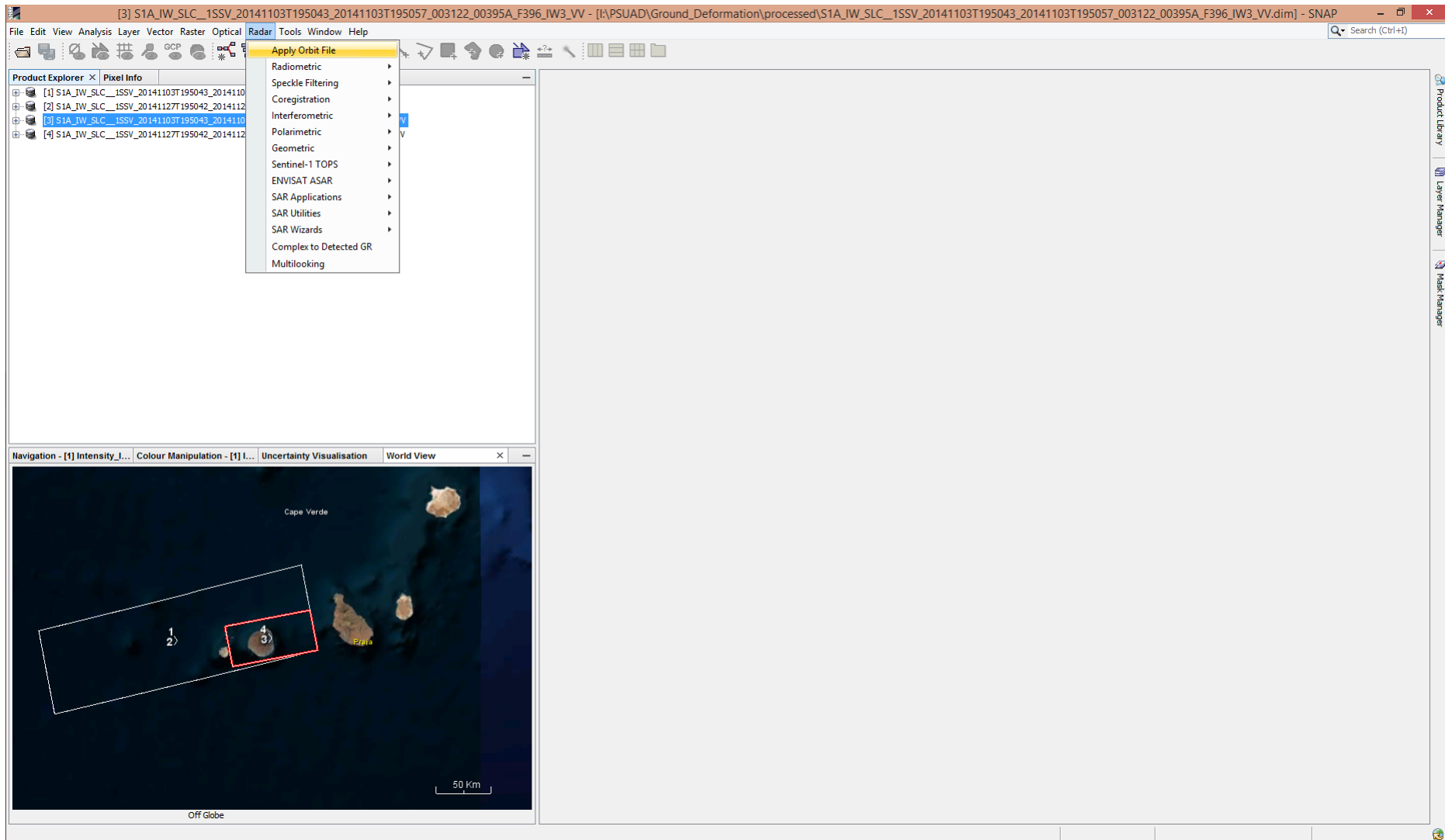
Selection of sub-swath (IW1, IW2 & IW3), burst and polarization (VV & VH)



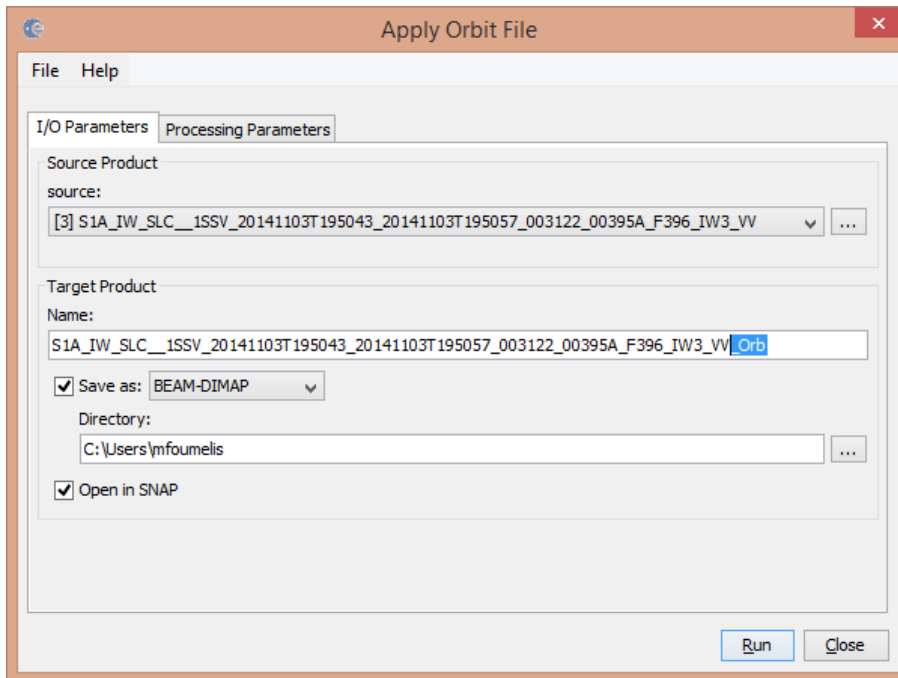
Splitting S1 SLC Products (@ Subswath and Burst level)



Update Orbital Information (Orbit State Vectors)



Automatically adding suffixes (product_*) indicating processing implemented



Apply Orbit File

File Help

I/O Parameters Processing Parameters

Source Product

source:

[3] S1A_IW_SLC__1SSV_20141103T195043_20141103T195057_003122_00395A_F396_IW3_VV

Target Product

Name:

S1A_IW_SLC__1SSV_20141103T195043_20141103T195057_003122_00395A_F396_IW3_VV Orb

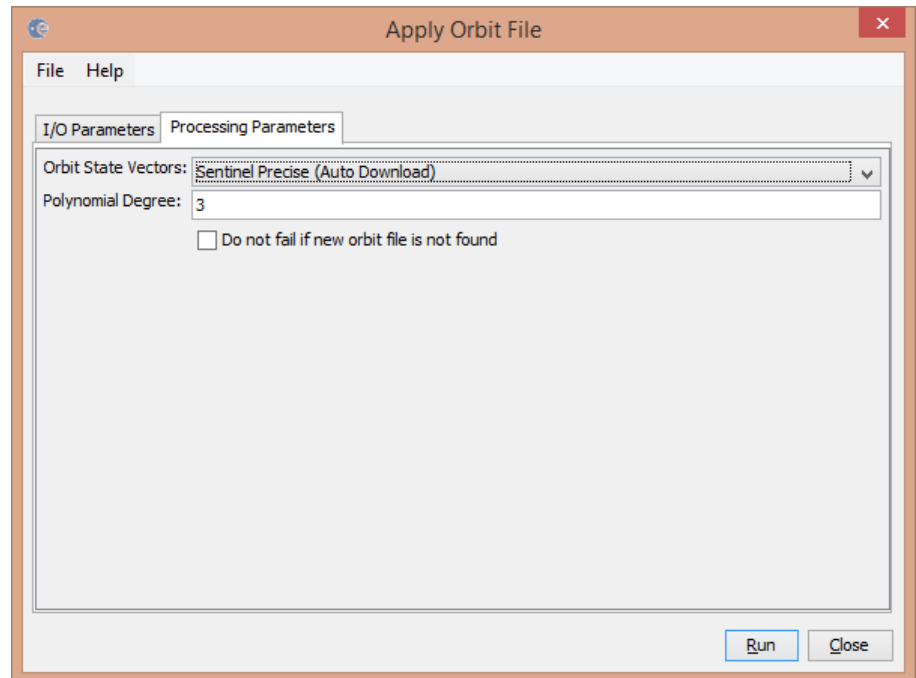
☒ Save as: BEAM-DIMAP

Directory:

C:\Users\mfoumelis

☒ Open in SNAP

Run Close



Apply Orbit File

File Help

I/O Parameters Processing Parameters

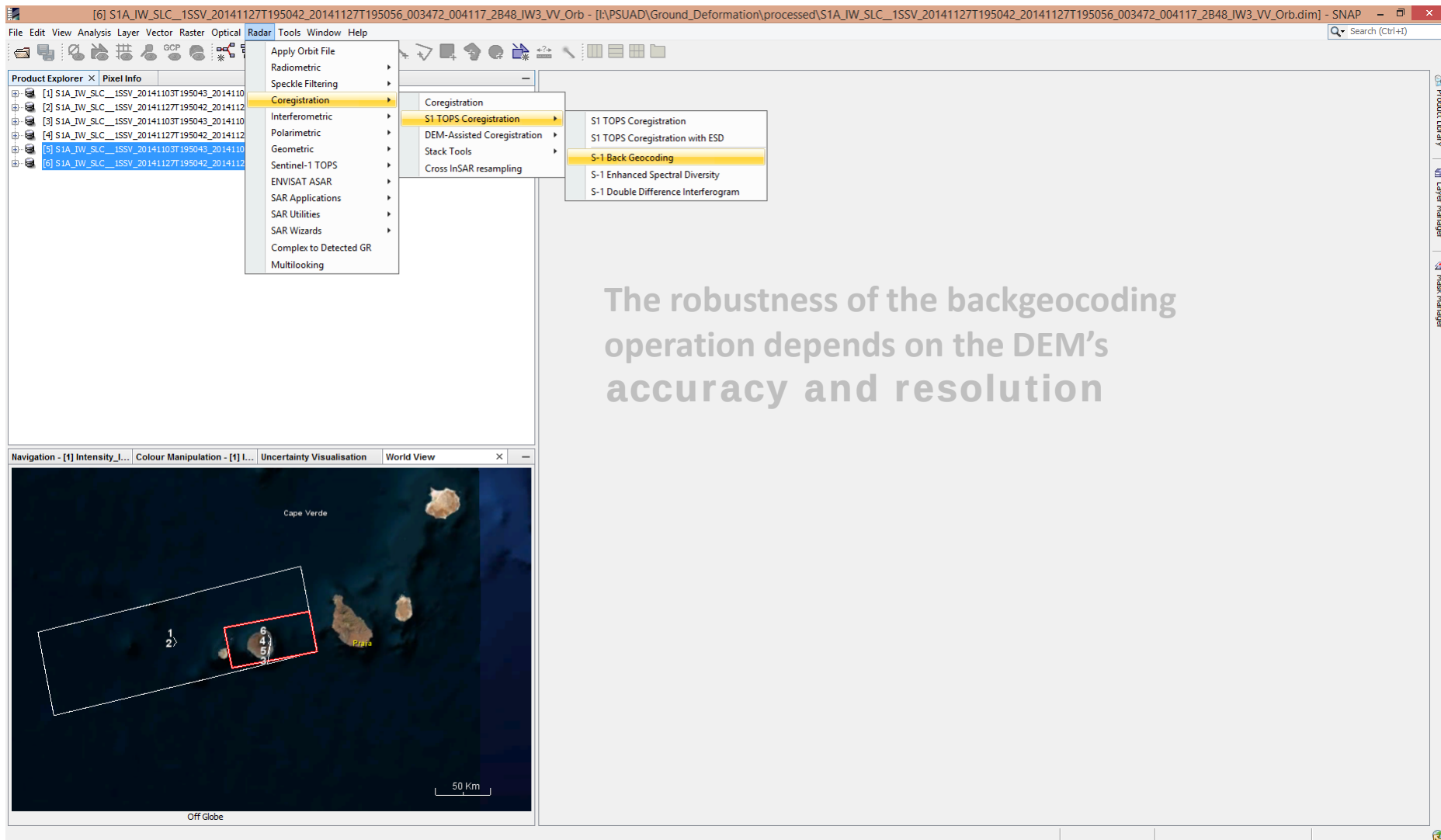
Orbit State Vectors: Sentinel Precise (Auto Download)

Polynomial Degree: 3

☐ Do not fail if new orbit file is not found

Run Close

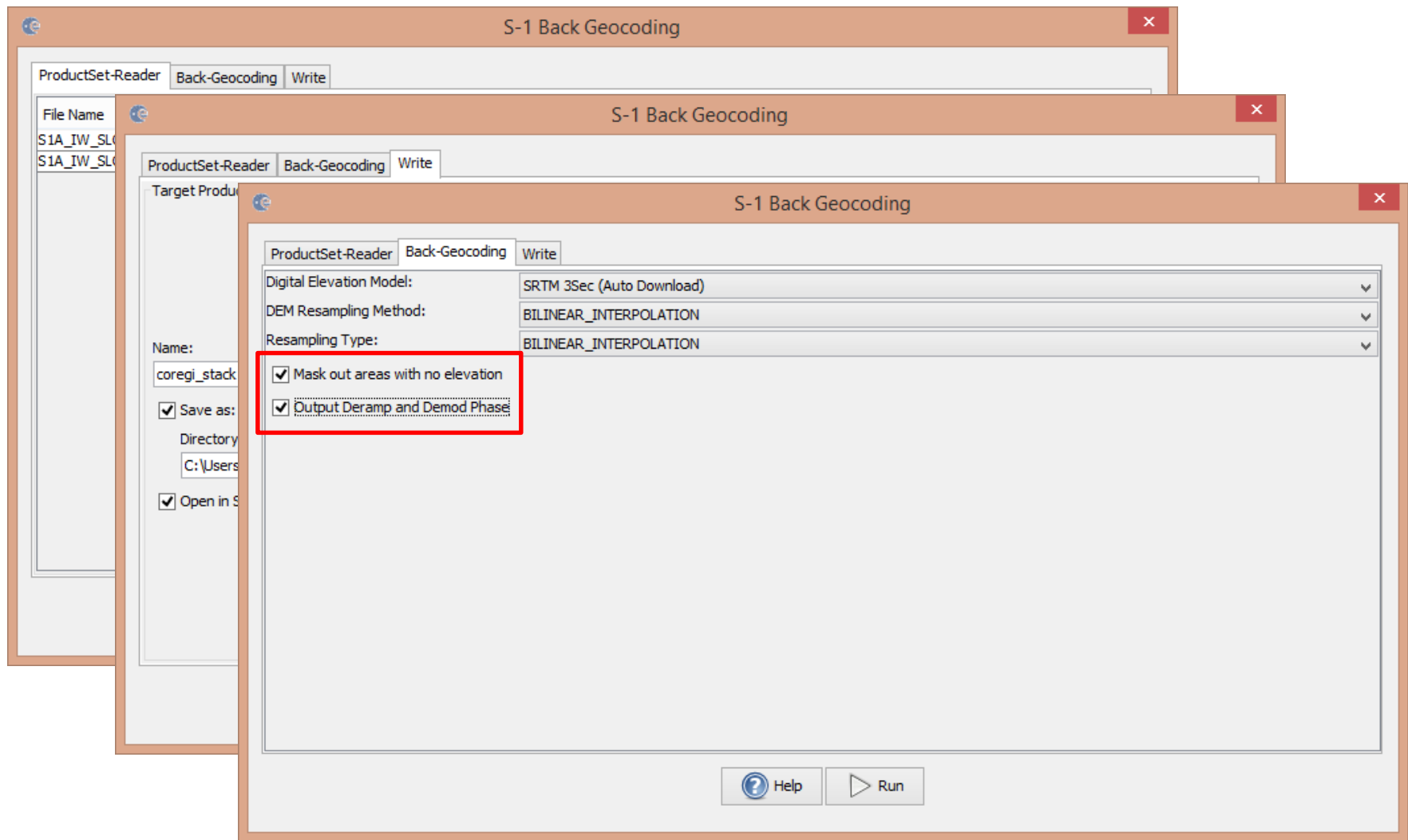
Back-geocoding TOPS SLCs (Geometric Co-registration)



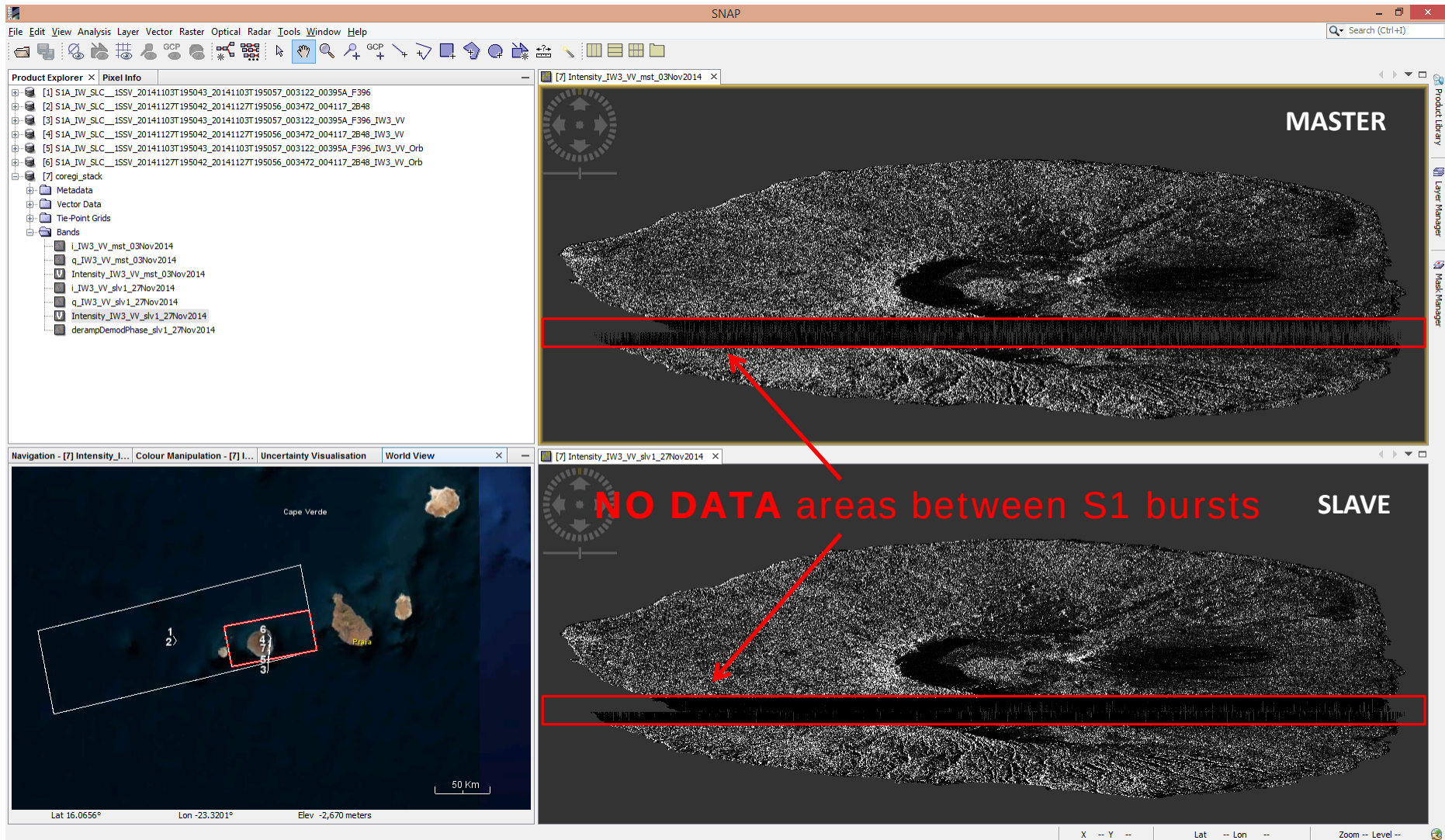
The screenshot displays the SNAP (Sentinel Application Platform) software interface. The main window shows a list of products in the 'Product Explorer' on the left, including S1A_IW_SLC_1SSV_20141127T195042_20141127T195056_003472_004117_2B48_IW3_VV_Orb. The 'Radar' menu is open, and the 'Coregistration' sub-menu is selected, showing options like 'S1 TOPS Coregistration', 'DEM-Assisted Coregistration', 'Stack Tools', and 'Cross InSAR resampling'. The 'S-1 Back Geocoding' option is highlighted. The 'World View' panel at the bottom shows a satellite image of Cape Verde with a red rectangle indicating the area of interest. A scale bar of 50 Km is visible in the bottom right corner of the World View panel.

The robustness of the backgeocoding operation depends on the DEM's accuracy and resolution

Back-geocoding TOPS SLCs (Geometric Co-registration)

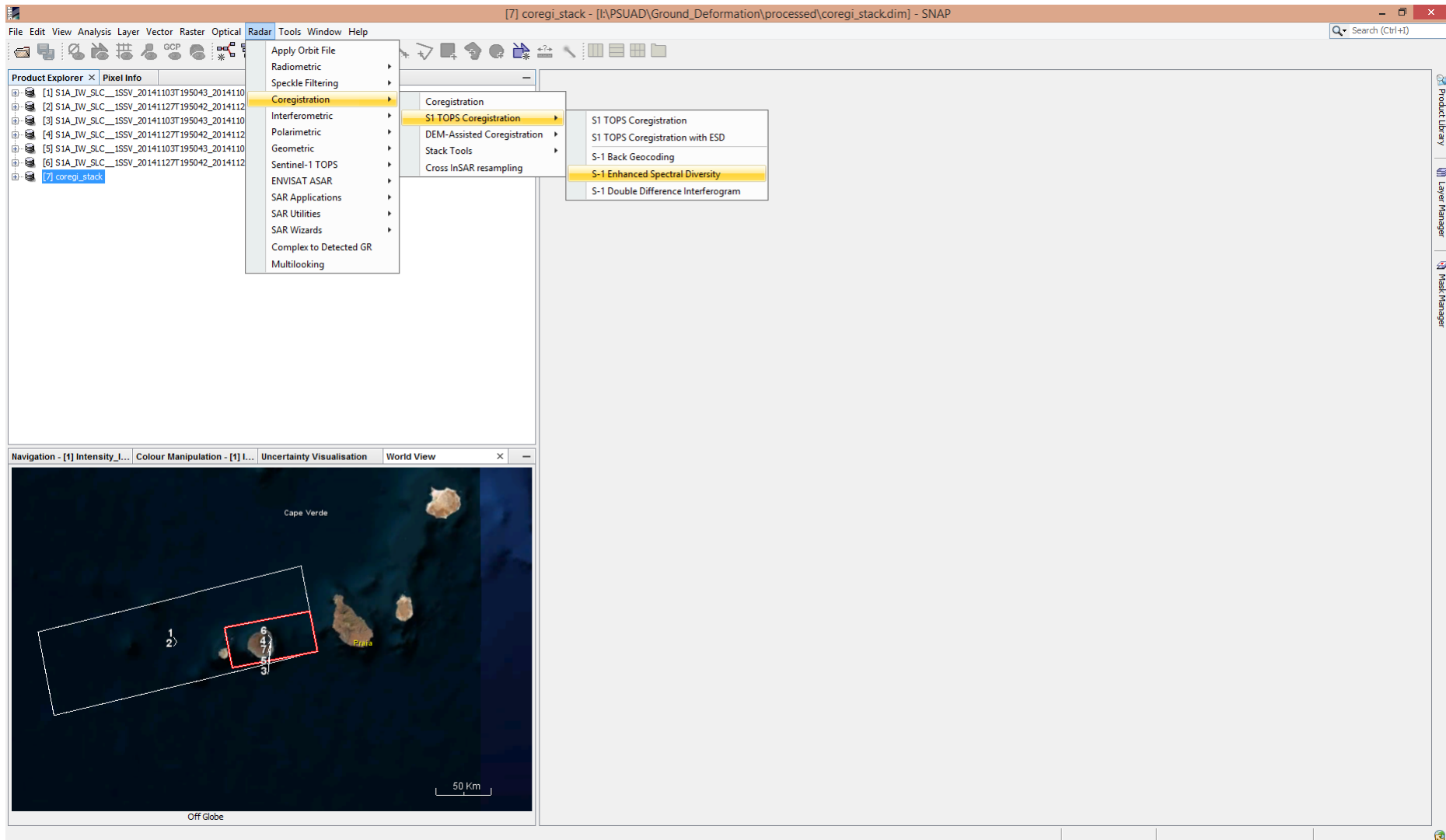


S1 TOPS Co-registered Stack

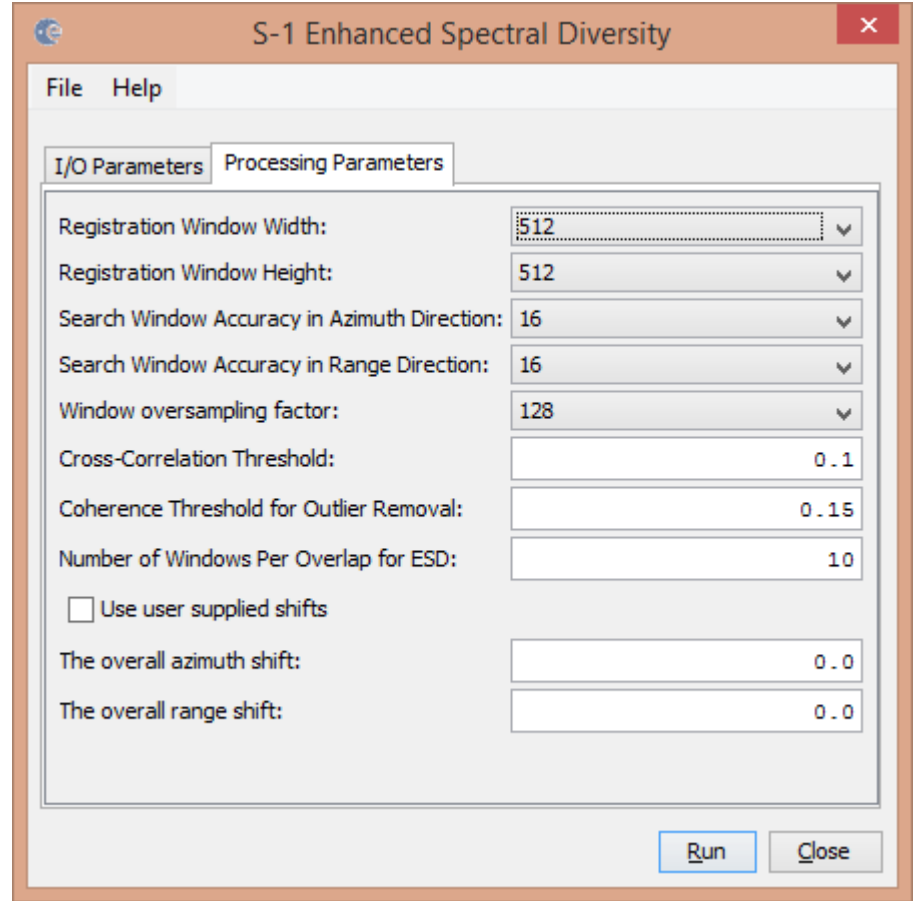


Improvement of Co-registration Accuracy

Enhanced Spectral Diversity (ESD)



Implementation of the
Enhanced Spectral Diversity (ESD)
algorithm for correcting shifts in
range and azimuth direction
considering the burst overlap areas



The screenshot shows a software window titled "S-1 Enhanced Spectral Diversity" with a standard Windows-style title bar (minimize, maximize, close buttons). Inside the window, there are two tabs: "I/O Parameters" and "Processing Parameters". The "Processing Parameters" tab is currently selected. It contains several configuration options:

- Registration Window Width: 512 (dropdown menu)
- Registration Window Height: 512 (dropdown menu)
- Search Window Accuracy in Azimuth Direction: 16 (dropdown menu)
- Search Window Accuracy in Range Direction: 16 (dropdown menu)
- Window oversampling factor: 128 (dropdown menu)
- Cross-Correlation Threshold: 0.1 (text input)
- Coherence Threshold for Outlier Removal: 0.15 (text input)
- Number of Windows Per Overlap for ESD: 10 (text input)
- ☐ Use user supplied shifts (checkbox)
- The overall azimuth shift: 0.0 (text input)
- The overall range shift: 0.0 (text input)

At the bottom right of the window, there are two buttons: "Run" and "Close".

S1 TOPS ESD Co-registered Stack

[8] coregi_stack_esd - [I:\PSUAD\Ground_Deformation\processed\coregi_stack_esd.dim] - SNAP

File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help

Product Explorer Pixel Info

- [1] S1A_IW_SLC__1SSV_20141103T195043_20141103T195057_003122_00395A_F396
- [2] S1A_IW_SLC__1SSV_20141127T195042_20141127T195056_003472_004117_2B48
- [3] S1A_IW_SLC__1SSV_20141103T195043_20141103T195057_003122_00395A_F396_IW3_VV
- [4] S1A_IW_SLC__1SSV_20141127T195042_20141127T195056_003472_004117_2B48_IW3_VV
- [5] S1A_IW_SLC__1SSV_20141103T195043_20141103T195057_003122_00395A_F396_IW3_VV_Orb
- [6] S1A_IW_SLC__1SSV_20141127T195042_20141127T195056_003472_004117_2B48_IW3_VV_Orb
- [7] coregi_stack
- [8] coregi_stack_esd

Navigation Colour Manipulation Uncertainty Visualisation World View X

Cape Verde

Pirajá

50 Km

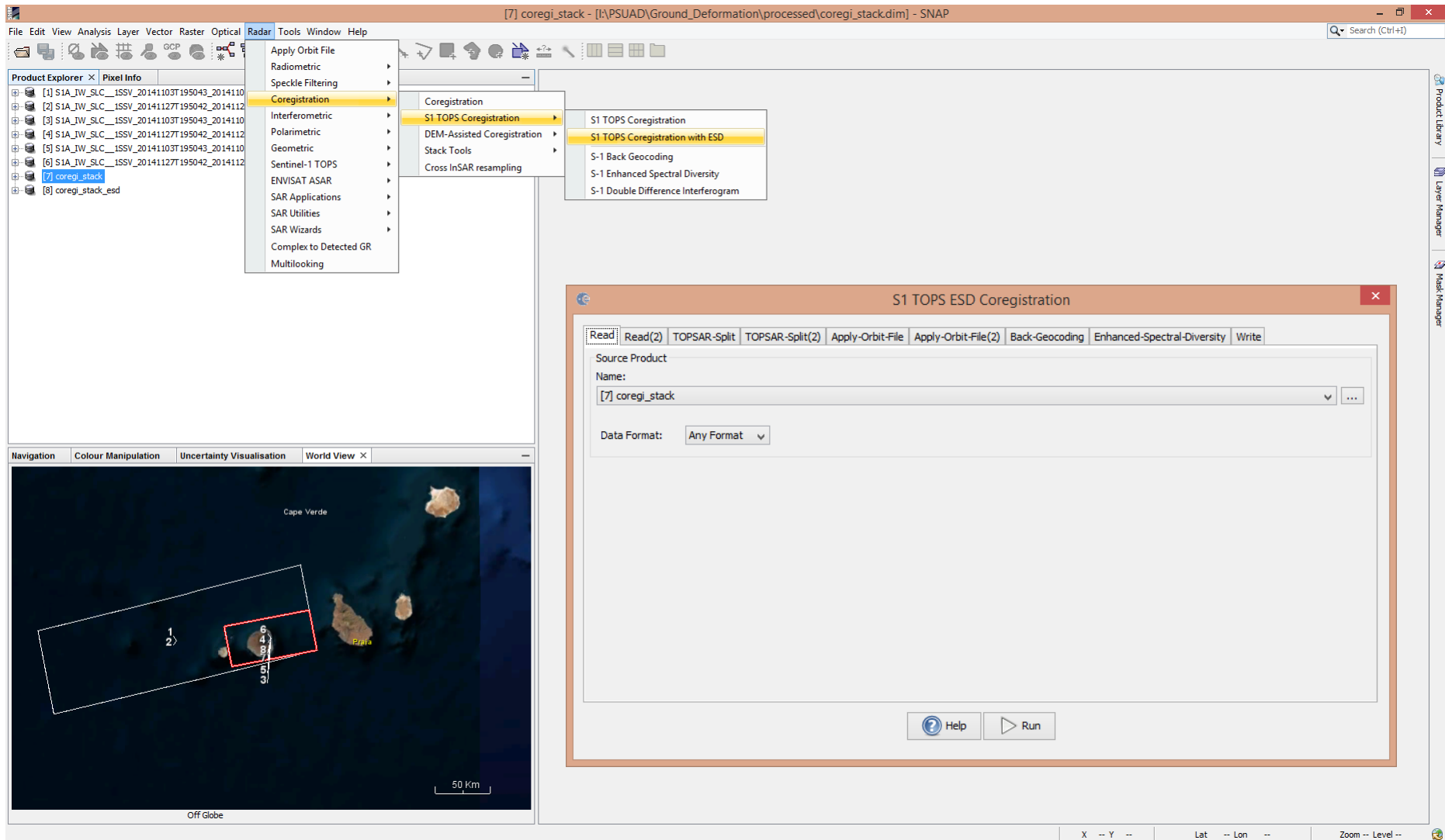
Off Globe

X -- Y -- Lat -- Lon -- Zoom -- Level --

TOPS interferometry
requires coregistration
accuracy ≤ 0.005 pixel

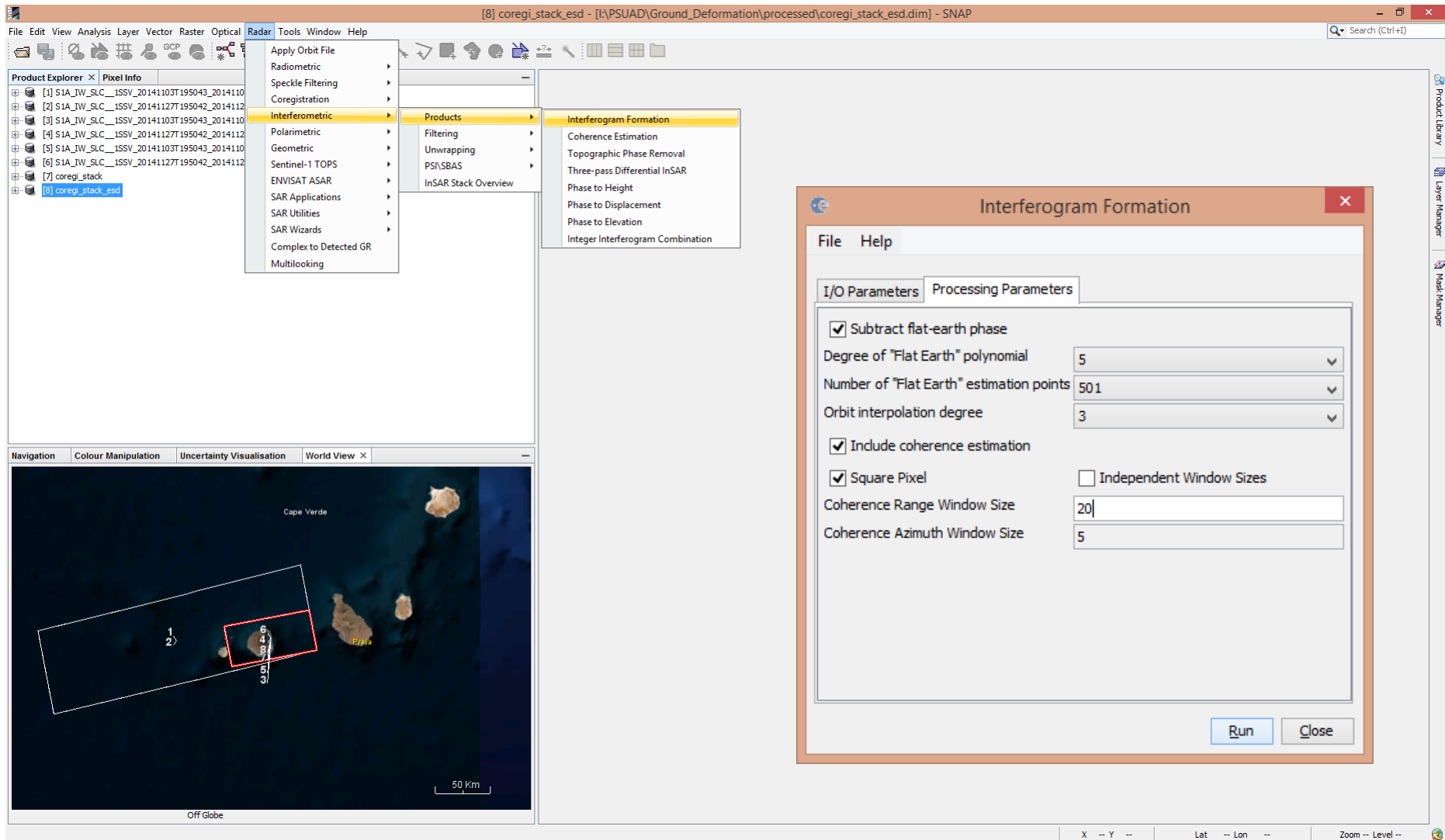
Product Library Layer Manager Mask Manager

Alternative Option for TOPS Coregistration (all-in-one)



The screenshot displays the SNAP (Scientific Data Processing) software interface. The main window is titled "[7] coregi_stack - [I:\PSUAD\Ground_Deformation\processed\coregi_stack.dim] - SNAP". The "Radar" menu is open, showing the "Coregistration" option. A sub-menu is visible, listing "S1 TOPS Coregistration" and "S1 TOPS Coregistration with ESD". The "S1 TOPS Coregistration with ESD" option is selected. The "Product Explorer" on the left shows a list of products, including "coregi_stack" and "coregi_stack_esd". The "S1 TOPS ESD Coregistration" dialog box is open, showing the "Read" tab. The "Source Product" is set to "[7] coregi_stack". The "Data Format" is set to "Any Format". The "Run" button is visible at the bottom of the dialog. The "Off Globe" view at the bottom left shows a map of Cape Verde with a red rectangle indicating the area of interest. The "Navigation" panel at the bottom right shows the "X -- Y --" coordinates and the "Lat -- Lon --" coordinates.

Sentinel-1 TOPS Interferogram Generation

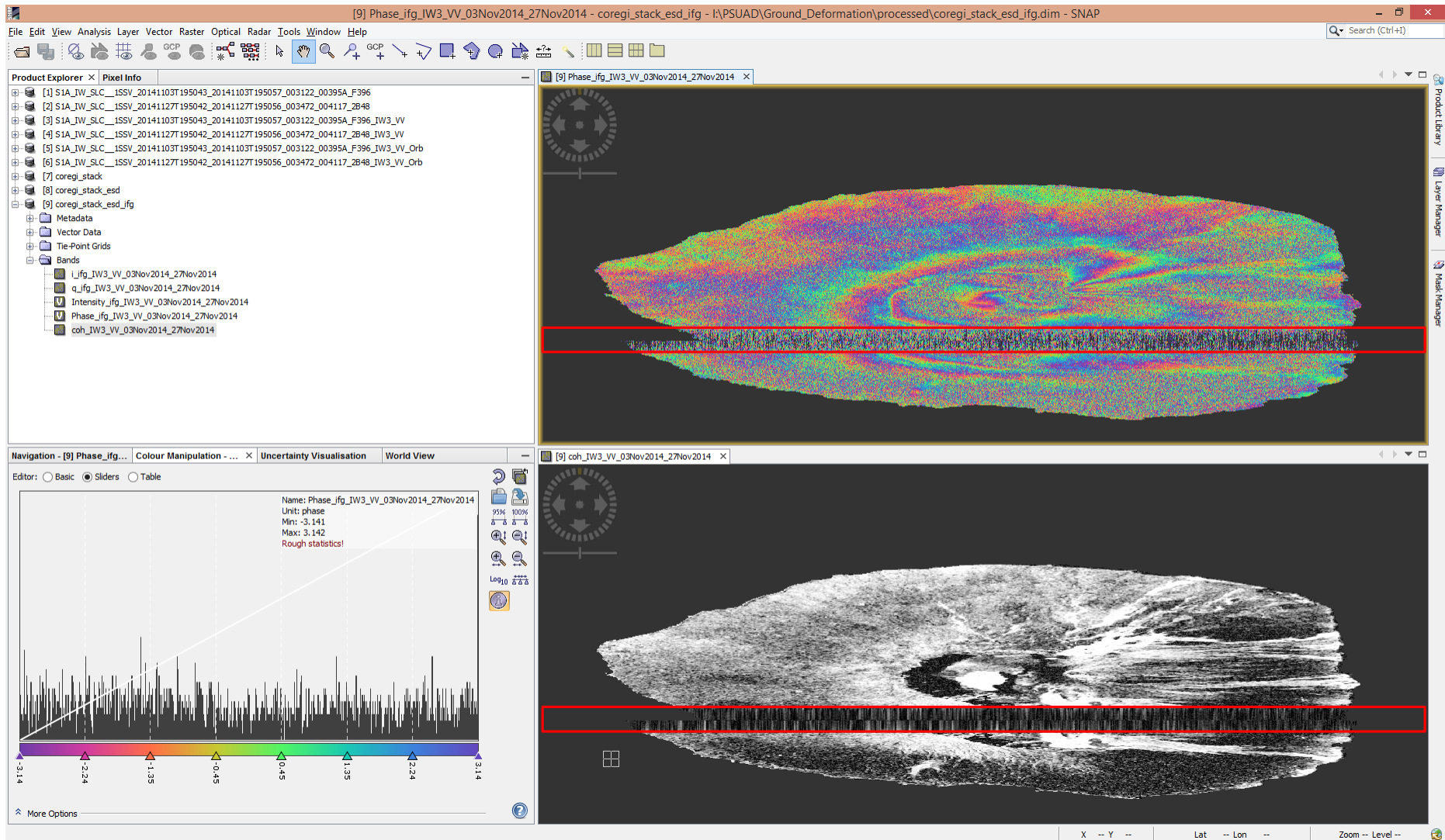


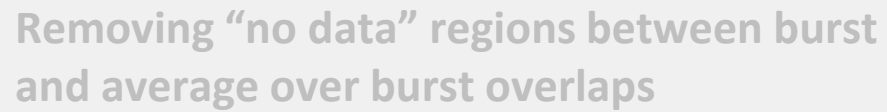
The screenshot displays the SNAP (Sentinel Application Platform) software interface. The main window shows a list of products in the Product Explorer, with 'coregi_stack_esd' selected. The 'Radar' menu is open, showing the 'Interferometric' sub-menu, which is further expanded to show 'Interferogram Formation'. The 'Interferogram Formation' dialog box is open, showing the 'Processing Parameters' tab. The parameters are set as follows:

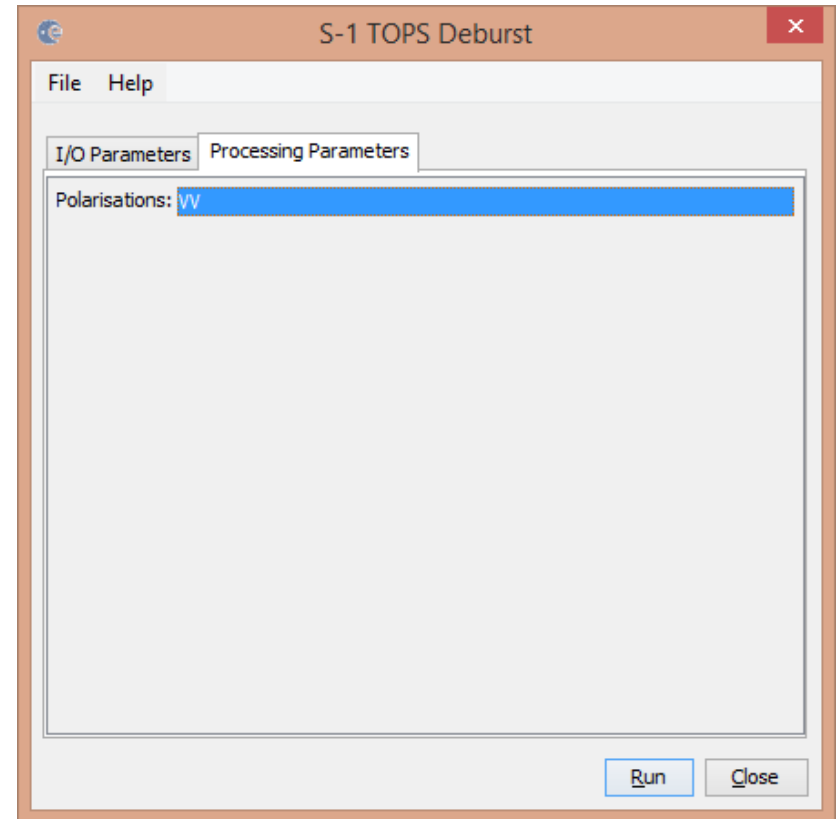
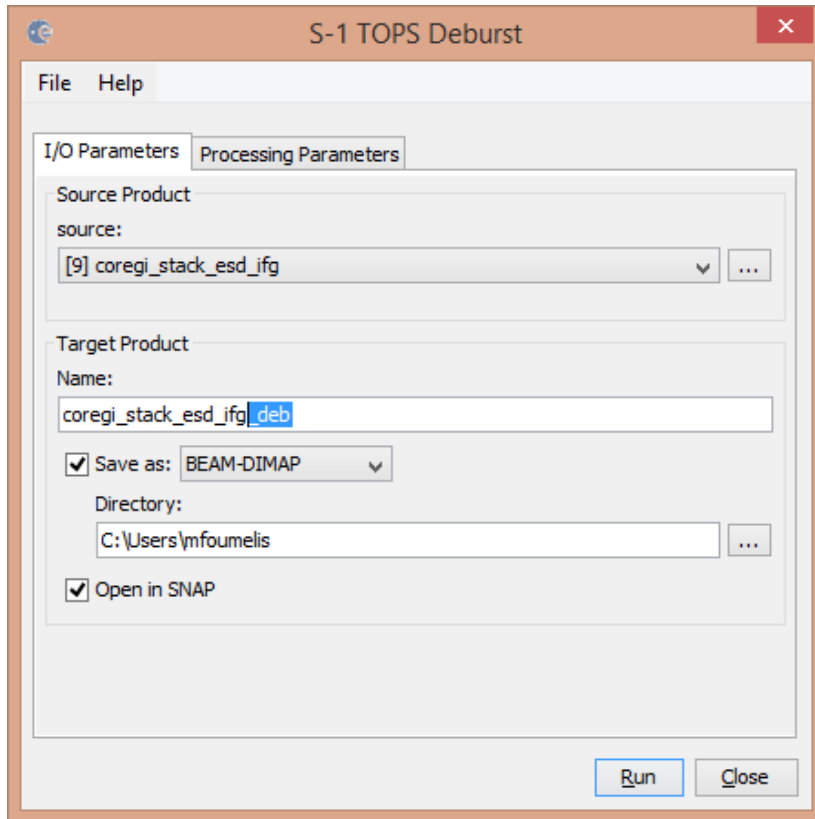
- ☒ Subtract flat-earth phase
- Degree of "Flat Earth" polynomial: 5
- Number of "Flat Earth" estimation points: 501
- Orbit interpolation degree: 3
- ☒ Include coherence estimation
- ☒ Square Pixel
- ☐ Independent Window Sizes
- Coherence Range Window Size: 20
- Coherence Azimuth Window Size: 5

The 'Run' button is highlighted. The background shows a map of Cape Verde with a red rectangle indicating the area of interest. The map is labeled 'Off Globe' and includes a 50 Km scale bar.

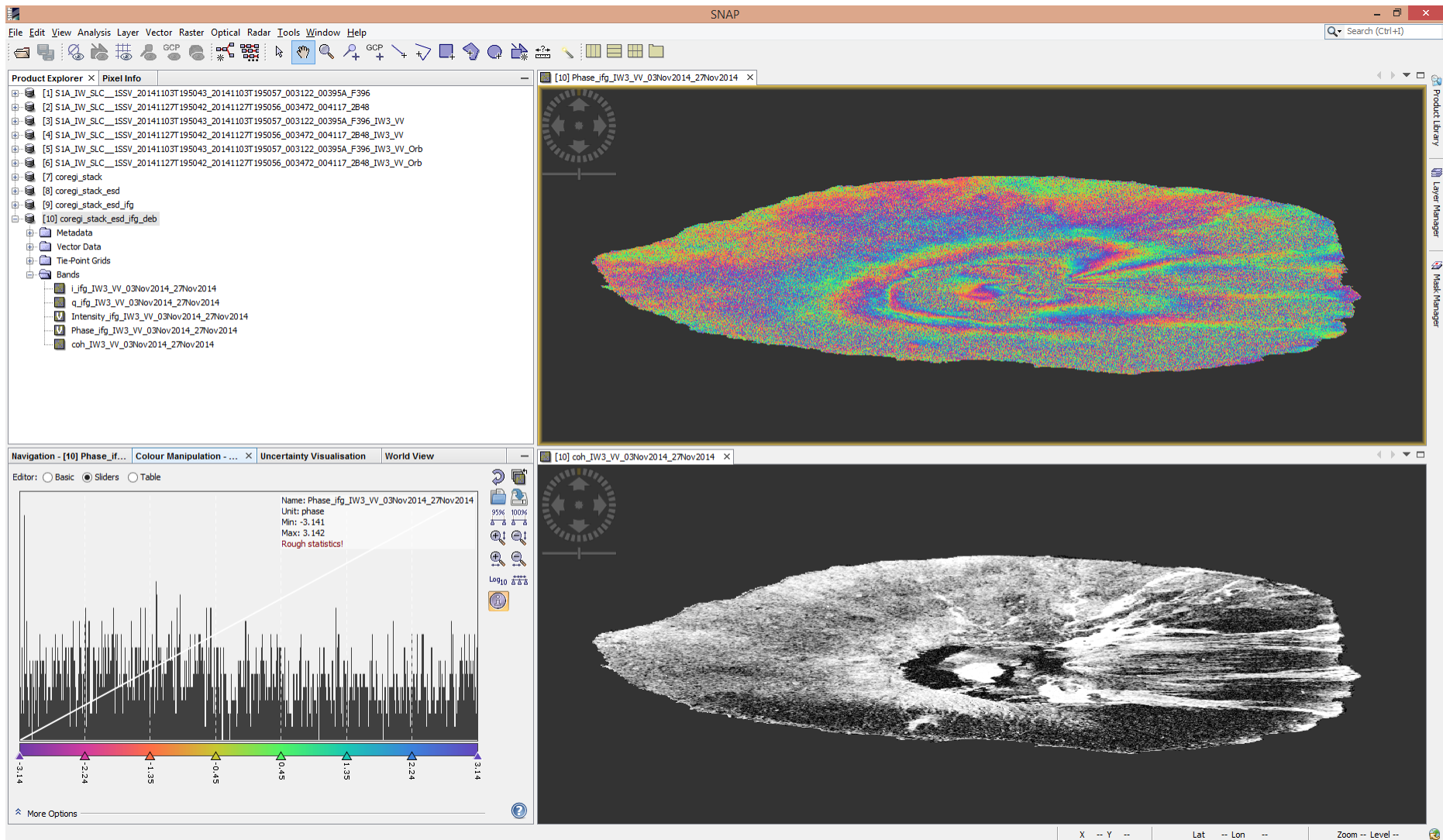
Sentinel-1 TOPS InSAR (InSAR Phase & Coherence)



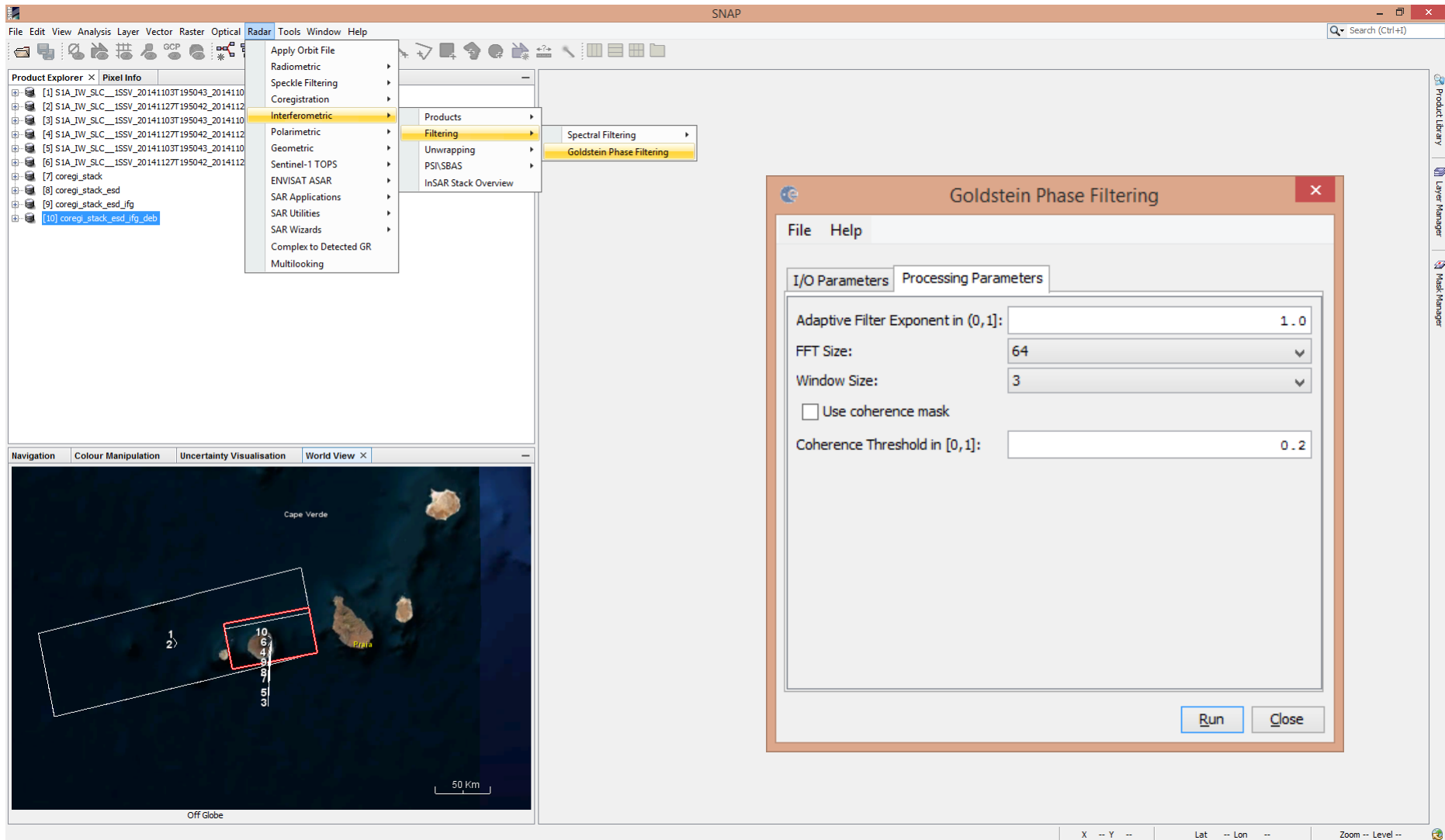




S1 Deburseded Products (InSAR Phase & Coherence)



Goldstein Phase Filtering (Adaptive Filter)

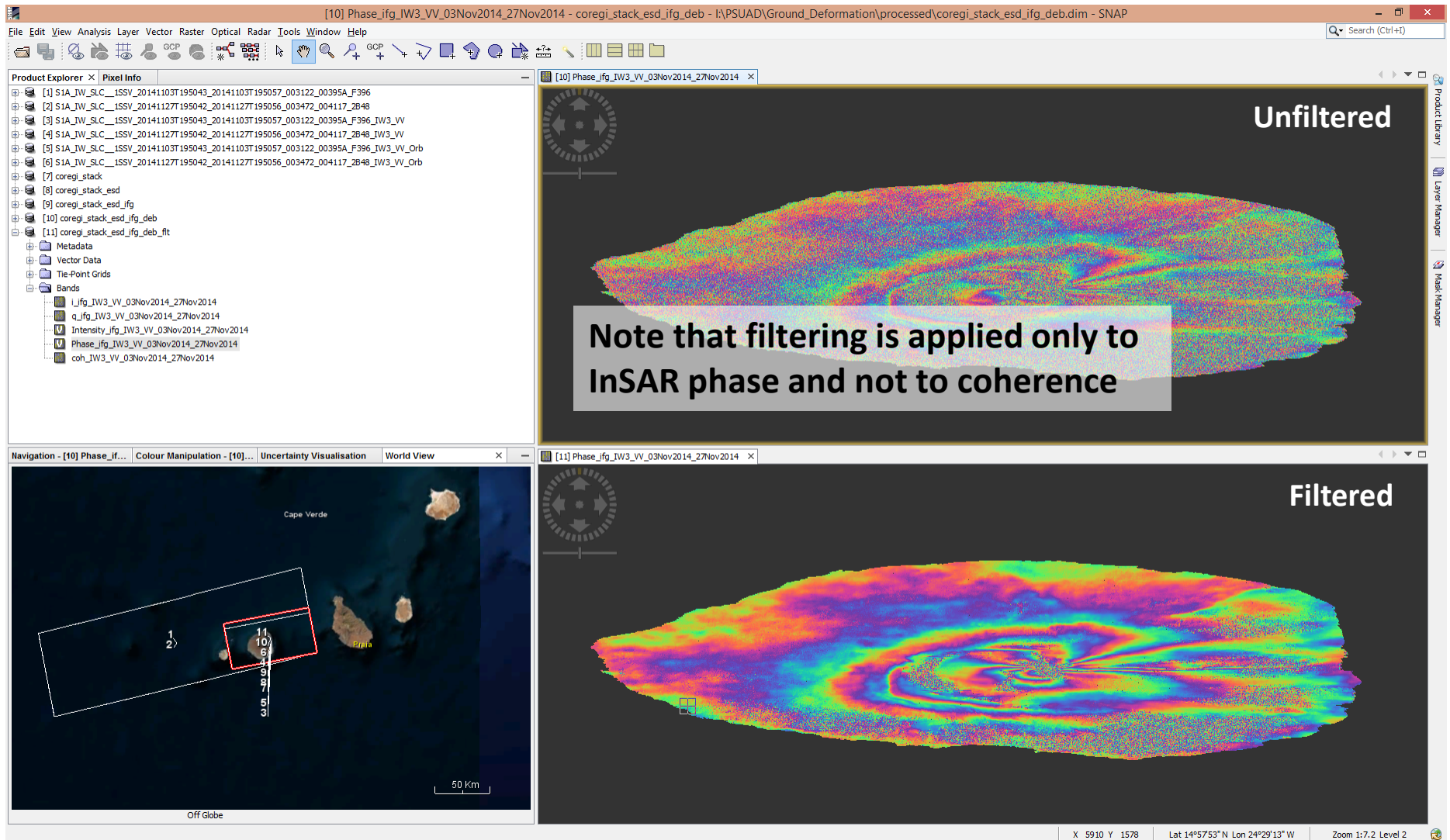


The screenshot displays the SNAP (Scientific Data Processing) software interface. The main window shows a map of Cape Verde with a red rectangular region of interest. The 'Radar' menu is open, and the 'Interferometric' sub-menu is selected, leading to the 'Goldstein Phase Filtering' option. The 'Goldstein Phase Filtering' dialog box is open, showing the 'Processing Parameters' tab. The parameters are as follows:

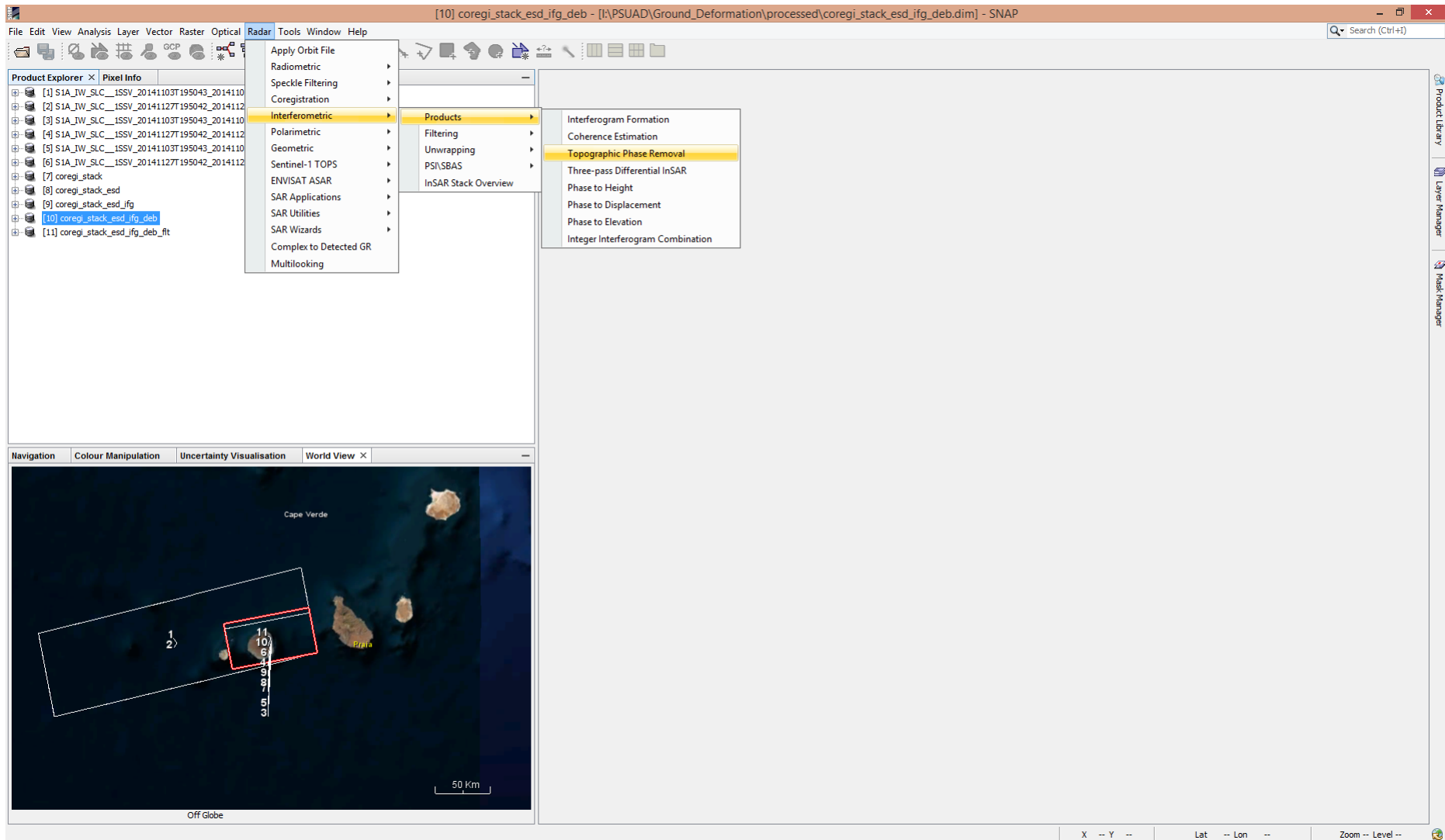
Parameter	Value
Adaptive Filter Exponent in $[0, 1]$:	1.0
FFT Size:	64
Window Size:	3
Use coherence mask:	☐
Coherence Threshold in $[0, 1]$:	0.2

The dialog box has 'Run' and 'Close' buttons at the bottom right. The background map shows Cape Verde islands with a scale bar of 50 Km. The bottom status bar shows coordinates and zoom level.

S1 Filtered InSAR Phase



Topographic Phase Removal (Differential InSAR Phase)



Topographic Phase Removal (Differential InSAR Phase)

Topographic Phase Removal

File Help

I/O Parameters Processing Parameters

Source Product

Source product:

[10] coregi_stack_esd_ifg_deb

Target Product

Name:

coregi_stack_esd_ifg_deb_dinsar

☒ Save as: BEAM-DIMAP

Directory:

C:\Users\mfoumelis

☒ Open in SNAP

Run Close

Topographic Phase Removal

File Help

I/O Parameters Processing Parameters

Orbit Interpolation Degree: 3

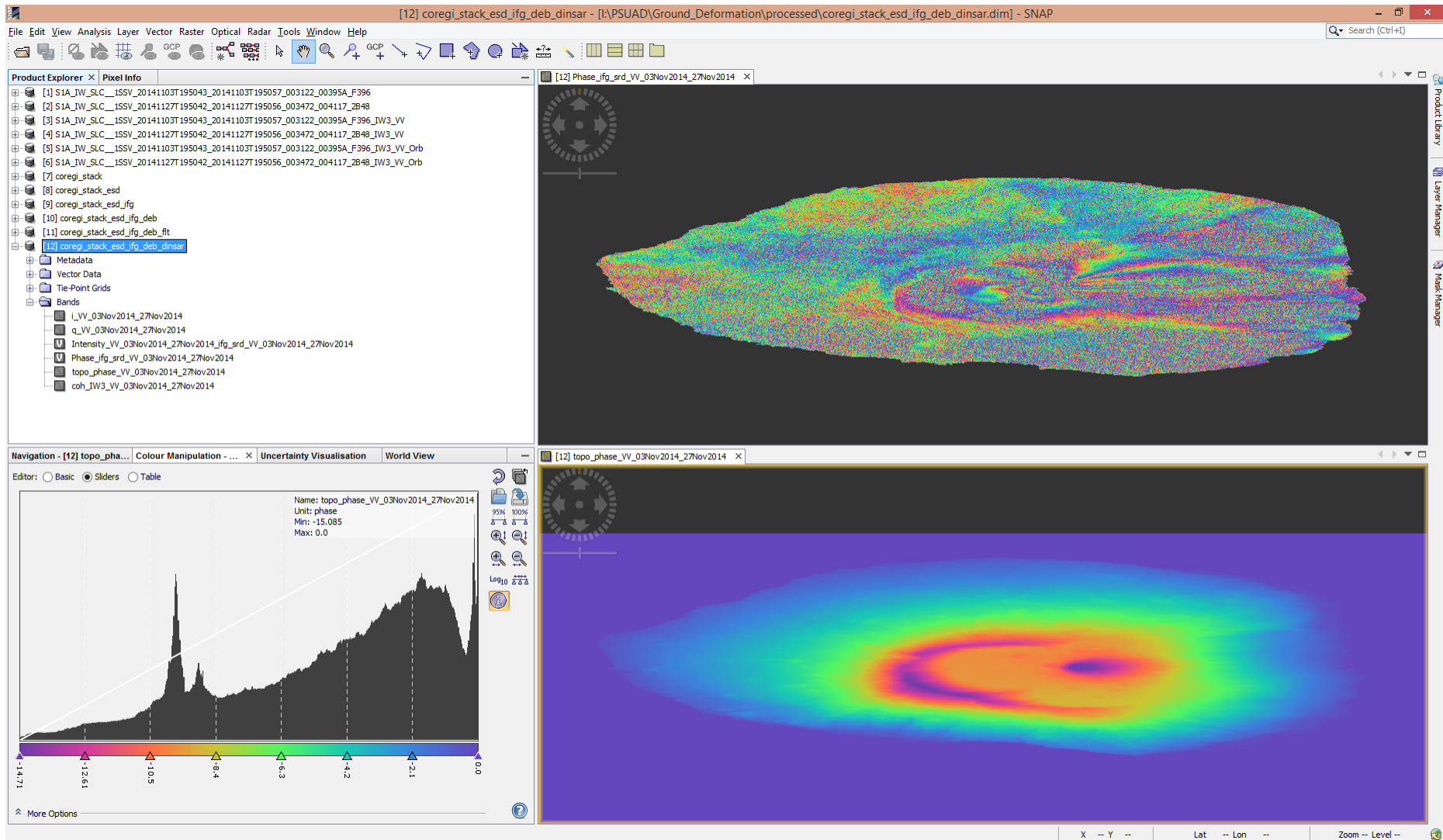
Digital Elevation Model: SRTM 3Sec (Auto Download)

Topo Phase Band Name: topo_phase

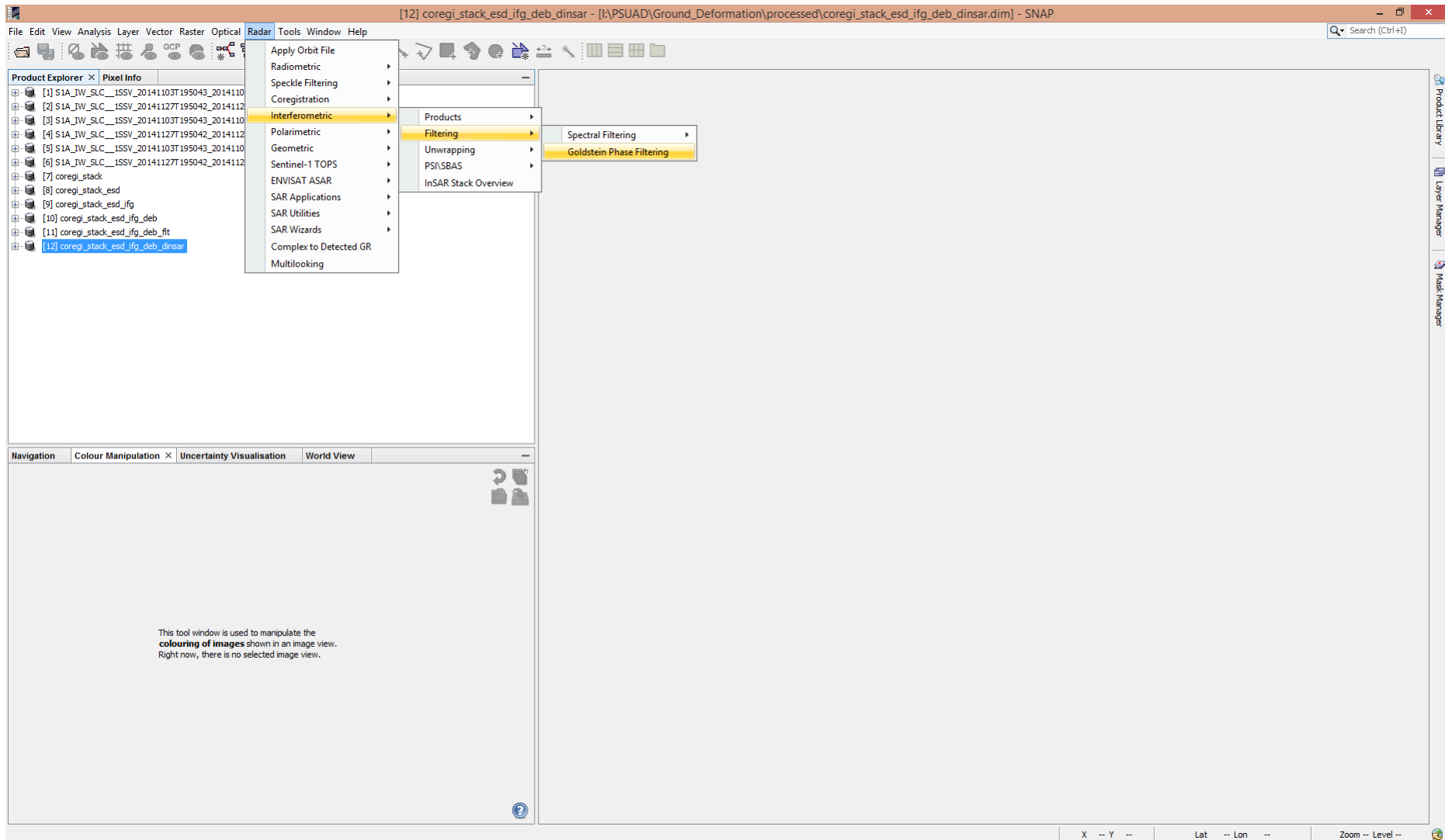
Tile Extension [%]: 100

Run Close

Differential Interferogram & Simulated Topo Phase



Differential Phase Filtering (Goldstein Filter)



Differential Phase Filtering

Goldstein Phase Filtering

File Help

I/O Parameters Processing Parameters

Source Product

Source product:

[12] coregi_stack_esd_ifg_deb_dinsar

Target Product

Name:

coregi_stack_esd_ifg_deb_dinsar_fit

☒ Save as: BEAM-DIMAP

Directory:

C:\Users\mfoumelis

☒ Open in SNAP

Run Close

Goldstein Phase Filtering

File Help

I/O Parameters Processing Parameters

Adaptive Filter Exponent in $(0,1]$: 1.0

FFT Size: 64

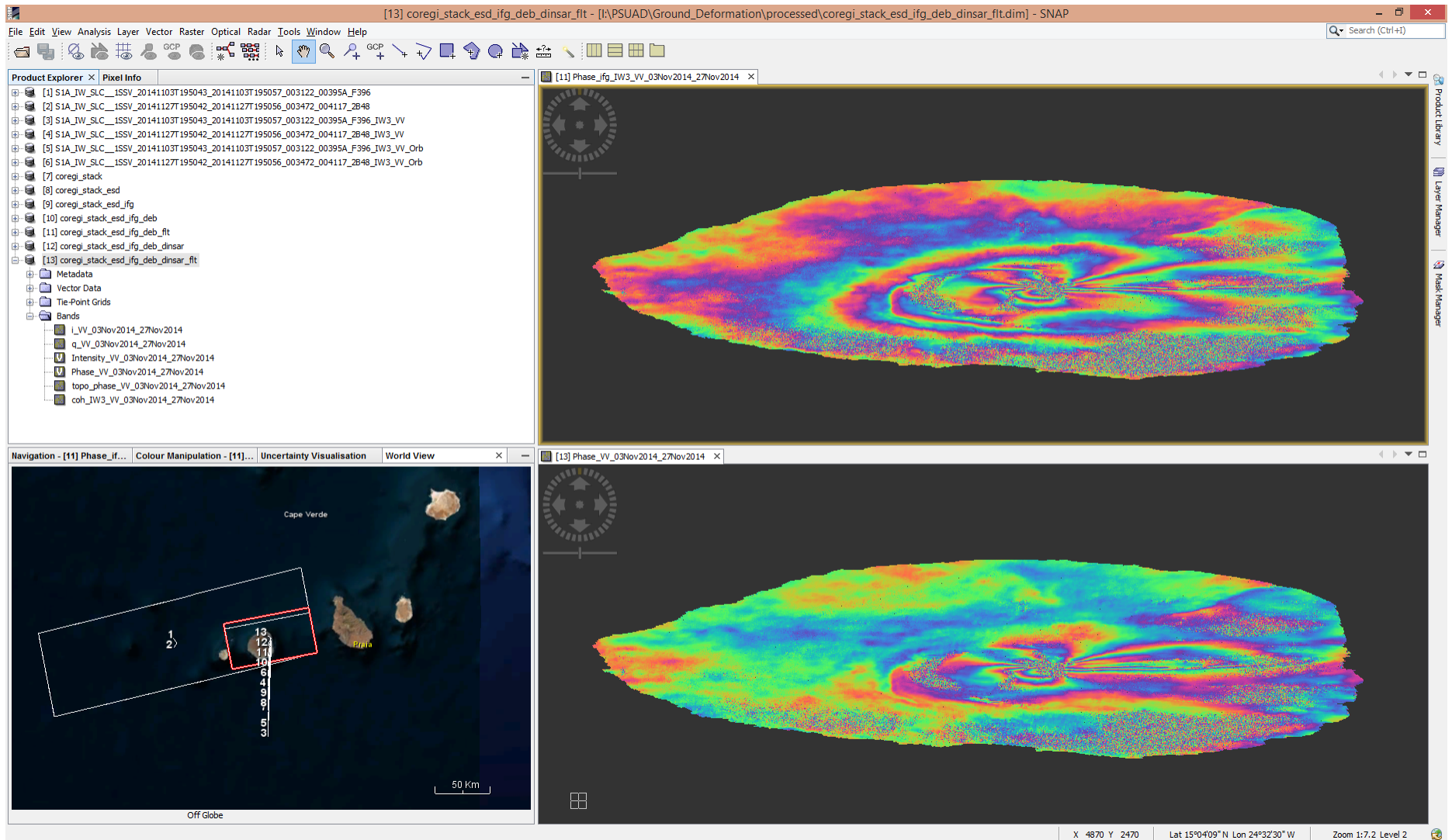
Window Size: 3

☐ Use coherence mask

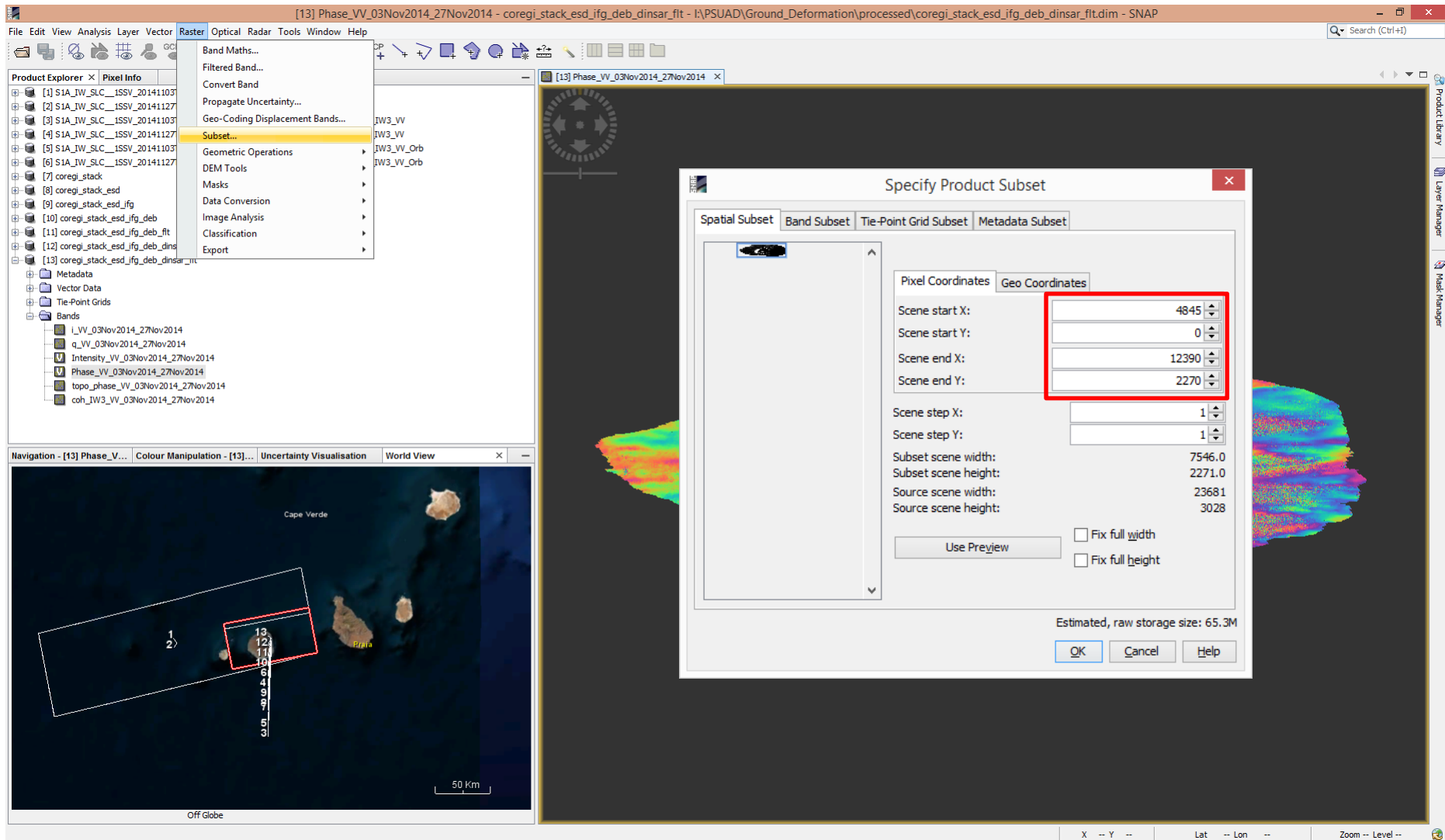
Coherence Threshold in $[0,1]$: 0.2

Run Close

S1 Filtered DInSAR Phase



Spatial Subset over AOI

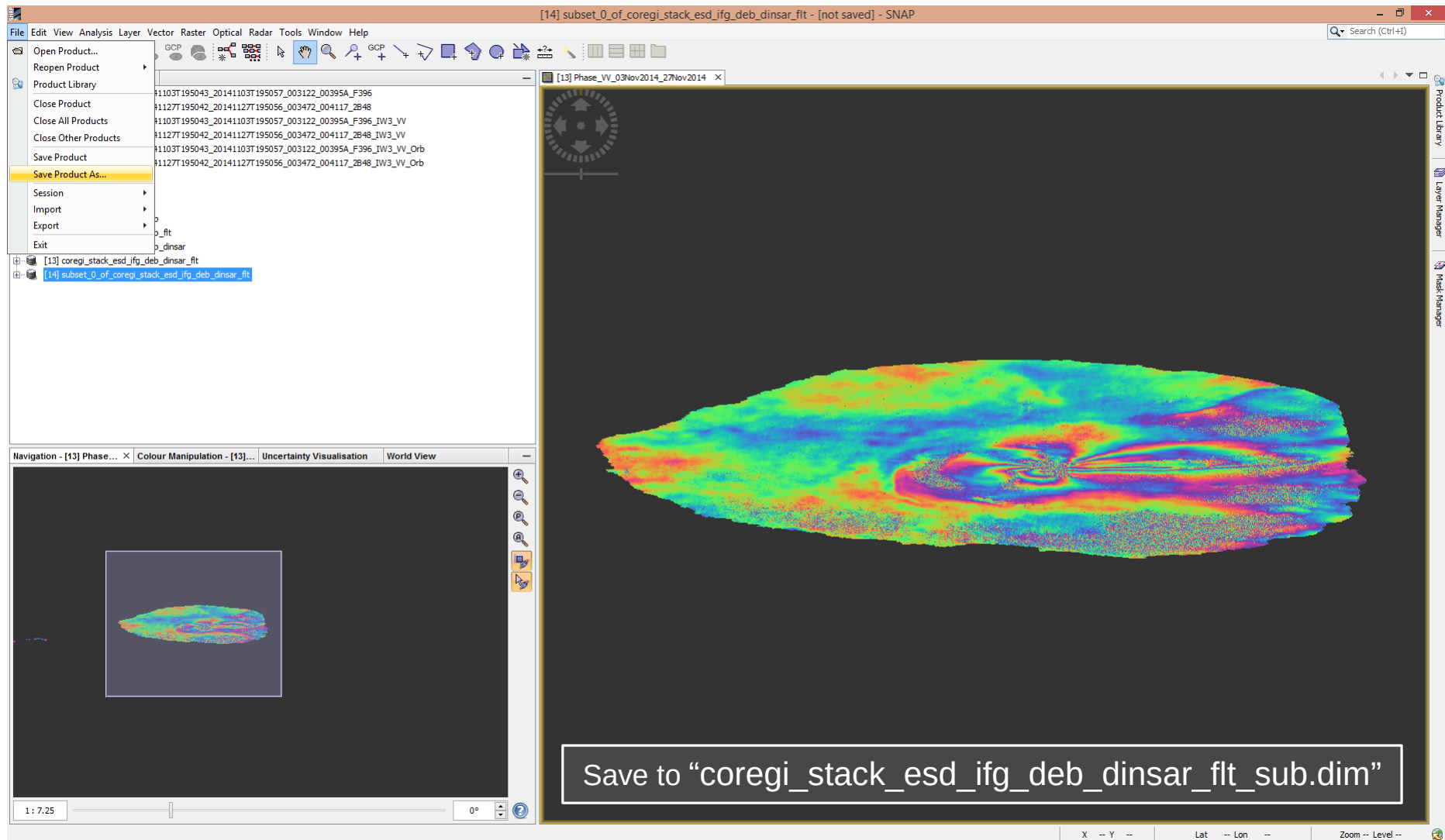


The screenshot displays the SNAP (Sentinel Application Platform) interface. The main window shows a map of Cape Verde with a red rectangular Area of Interest (AOI) and a numbered list of sub-images. The 'Raster' menu is open, highlighting the 'Subset...' option. The 'Specify Product Subset' dialog box is open, showing the 'Spatial Subset' tab. The 'Pixel Coordinates' section is active, with the following values:

Parameter	Value
Scene start X:	4845
Scene start Y:	0
Scene end X:	12390
Scene end Y:	2270
Scene step X:	1
Scene step Y:	1
Subset scene width:	7546.0
Subset scene height:	2271.0
Source scene width:	23681
Source scene height:	3028

The 'Use Preview' button is disabled. The estimated raw storage size is 65.3M. The 'OK' button is highlighted.

Spatial Subset over AOI



[14] subset_0_of_coregi_stack_esd_ifg_deb_dinsar_fit - [not saved] - SNAP

File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help

Open Product...
Reopen Product
Product Library
Close Product
Close All Products
Close Other Products
Save Product
Save Product As...
Session
Import
Export
Exit

[13] coregi_stack_esd_ifg_deb_dinsar_fit
[14] subset_0_of_coregi_stack_esd_ifg_deb_dinsar_fit

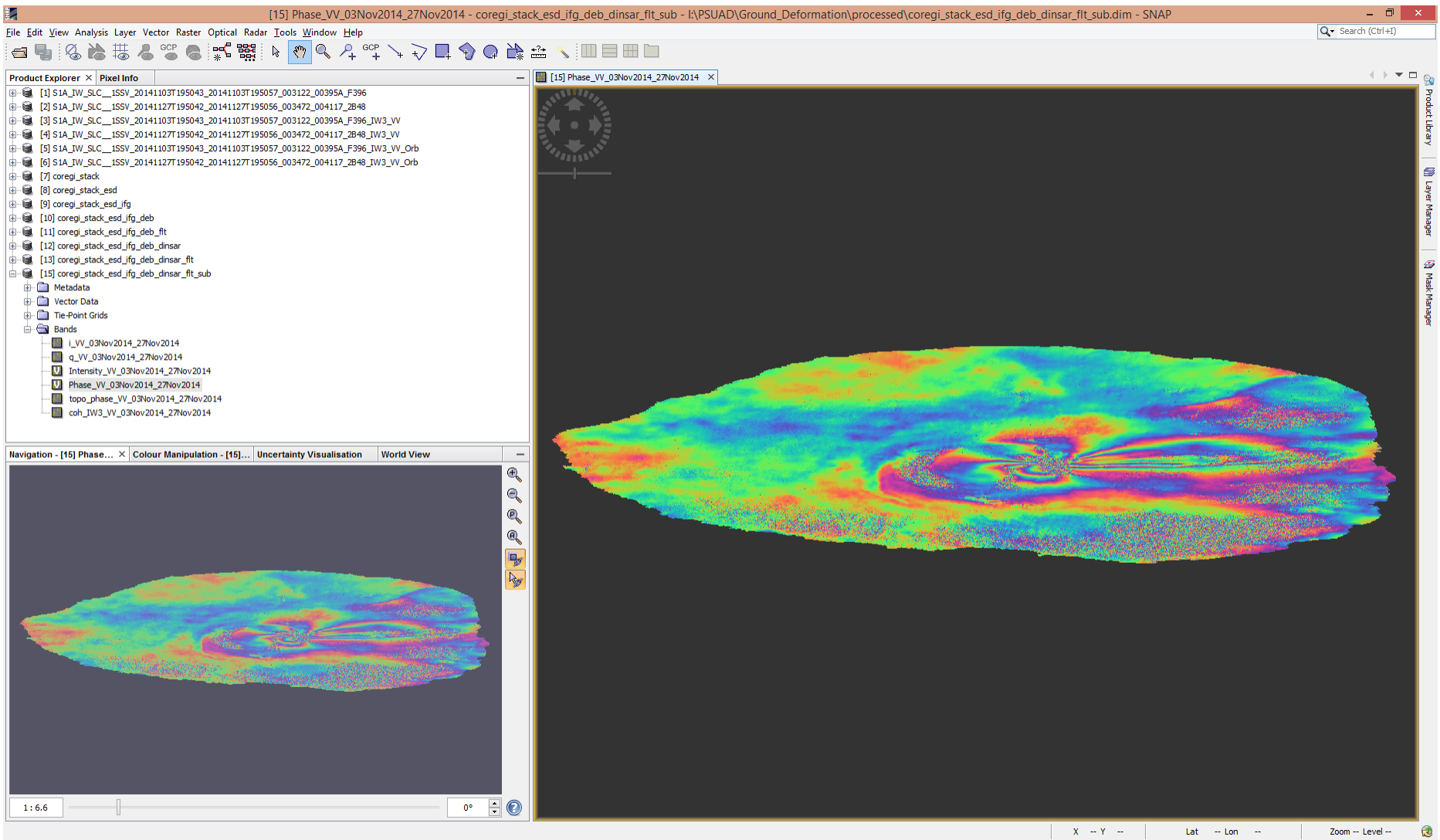
Navigation - [13] Phase... x Colour Manipulation - [13]... Uncertainty Visualisation World View

1 : 7.25 0°

Save to "coregi_stack_esd_ifg_deb_dinsar_fit_sub.dim"

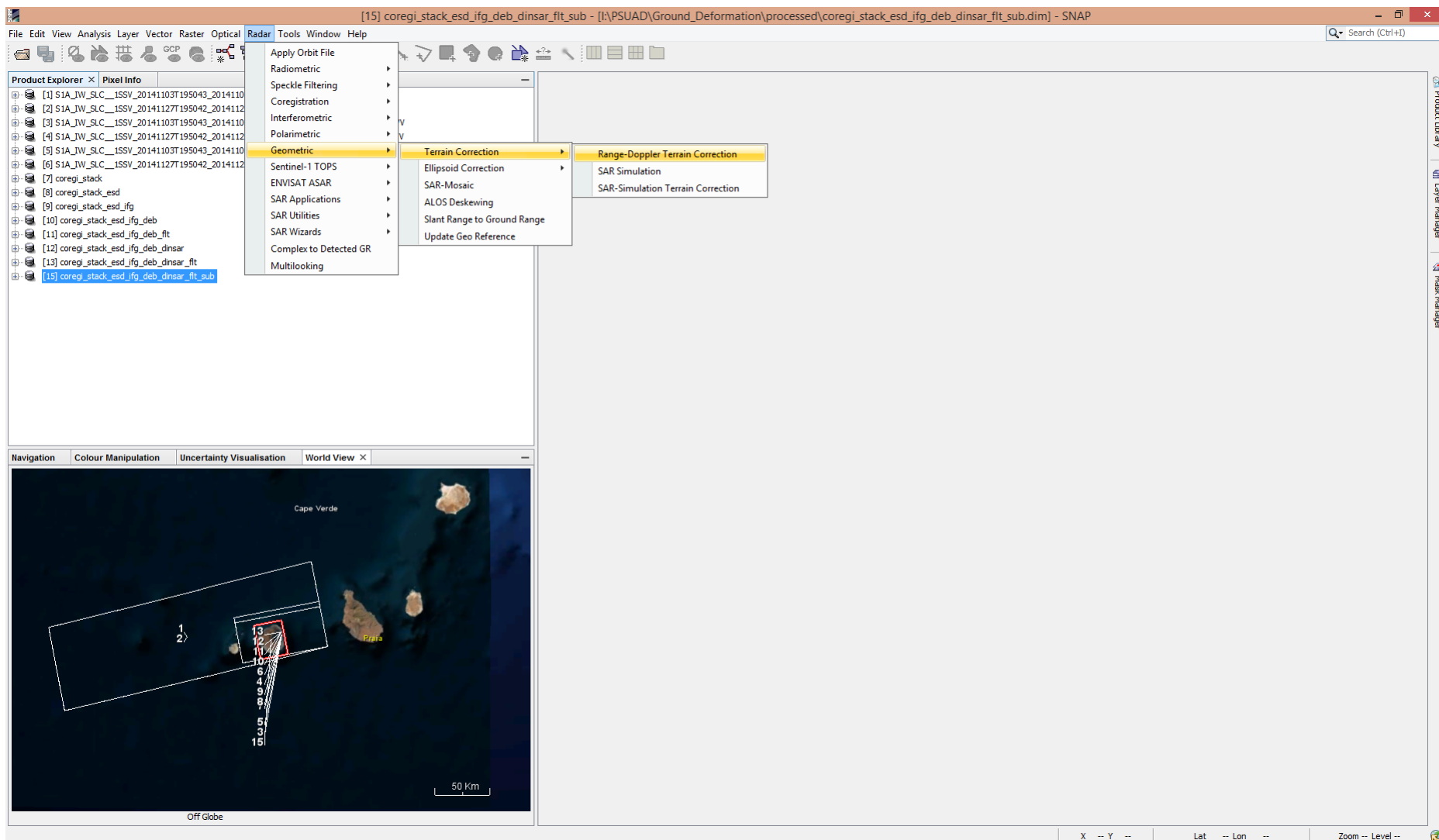
X -- Y -- Lat -- Lon -- Zoom -- Level --

S1 TOPS Filtered DInSAR Phase (Wrapped)



Geocoding of Wrapped DInSAR Phase & Coherence

Range-Doppler Terrain Correction approach



Range-Doppler Terrain Correction

Range Doppler Terrain Correction

File Help

I/O Parameters Processing Parameters

Source Bands:

- i_VV_03Nov2014_27Nov2014
- q_VV_03Nov2014_27Nov2014
- Intensity_VV_03Nov2014_27Nov2014
- Phase_VV_03Nov2014_27Nov2014
- topo_phase_VV_03Nov2014_27Nov2014
- coh_IW3_VV_03Nov2014_27Nov2014

Digital Elevation Model: SRTM 3Sec (Auto Download)

DEM Resampling Method: BILINEAR_INTERPOLATION

Image Resampling Method: BILINEAR_INTERPOLATION

Source GR Pixel Spacings (az x rg): 13.98(m) x 3.39(m)

Pixel Spacing (m): 15

Pixel Spacing (deg): 1.3474729261792824E-4

Map Projection: WGS84(DD)

☒ Mask out areas without elevation ☒ Output complex data

Output bands for:

Map Projection

Coordinate Reference System (CRS)

☒ Custom CRS

Geodetic datum: World Geodetic System 1984

Projection: UTM / WGS 84 (Automatic)

Projection Parameters...

☐ Predefined CRS

OK Cancel Help

Range Doppler Terrain Correction

File Help

I/O Parameters Processing Parameters

Source Bands:

- i_VV_03Nov2014_27Nov2014
- q_VV_03Nov2014_27Nov2014
- Intensity_VV_03Nov2014_27Nov2014
- Phase_VV_03Nov2014_27Nov2014
- topo_phase_VV_03Nov2014_27Nov2014
- coh_IW3_VV_03Nov2014_27Nov2014

Digital Elevation Model: SRTM 3Sec (Auto Download)

DEM Resampling Method: BILINEAR_INTERPOLATION

Image Resampling Method: BILINEAR_INTERPOLATION

Source GR Pixel Spacings (az x rg): 13.98(m) x 3.39(m)

Pixel Spacing (m): 15

Pixel Spacing (deg): 1.3474729261792824E-4

Map Projection: UTM Zone 26 / World Geodetic System 1984

☒ Mask out areas without elevation ☒ Output complex data

Output bands for:

☒ Selected source band ☐ DEM ☐ Latitude & Longitude

☐ Incidence angle from ellipsoid ☐ Local incidence angle ☐ Projected local incidence angle

☐ Apply radiometric normalization

☐ Save Sigma0 band Use projected local incidence angle from DEM

☐ Save Gamma0 band Use projected local incidence angle from DEM

☐ Save Beta0 band

Auxiliary File (ASAR only): Latest Auxiliary File

Run Close



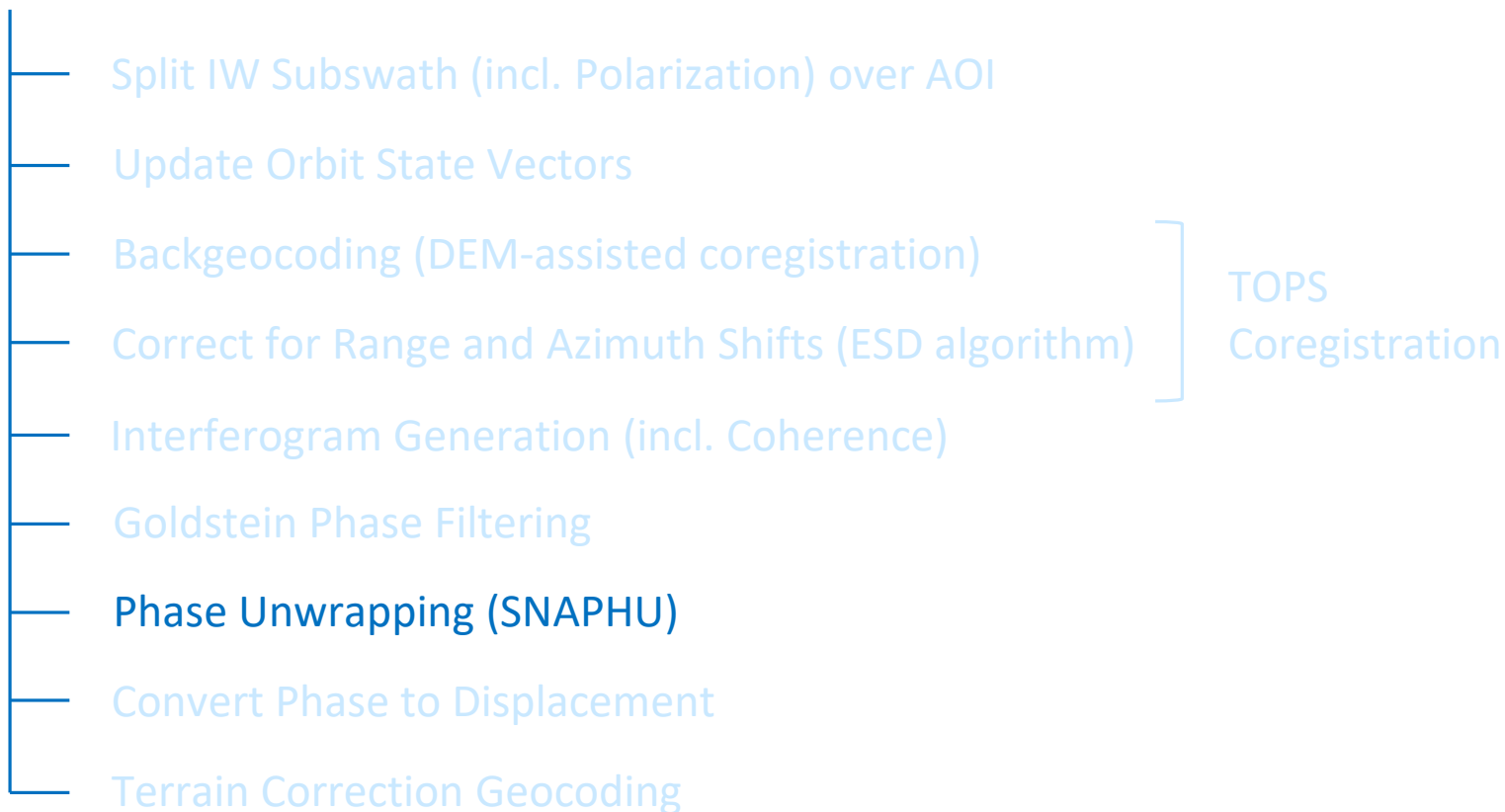
EXERCISE

PART 2

Unwrapping using SNAPHU

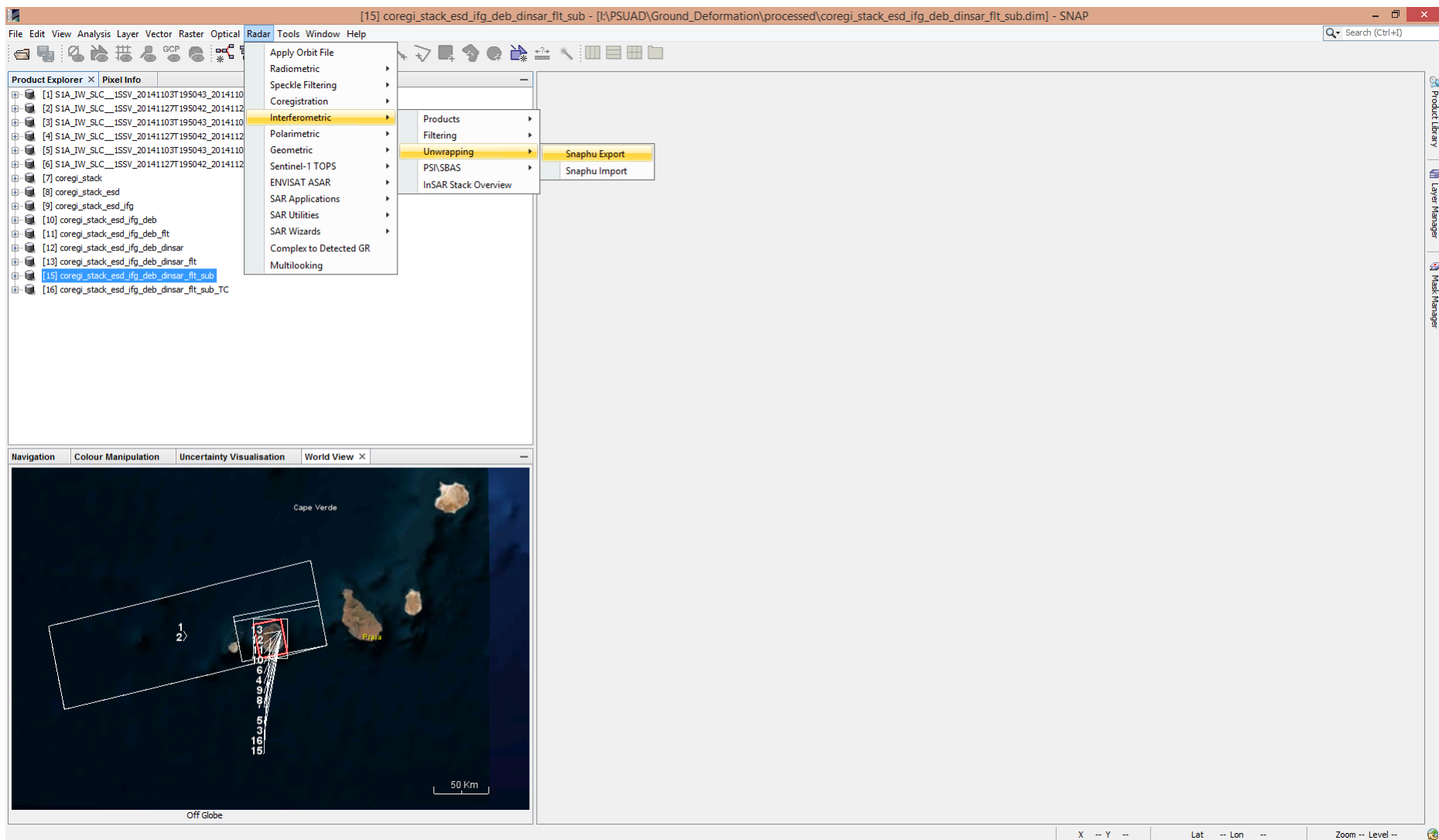


EXERCISE Processing Steps (PART 2)



Phase Unwrapping

Statistical-cost Network-flow Algorithm for Phase Unwrapping (SNAPHU)

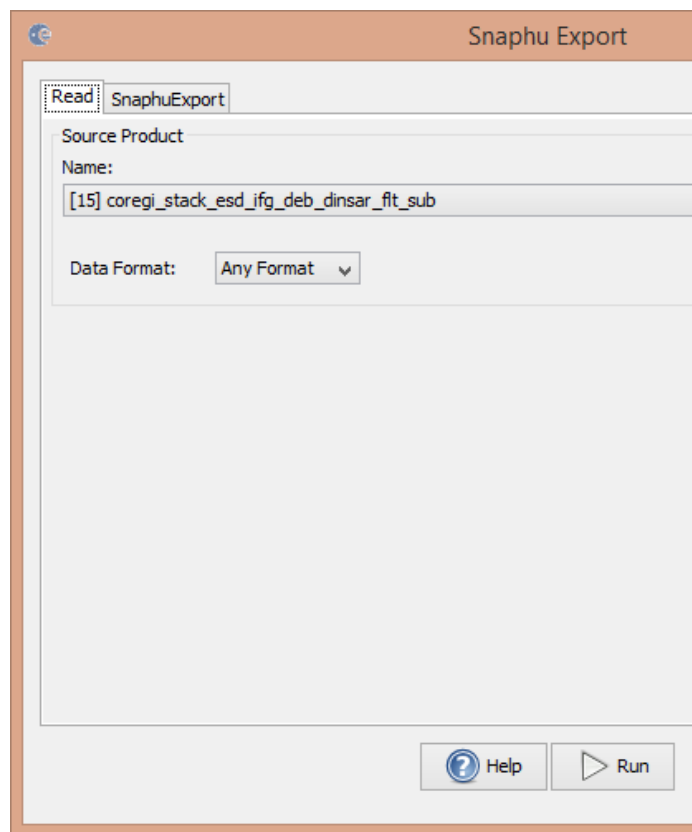


Phase Unwrapping

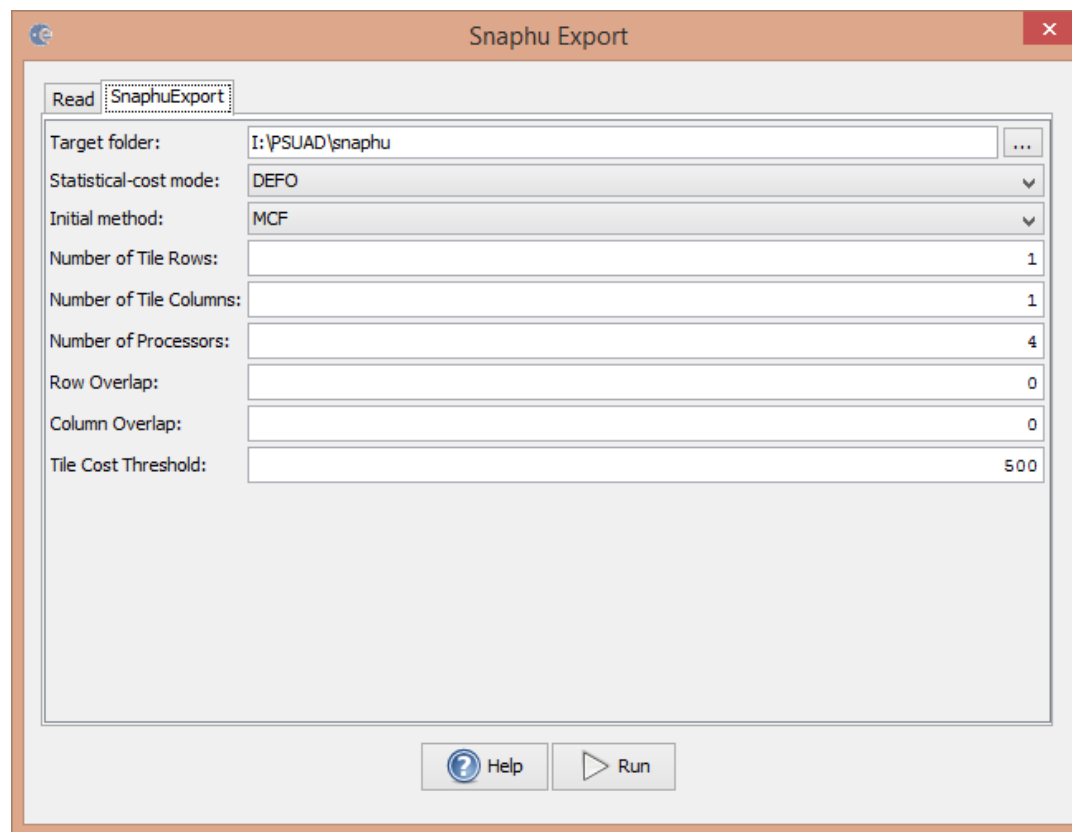
Export to SNAPHU format

Export files required by SNAPHU to “...\outputs\snaphu” folder

Copy wrapped phases to “...\outputs\snaphu”

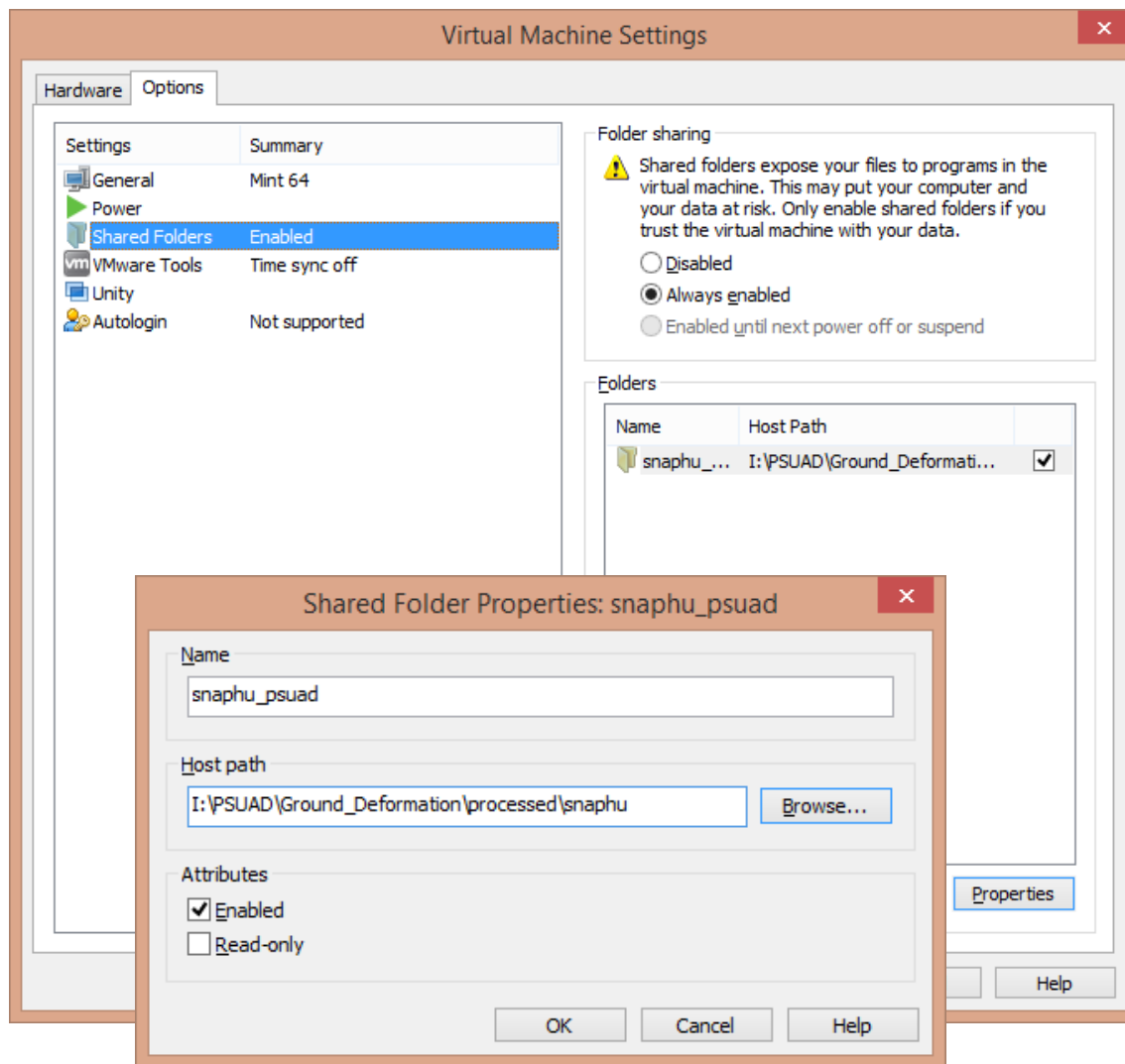


The dialog box is titled "Snaphu Export". It has a "Read" tab and a "SnaphuExport" sub-tab. The "Source Product" section contains a "Name:" field with the value "[15] coregi_stack_esd_ifg_deb_dinsar_fit_sub". Below this is a "Data Format:" dropdown menu set to "Any Format". At the bottom are "Help" and "Run" buttons.



The dialog box is titled "Snaphu Export". It has a "Read" tab and a "SnaphuExport" sub-tab. The "Target folder:" field is set to "I:\PSUAD\snaphu". The "Statistical-cost mode:" dropdown is set to "DEFO". The "Initial method:" dropdown is set to "MCF". The "Number of Tile Rows:" field is set to "1". The "Number of Tile Columns:" field is set to "1". The "Number of Processors:" field is set to "4". The "Row Overlap:" field is set to "0". The "Column Overlap:" field is set to "0". The "Tile Cost Threshold:" field is set to "500". At the bottom are "Help" and "Run" buttons.

Phase Unwrapping Virtual Machine (VM) Setup



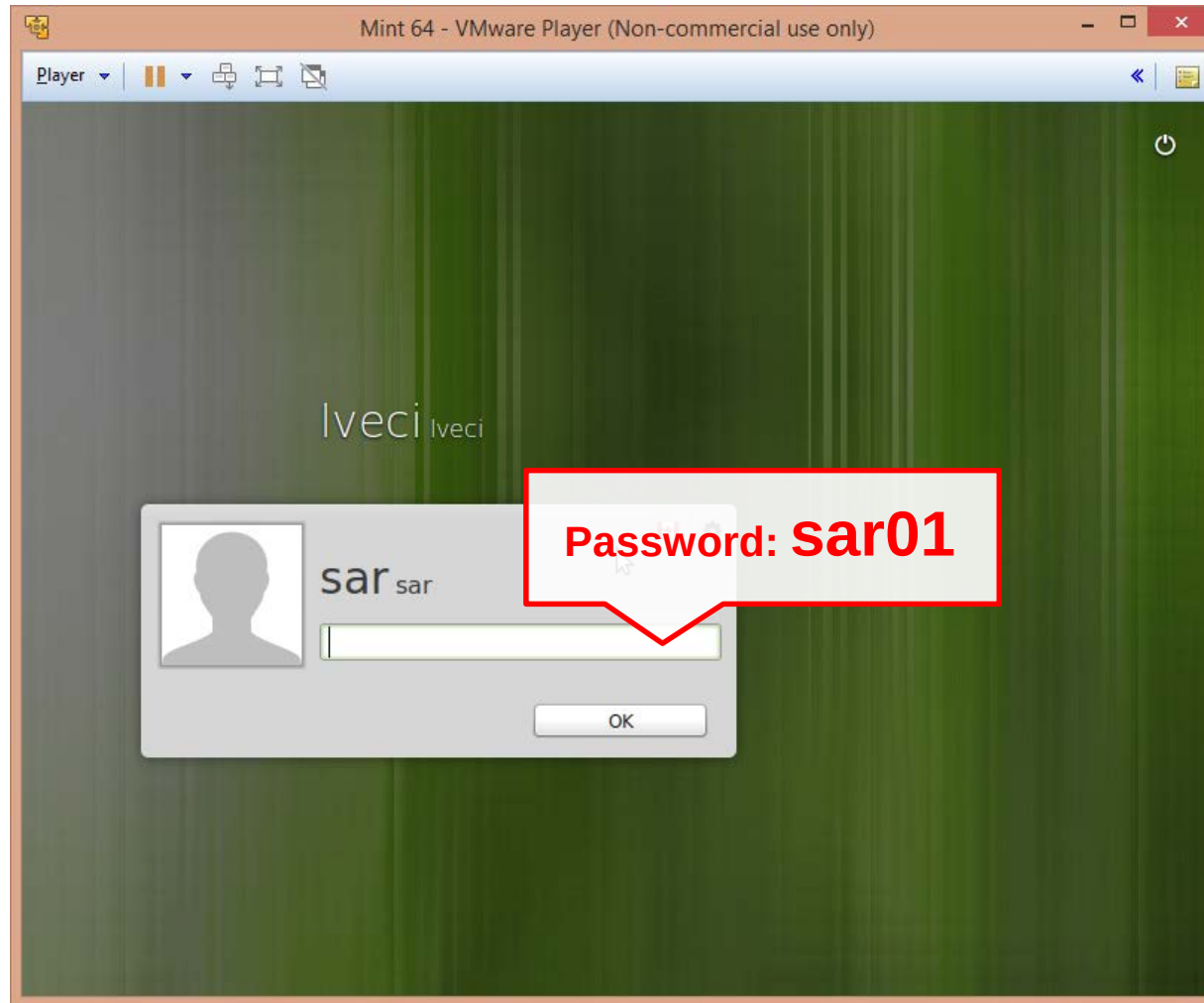
Download and install the dedicated Linux VM on Windows to run SNAPHU and apply phase unwrapping

http://sourceforge.net/projects/s1tbx/files/snaphu_vm/SAR%20Mint%2064.zip/download

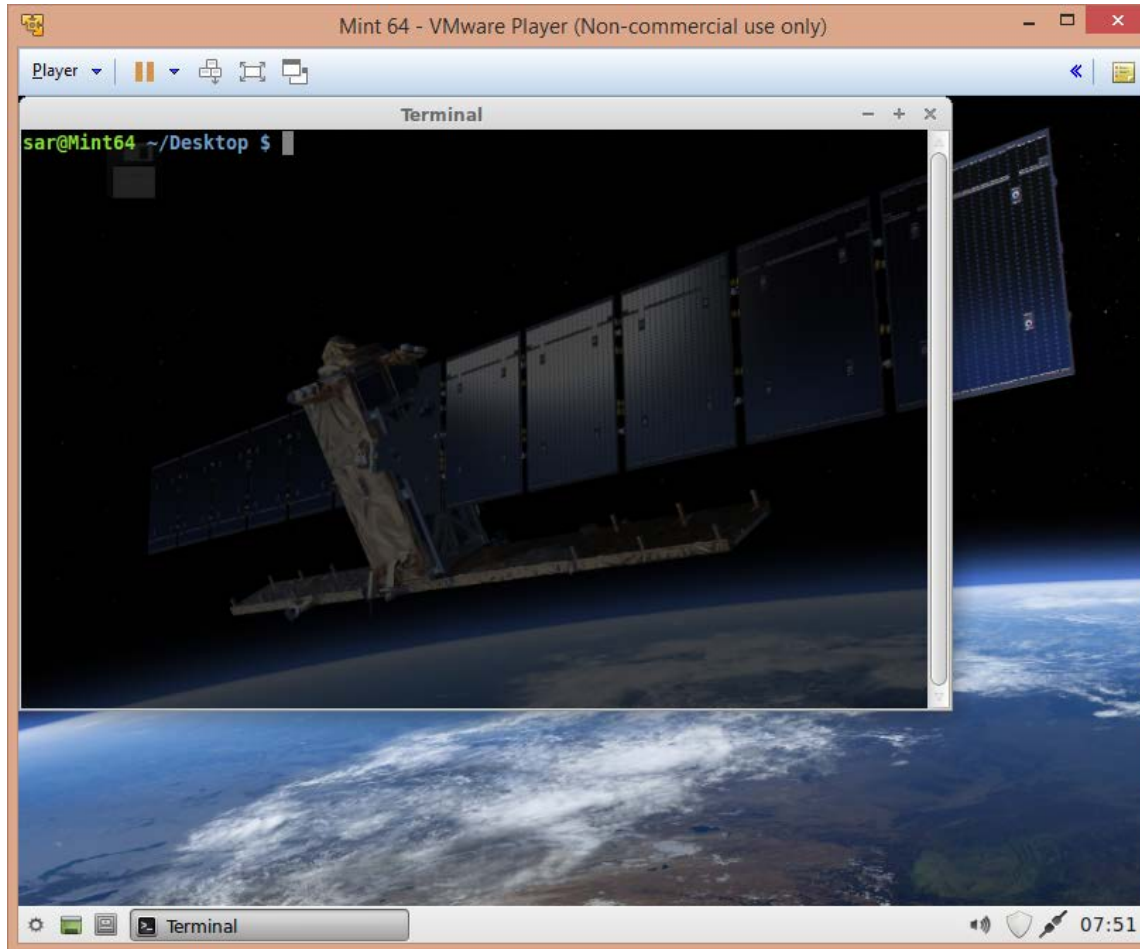
Open the VMware player and browse for the virtual machine

Edit the virtual machine settings to increase the memory and setup a shared folder between Linux and Windows.

Phase Unwrapping VM Initialization



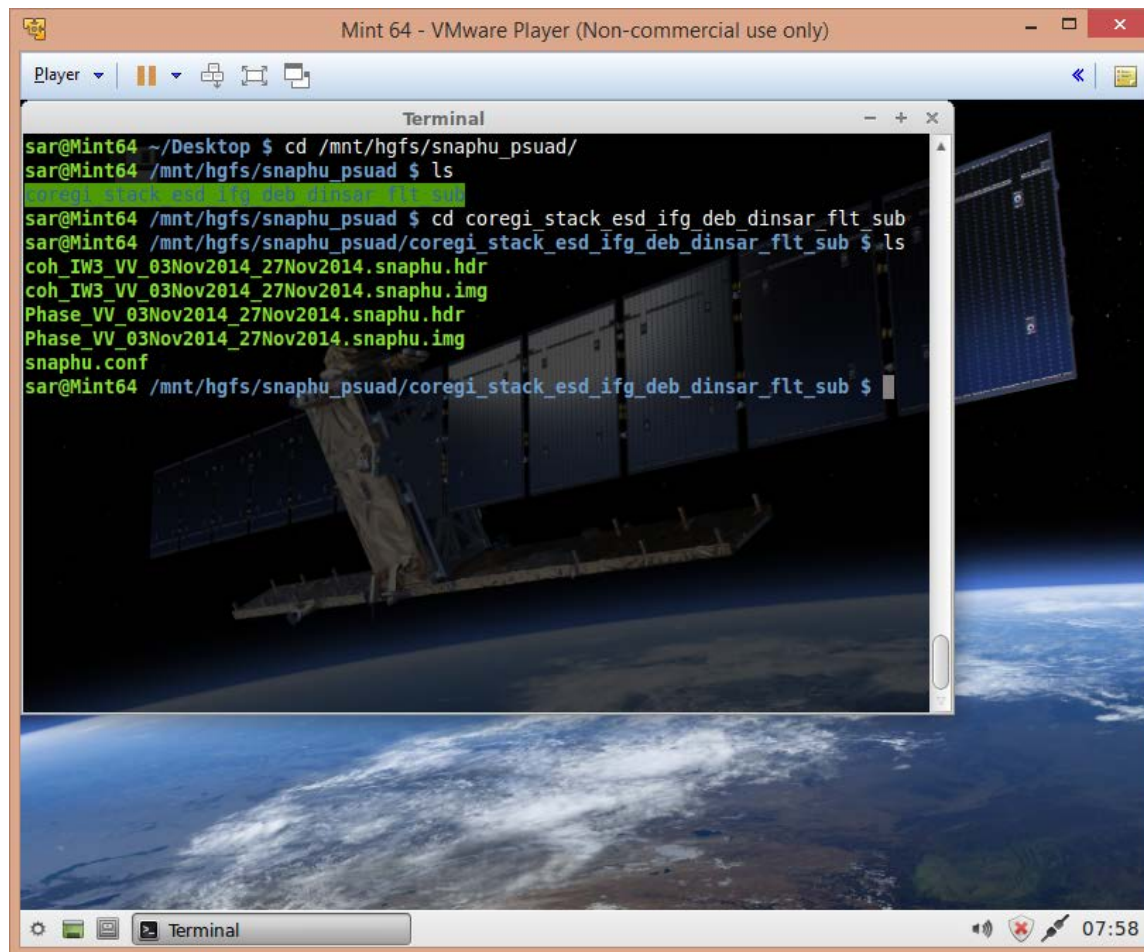
Phase Unwrapping Working in Linux Terminal



Right Click and select
“Open Terminal Here”

Phase Unwrapping

NAVigating to Processing Folder



```
sar@Mint64 ~/Desktop $ cd /mnt/hgfs/snaphu_psuad/
sar@Mint64 /mnt/hgfs/snaphu_psuad $ ls
coregi_stack_esd_ifg_deb_dinsar_flt_sub
sar@Mint64 /mnt/hgfs/snaphu_psuad $ cd coregi_stack_esd_ifg_deb_dinsar_flt_sub
sar@Mint64 /mnt/hgfs/snaphu_psuad/coregi_stack_esd_ifg_deb_dinsar_flt_sub $ ls
coh_IW3_VV_03Nov2014_27Nov2014.snaphu.hdr
coh_IW3_VV_03Nov2014_27Nov2014.snaphu.img
Phase_VV_03Nov2014_27Nov2014.snaphu.hdr
Phase_VV_03Nov2014_27Nov2014.snaphu.img
snaphu.conf
sar@Mint64 /mnt/hgfs/snaphu_psuad/coregi_stack_esd_ifg_deb_dinsar_flt_sub $
```

> cd /mnt/hgfs/snaphu/

Phase Unwrapping

Running Predefined Unwrapping Command

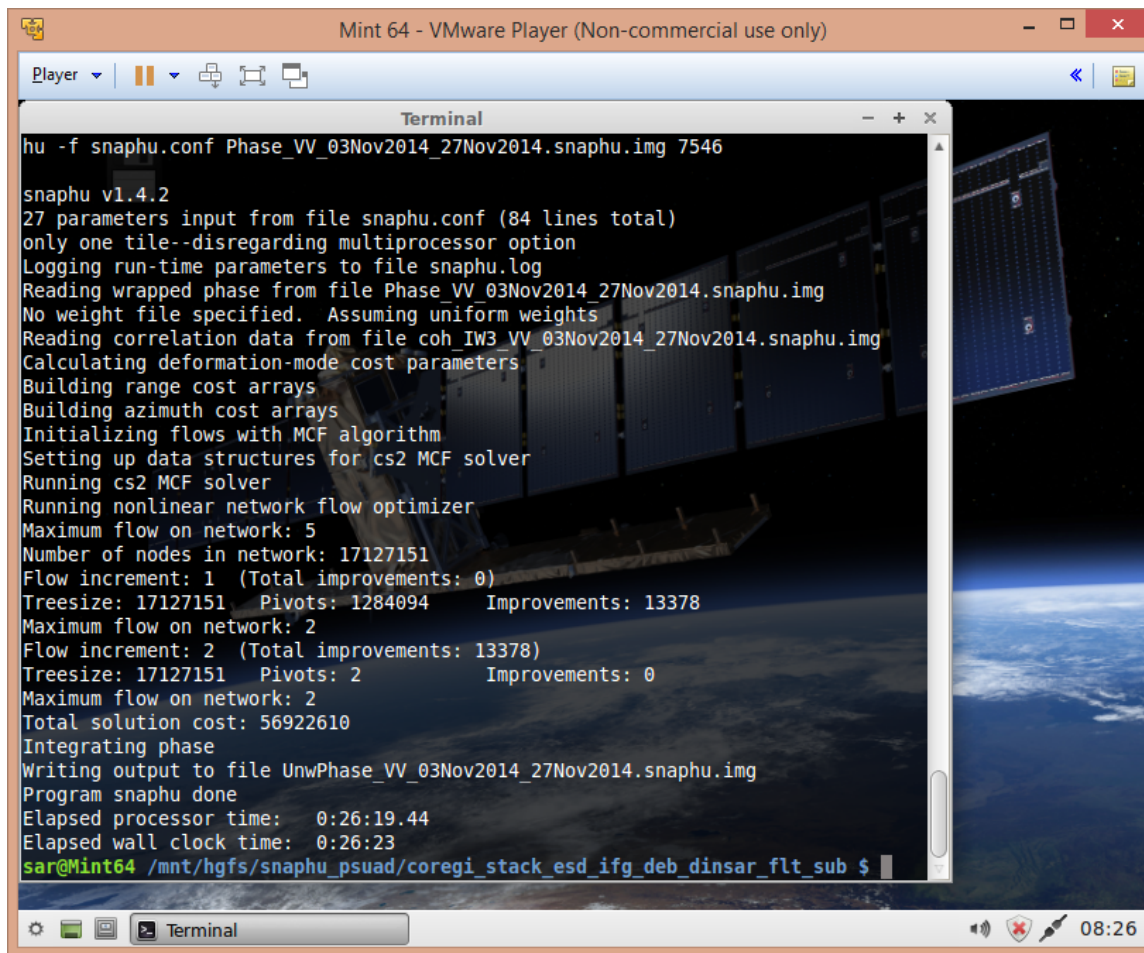


```
sar@Mint64 ~/Desktop $ cd /mnt/hgfs/snaphu_psuad/
sar@Mint64 /mnt/hgfs/snaphu_psuad $ ls
coregi_stack_esd_ifg_deb_dinsarflt_sub
sar@Mint64 /mnt/hgfs/snaphu_psuad $ cd coregi_stack_esd_ifg_deb_dinsarflt_sub
sar@Mint64 /mnt/hgfs/snaphu_psuad/coregi_stack_esd_ifg_deb_dinsarflt_sub $ ls
coh_IW3_VV_03Nov2014_27Nov2014.snaphu.hdr
coh_IW3_VV_03Nov2014_27Nov2014.snaphu.img
Phase_VV_03Nov2014_27Nov2014.snaphu.hdr
Phase_VV_03Nov2014_27Nov2014.snaphu.img
snaphu.conf
sar@Mint64 /mnt/hgfs/snaphu_psuad/coregi_stack_esd_ifg_deb_dinsarflt_sub $ snaphu
-hu -f snaphu.conf Phase_VV_03Nov2014_27Nov2014.snaphu.img 7546
```

Unwrapping command
for the specific data
inputs can be found in
snaphu.conf

> snaphu -f snaphu.conf Phase_VV_03Nov2014_27Nov2014.snaphu.img 7546

Phase Unwrapping SNAPHU Processing

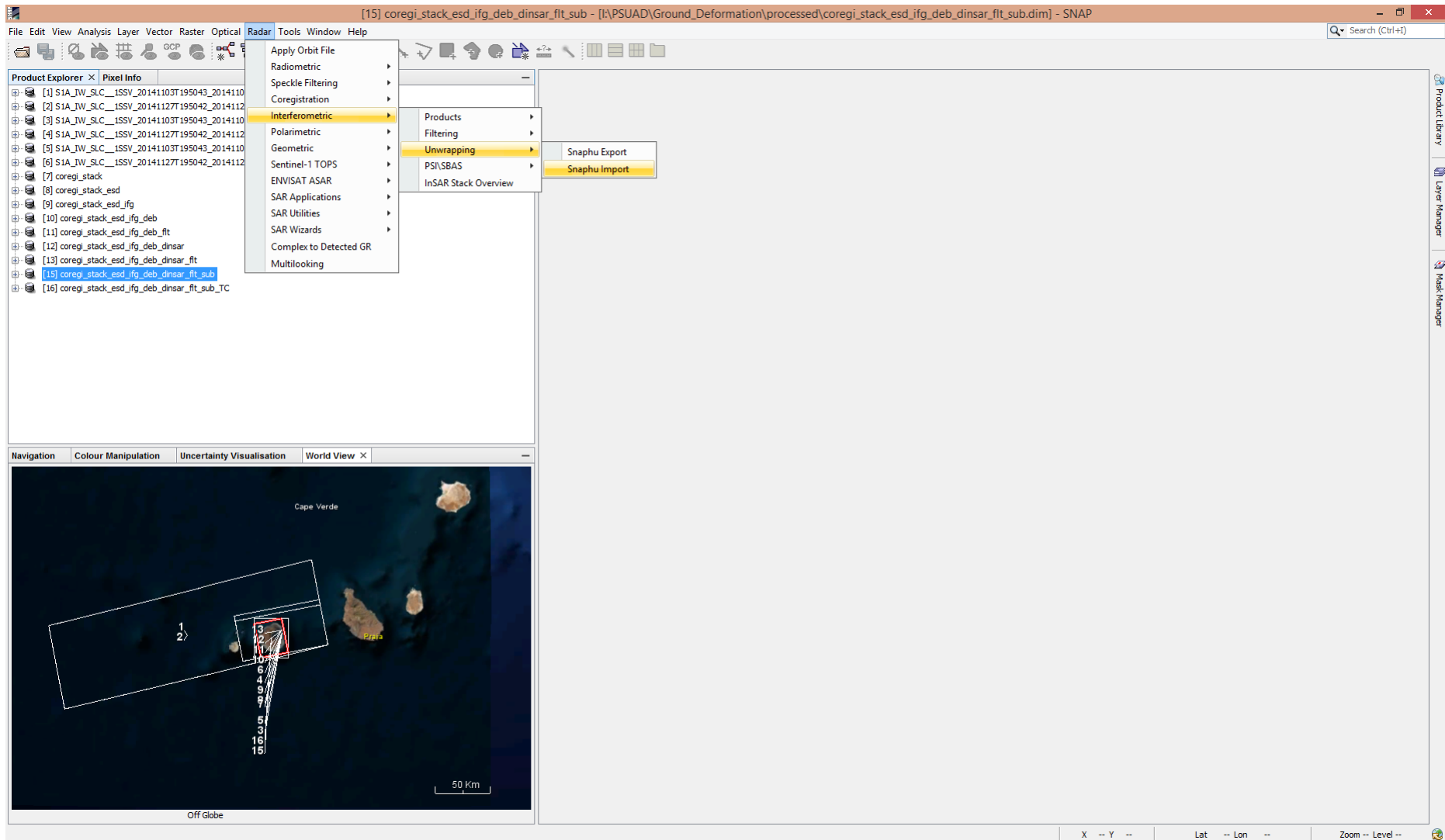


```
hu -f snaphu.conf Phase_VV_03Nov2014_27Nov2014.snaphu.img 7546

snaphu v1.4.2
27 parameters input from file snaphu.conf (84 lines total)
only one tile--disregarding multiprocessor option
Logging run-time parameters to file snaphu.log
Reading wrapped phase from file Phase_VV_03Nov2014_27Nov2014.snaphu.img
No weight file specified. Assuming uniform weights
Reading correlation data from file coh_IW3_VV_03Nov2014_27Nov2014.snaphu.img
Calculating deformation-mode cost parameters
Building range cost arrays
Building azimuth cost arrays
Initializing flows with MCF algorithm
Setting up data structures for cs2 MCF solver
Running cs2 MCF solver
Running nonlinear network flow optimizer
Maximum flow on network: 5
Number of nodes in network: 17127151
Flow increment: 1 (Total improvements: 0)
Treesize: 17127151 Pivots: 1284094 Improvements: 13378
Maximum flow on network: 2
Flow increment: 2 (Total improvements: 13378)
Treesize: 17127151 Pivots: 2 Improvements: 0
Maximum flow on network: 2
Total solution cost: 56922610
Integrating phase
Writing output to file UnwPhase_VV_03Nov2014_27Nov2014.snaphu.img
Program snaphu done
Elapsed processor time: 0:26:19.44
Elapsed wall clock time: 0:26:23
sar@Mint64 /mnt/hgfs/snaphu_psuad/coregi_stack_esd_ifg_deb_dinsarflt_sub $
```

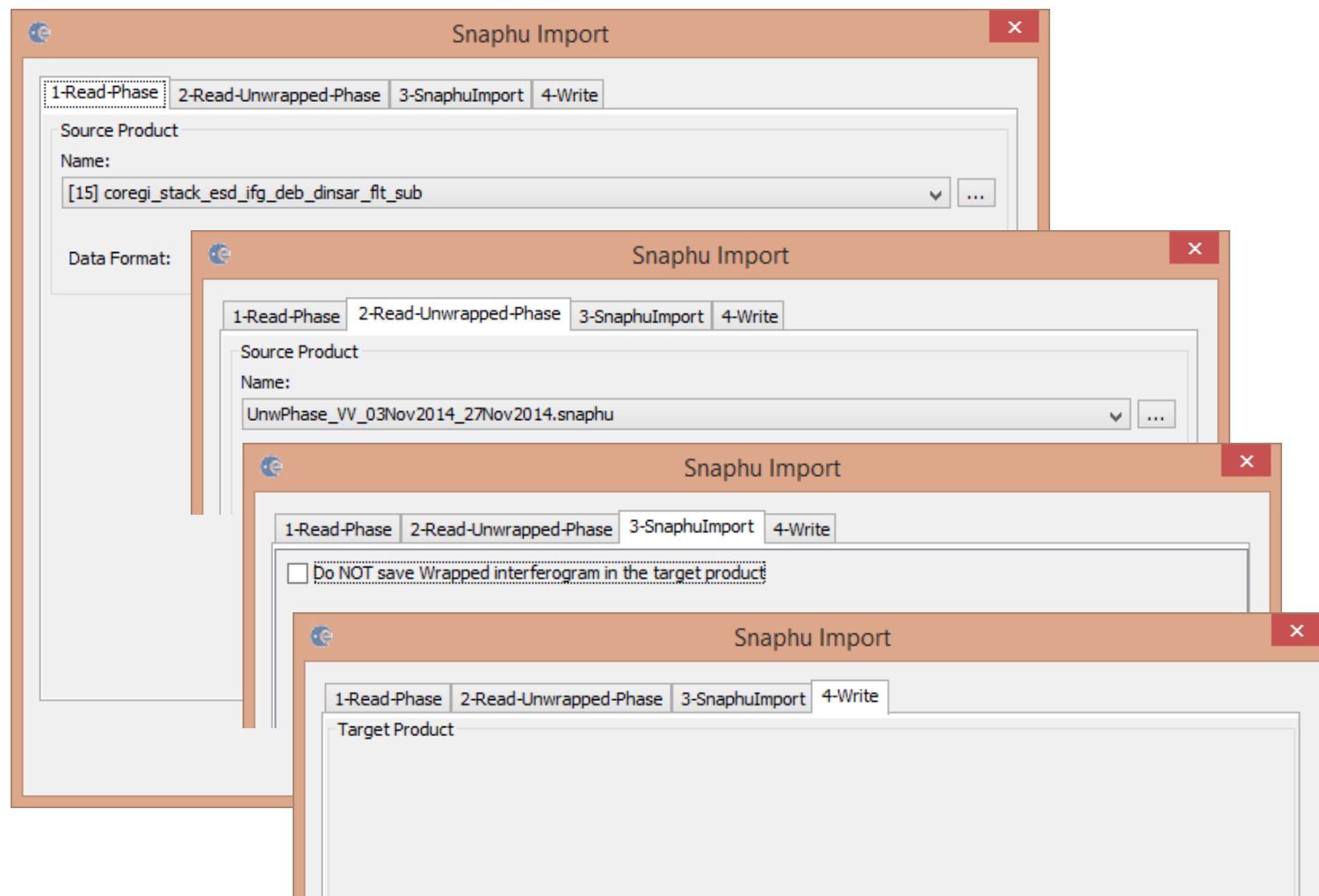
Elapsed Time
00:26:23

Phase Unwrapping Import from SNAPHU format

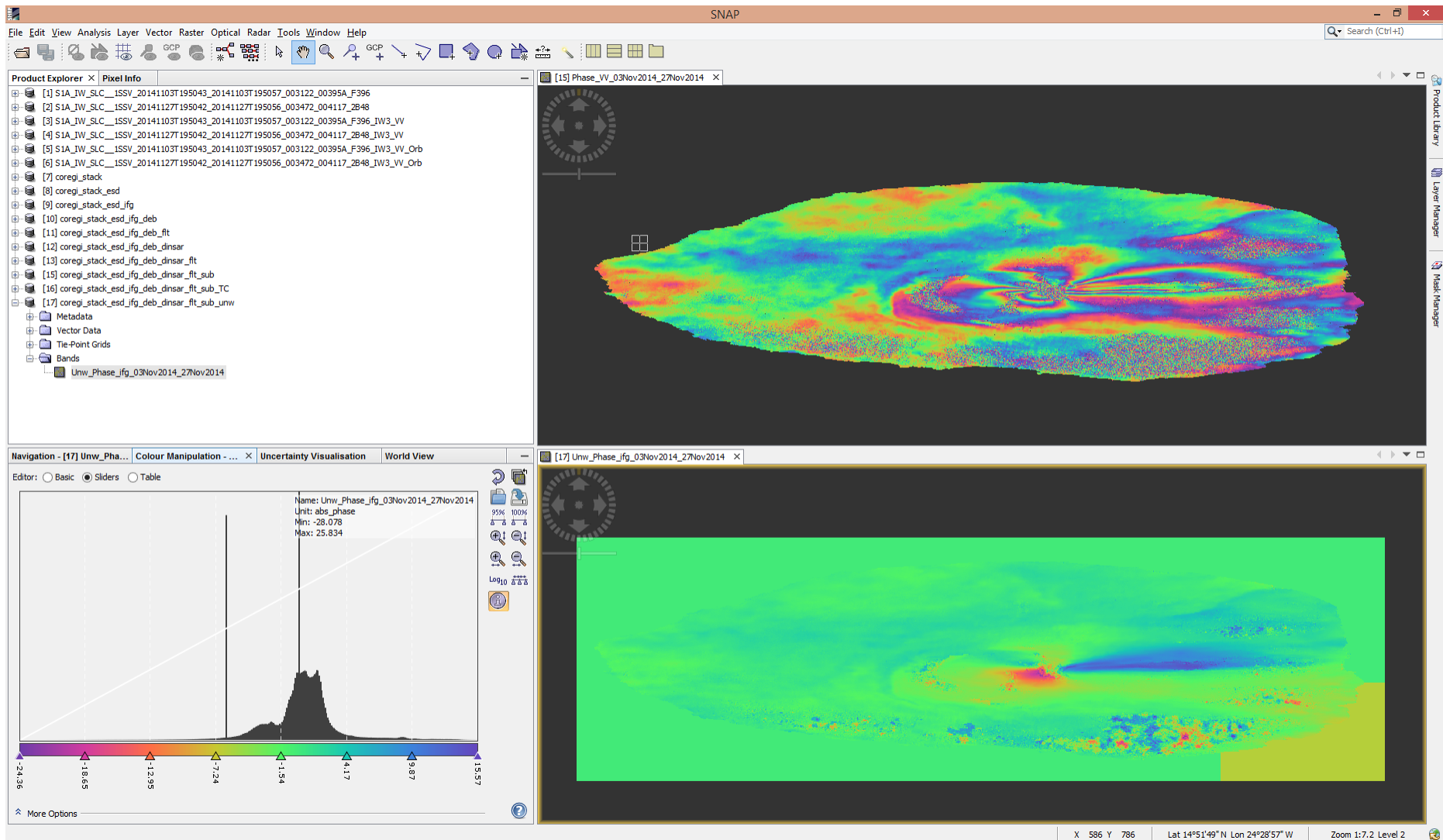


Phase Unwrapping

Import from SNAPHU format



Unwrapped Differential Phase (in radians)



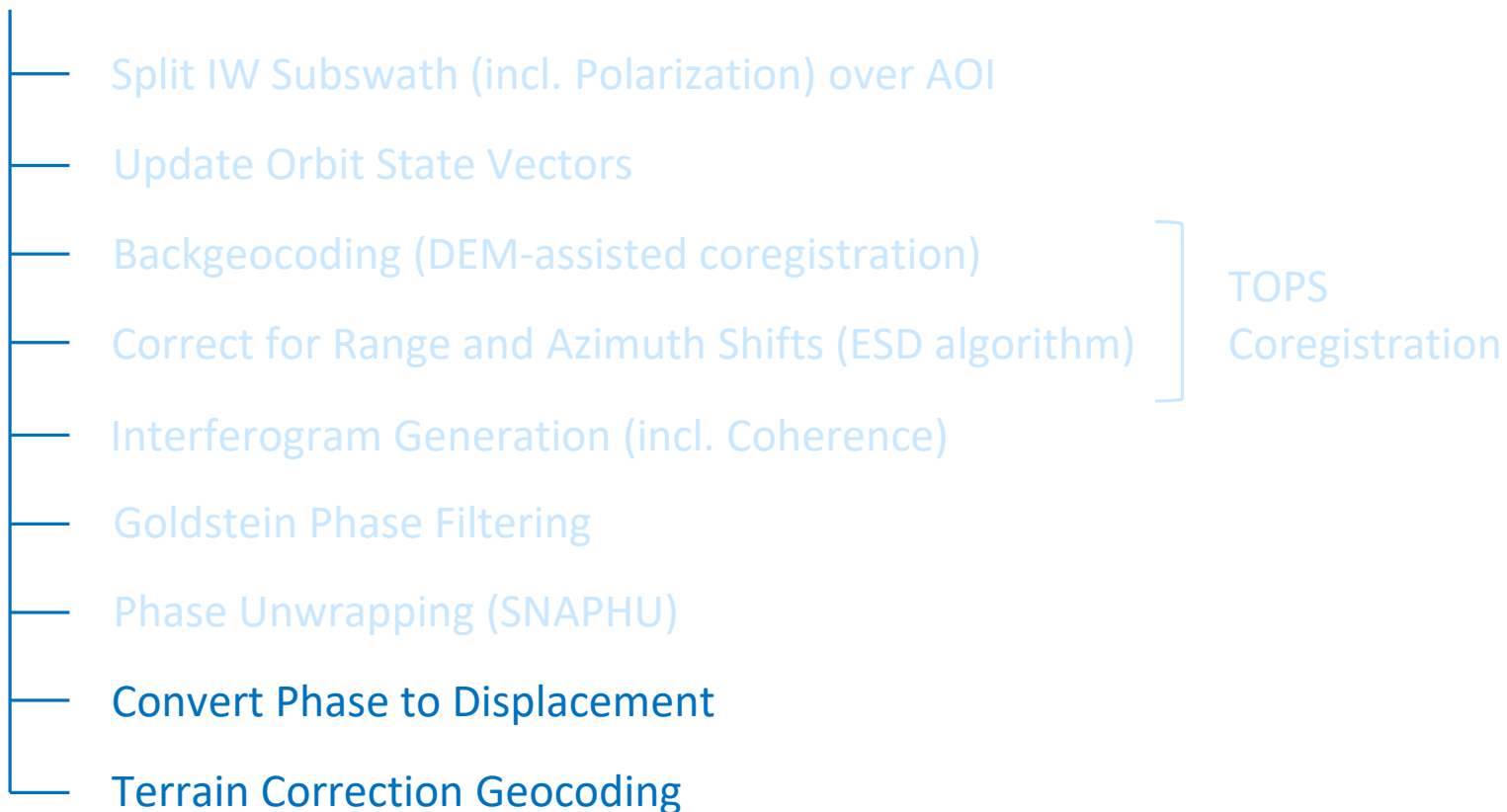
EXERCISE

PART 3

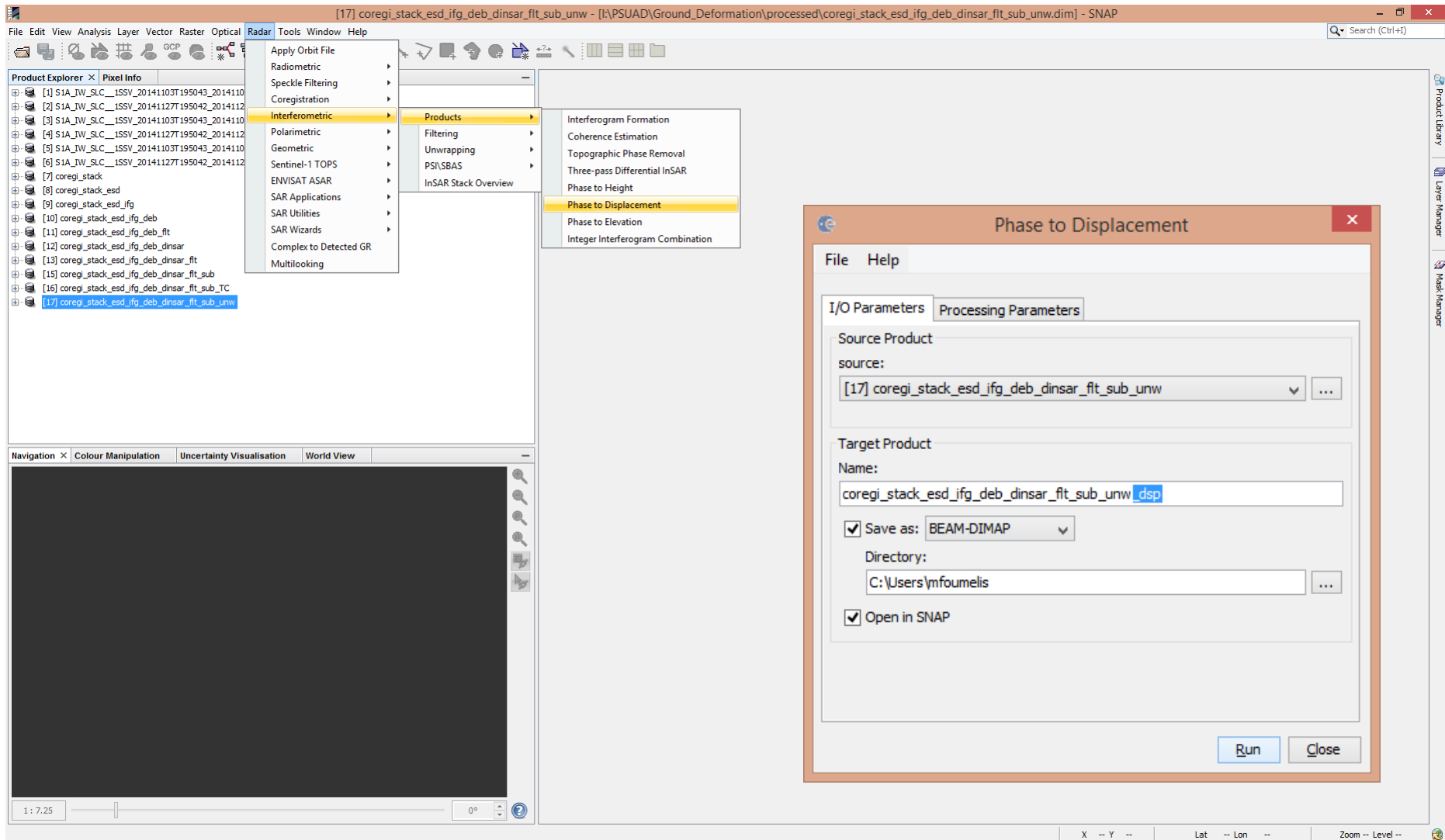
Displacement Measurements & Terrain Geocoding



EXERCISE Processing Steps (PART 3)

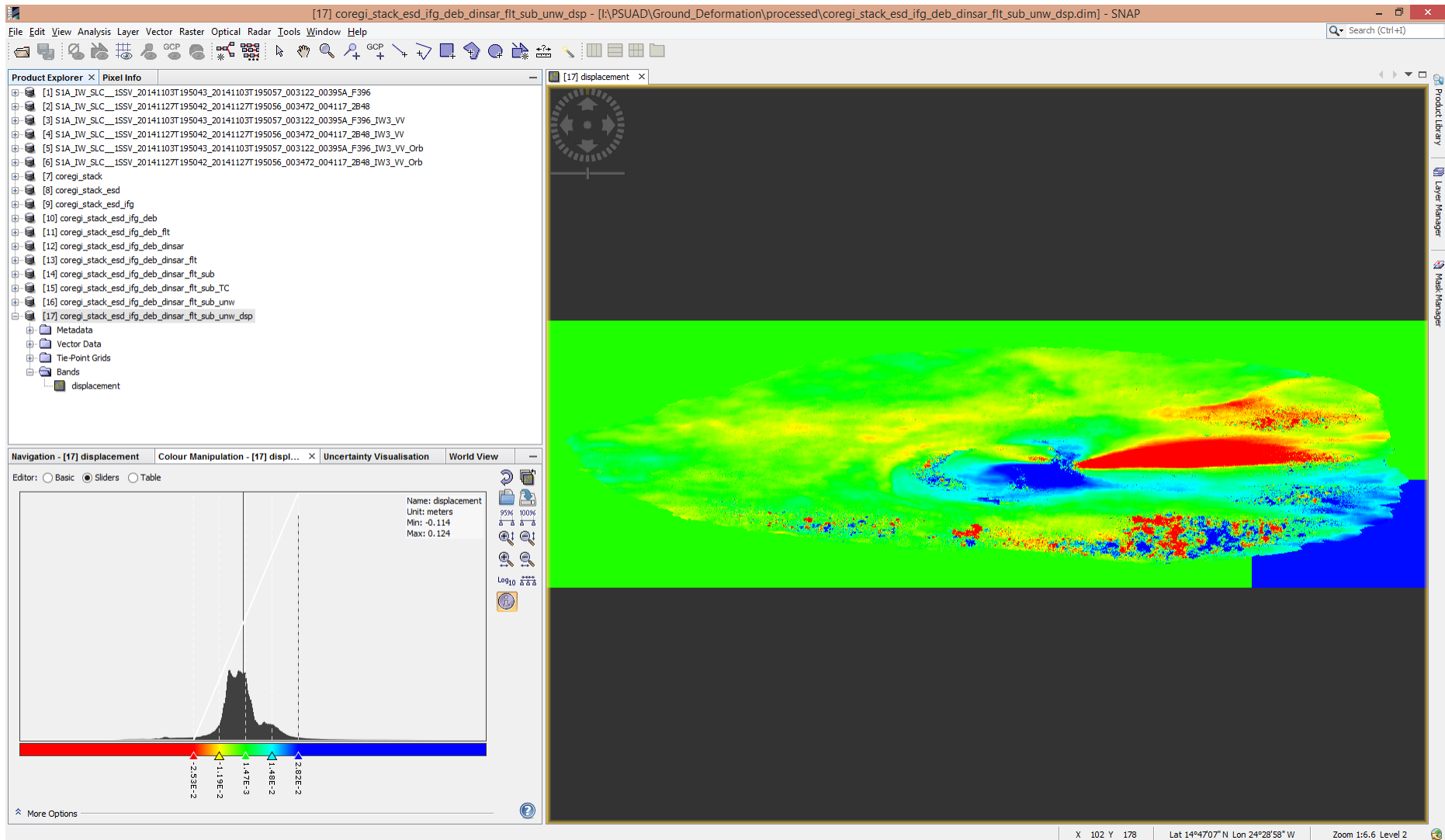


Conversion of Unwrapped Phase to Displacement

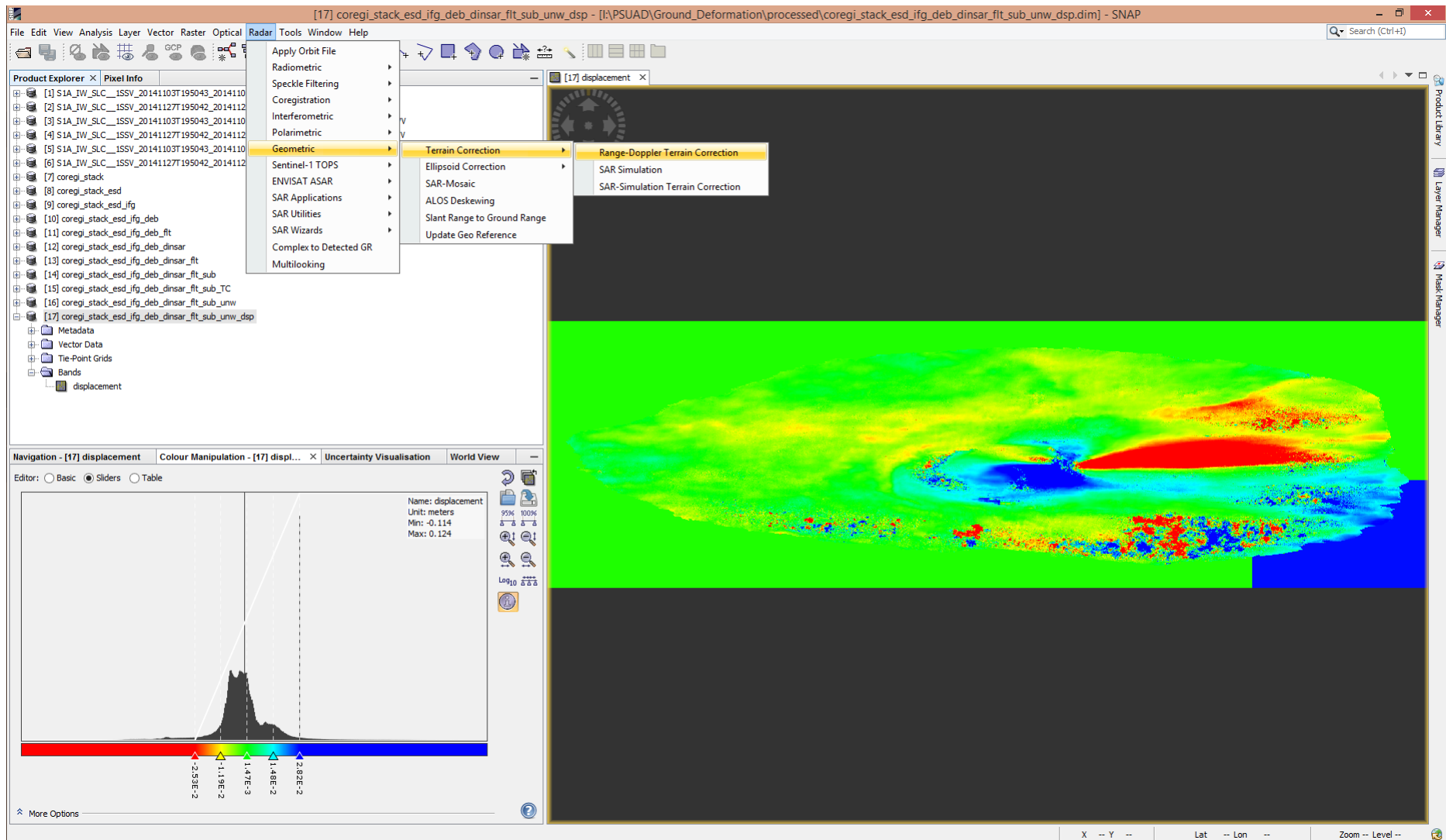


The screenshot displays the SNAP (Scientific Data Processing) software interface. The main window shows a list of products in the 'Product Explorer' on the left, with the selected product being '[17] coregi_stack_esd_ifg_deb_dinsar_fit_sub_unw'. The 'Radar' menu is open, and the 'Interferometric' sub-menu is selected, leading to the 'Phase to Displacement' option. The 'Phase to Displacement' dialog box is open, showing the 'I/O Parameters' tab. The 'Source Product' is set to '[17] coregi_stack_esd_ifg_deb_dinsar_fit_sub_unw'. The 'Target Product' name is 'coregi_stack_esd_ifg_deb_dinsar_fit_sub_unw_dsp'. The 'Save as' option is set to 'BEAM-DIMAP', and the 'Directory' is 'C:\Users\mfoumelis'. The 'Open in SNAP' checkbox is checked. The 'Run' button is highlighted.

Ground Displacement along the Line-of-Sight (LOS)



Geocoding of Sentinel-1 Ground Displacements



Geocoding of Sentinel-1 Ground Displacements

Range Doppler Terrain Correction

File Help

I/O Parameters Processing Parameters

Source Product

source:

[17] coregi_stack_esd_ifg_deb_dinsar_fit_sub_unw_dsp

Target Product

Name:

coregi_stack_esd_ifg_deb_dinsar_fit_sub_unw_dsp_TC

☒ Save as: BEAM-DIMAP

Directory:

C:\Users\mfoumelis

☒ Open in SNAP

Run Close

Range Doppler Terrain Correction

File Help

I/O Parameters Processing Parameters

Source Bands:

displacement

Digital Elevation Model:

SRTM 3Sec (Auto Download)

DEM Resampling Method:

BILINEAR_INTERPOLATION

Image Resampling Method:

BILINEAR_INTERPOLATION

Source GR Pixel Spacings (az x rg):

13.98(m) x 3.39(m)

Pixel Spacing (m):

15

Pixel Spacing (deg):

1.3474729261792824E-4

Map Projection:

UTM Zone 26 / World Geodetic System 1984

☒ Mask out areas without elevation ☐ Output complex data

Output bands for:

☒ Selected source band ☐ DEM ☐ Latitude & Longitude

☐ Incidence angle from ellipsoid ☐ Local incidence angle ☐ Projected local incidence angle

☐ Apply radiometric normalization

☐ Save Sigma0 band Use projected local incidence angle from DEM

☐ Save Gamma0 band Use projected local incidence angle from DEM

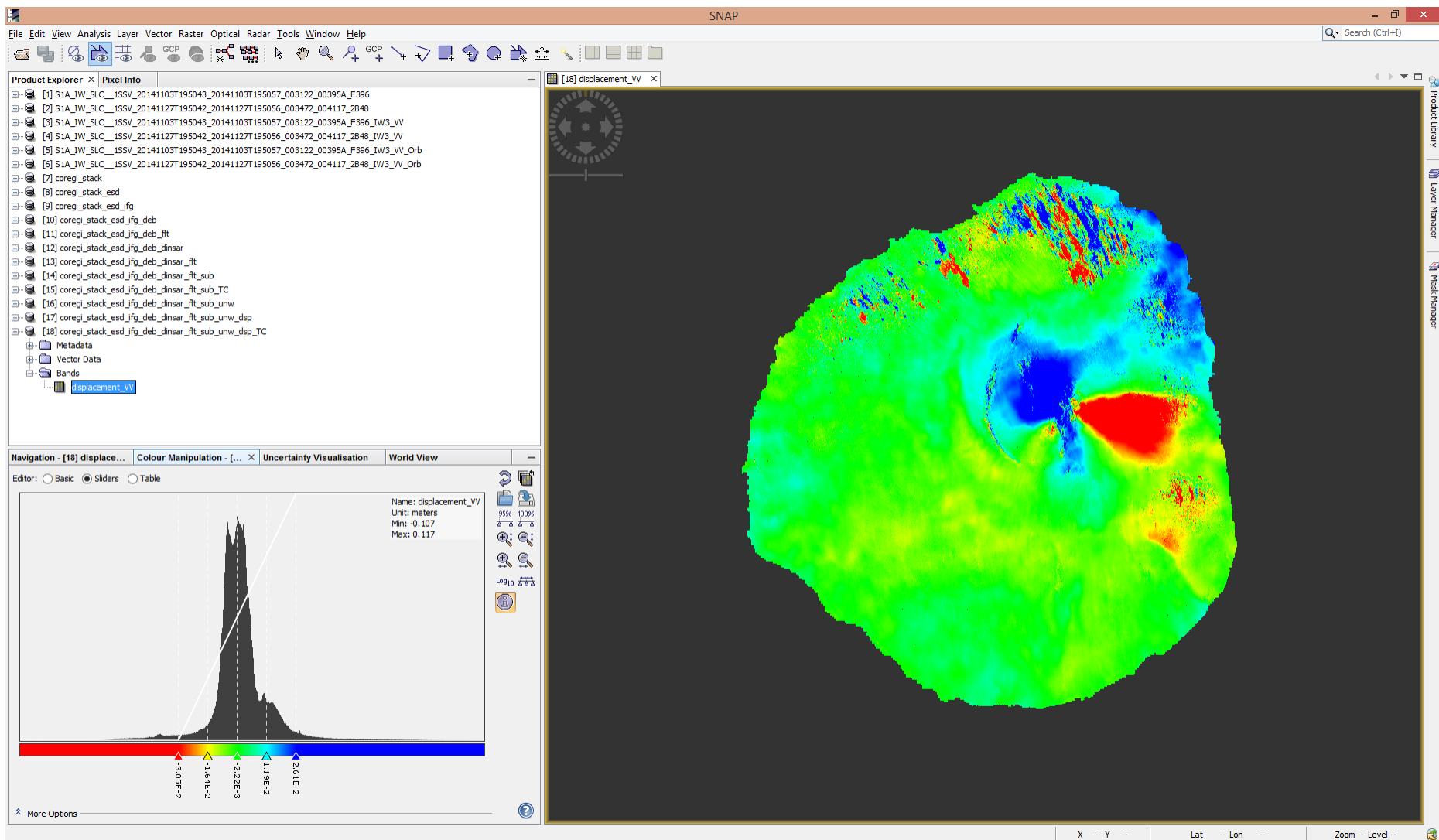
☐ Save Beta0 band

Auxiliary File (ASAR only):

Latest Auxiliary File

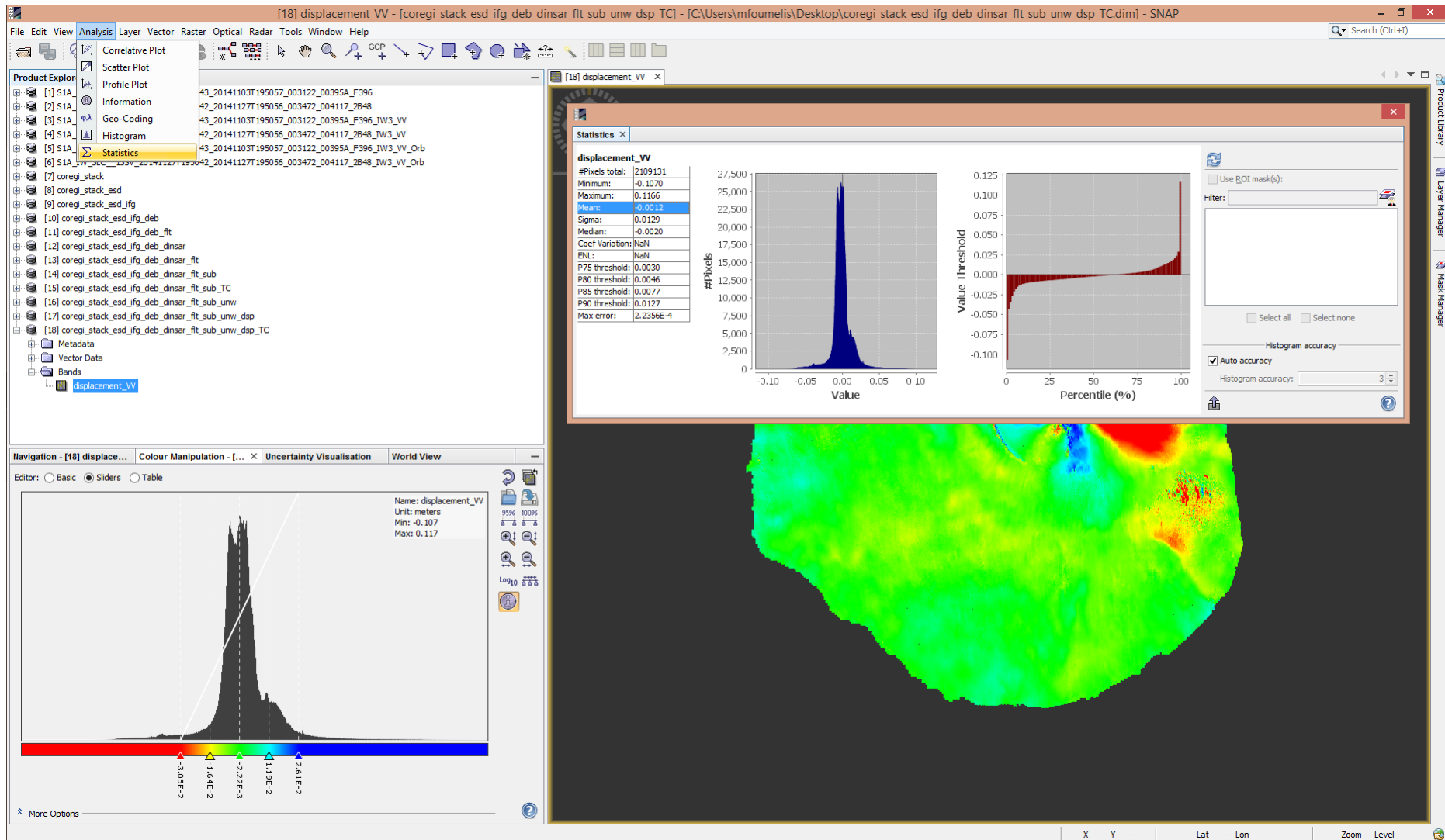
Run Close

Terrain Corrected S1 TOPS Ground Displacements

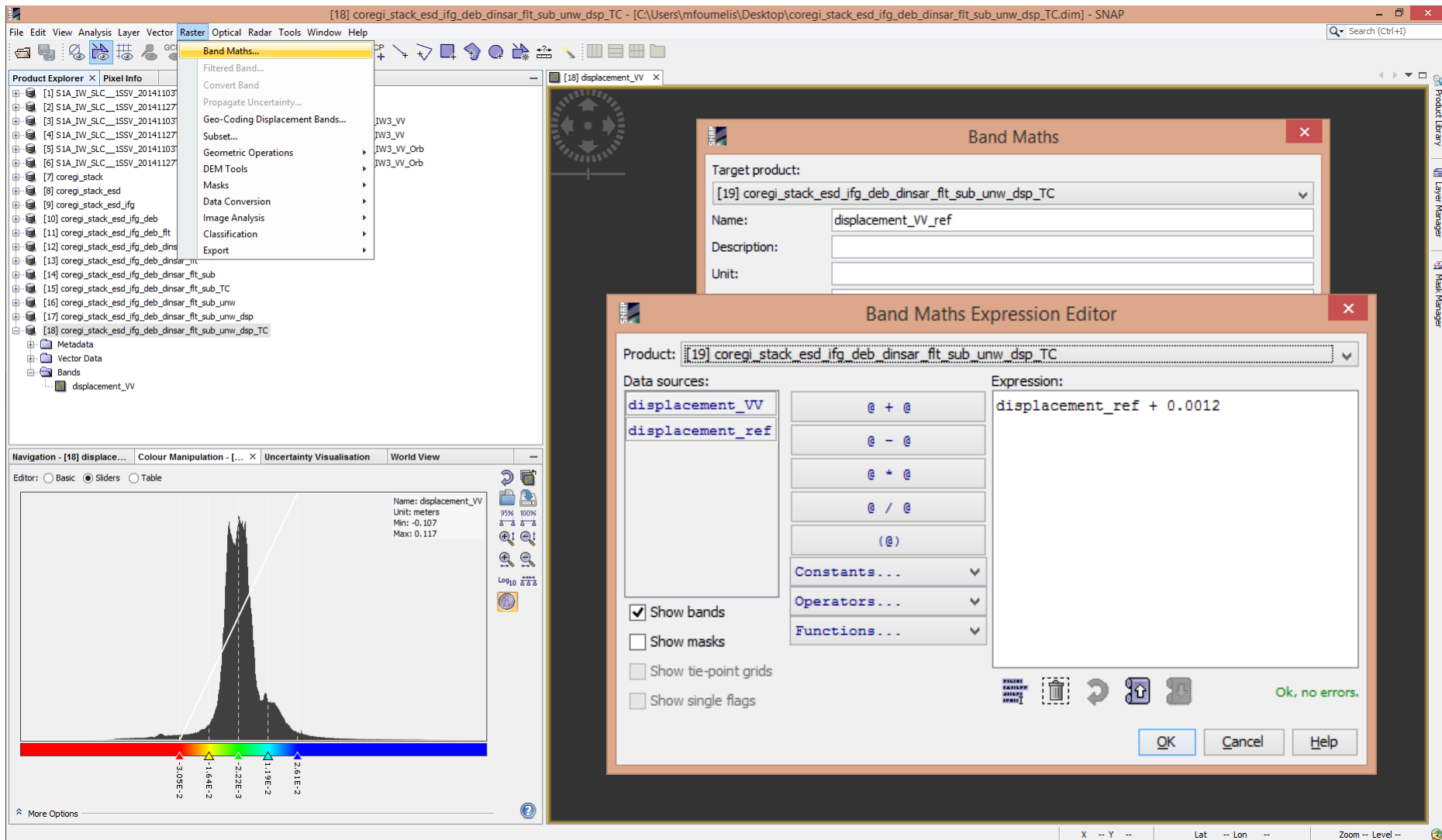


Post-processing

Selection of Local Reference

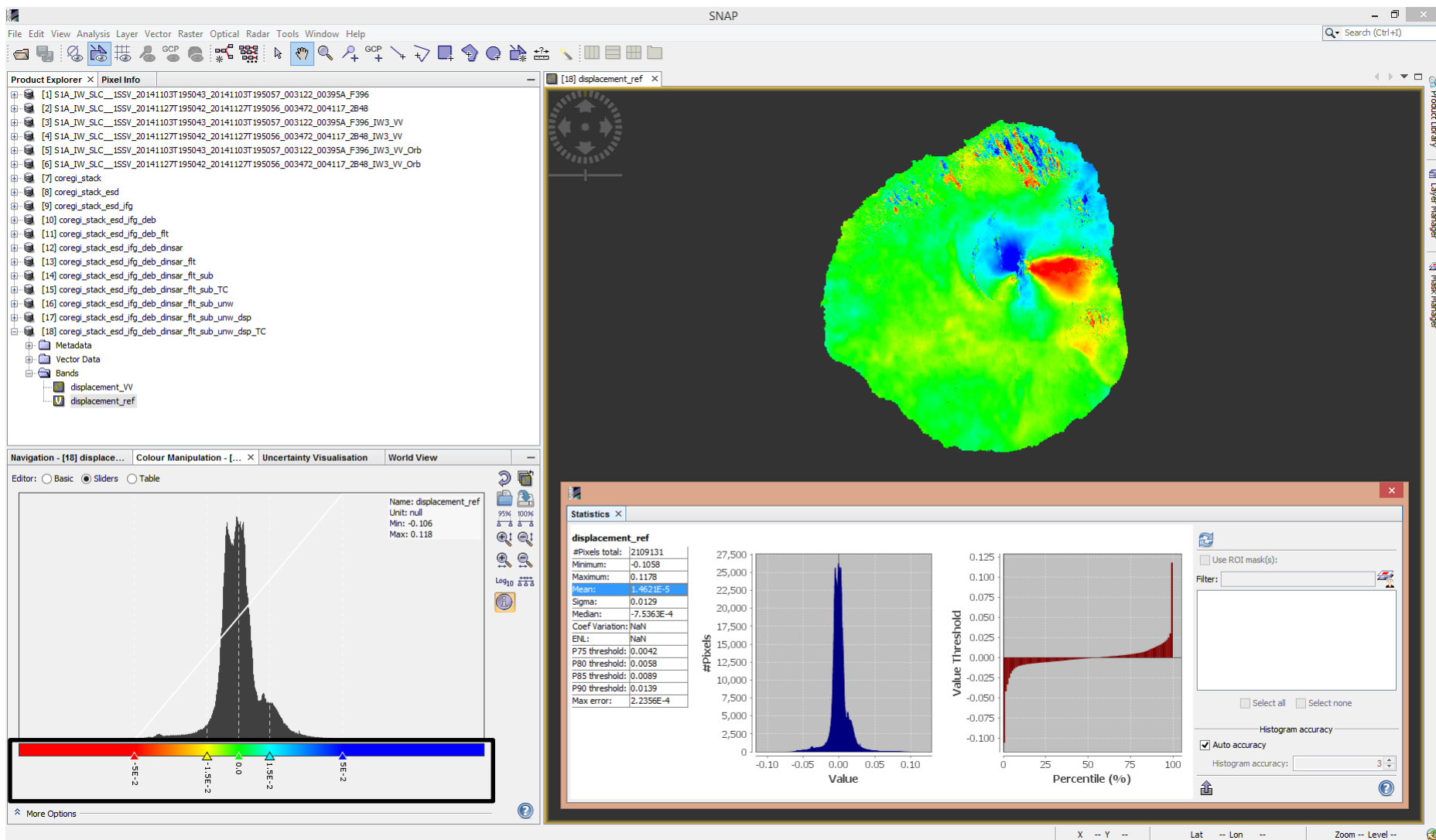


Post-processing Referencing Displacements

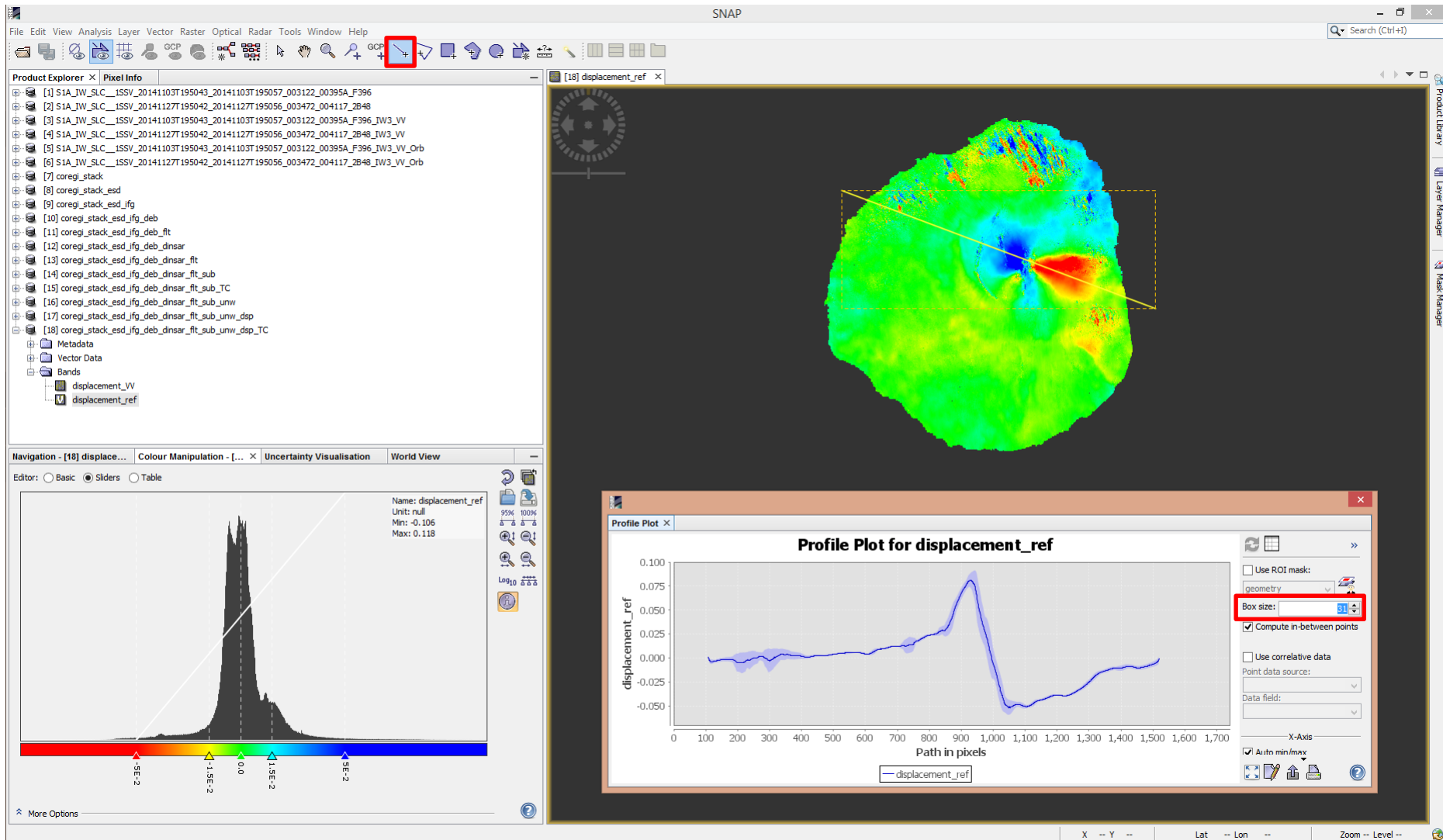


The screenshot displays the SNAP (Scientific Data Processing) software interface. The main window shows a list of products in the Product Explorer on the left, including various displacement and stack products. The central area displays a histogram for the product 'displacement_VV' with a color bar below it. The 'Band Maths' dialog is open, showing the 'Target product' as '[19] coregi_stack_esd_ifg_deb_dinsar_fit_sub_unw_dsp_TC'. The 'Name' field is set to 'displacement_VV_ref'. The 'Band Maths Expression Editor' dialog is also open, showing the 'Product' as '[19] coregi_stack_esd_ifg_deb_dinsar_fit_sub_unw_dsp_TC'. The 'Data sources' list includes 'displacement_VV' and 'displacement_ref'. The 'Expression' field contains the formula: $\text{displacement_ref} + 0.0012$. The 'Show bands' checkbox is checked, and the 'Show masks' checkbox is unchecked. The 'Show tie-point grids' and 'Show single flags' checkboxes are also unchecked. The 'OK' button is highlighted.

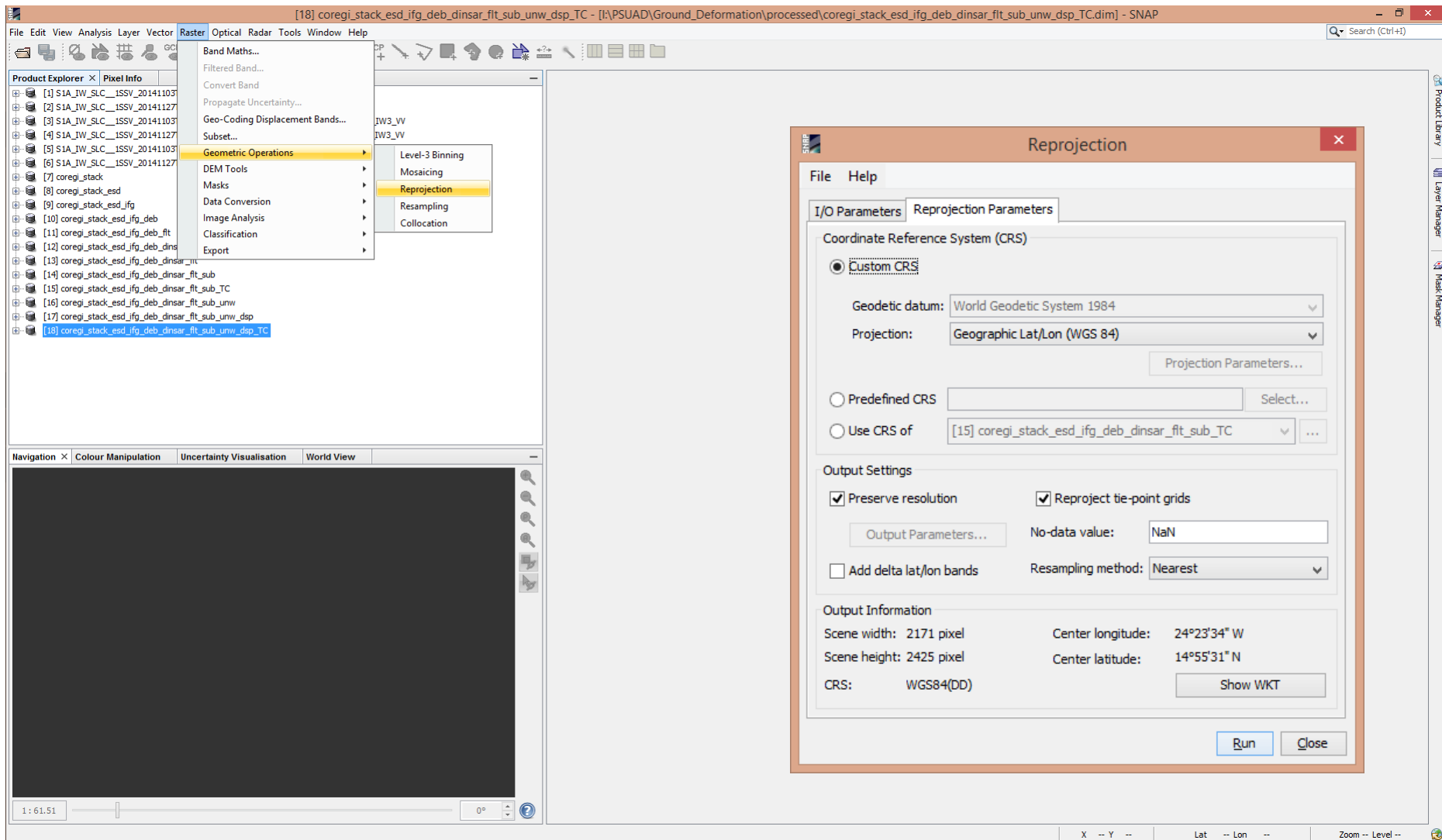
Post-processing Arranging Colour Ramps



Post-processing Spatial Profile Plots

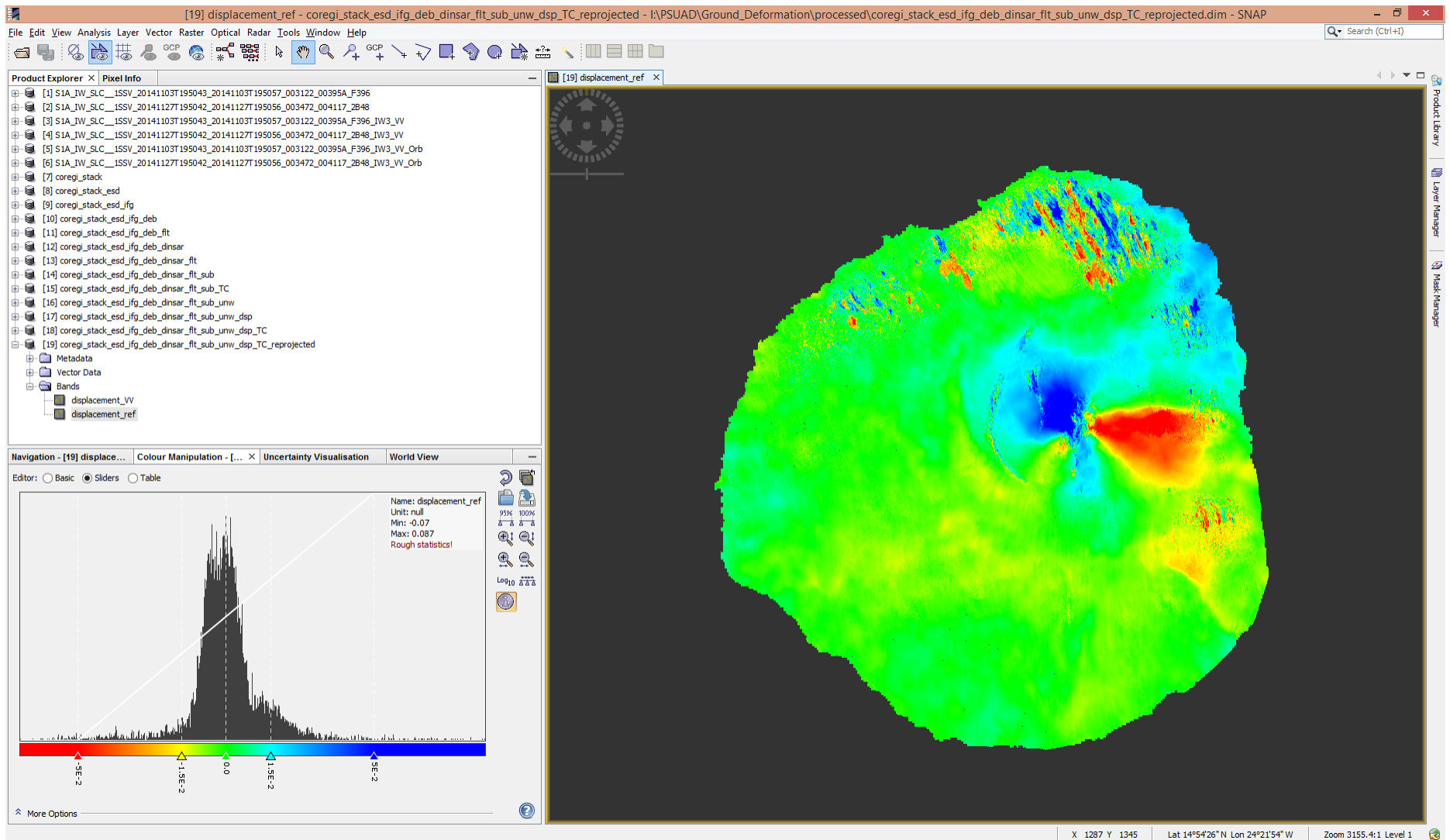


Data Reprojection Geographic Lat/Lon (WGS'84)

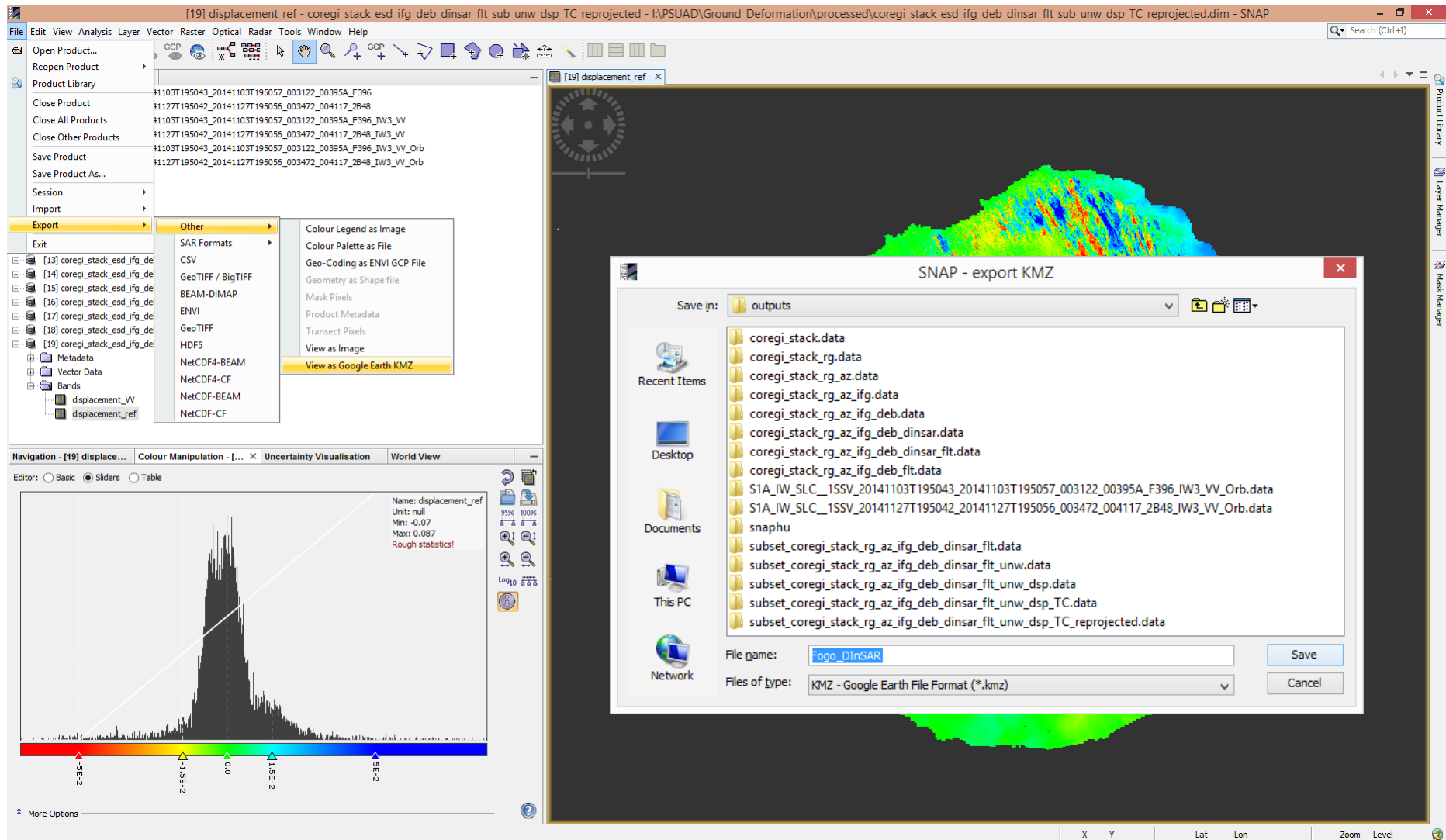


The screenshot displays the SNAP (Scientific Data Processing) software interface. The main window shows a list of data products in the Product Explorer on the left, with the file `[18] coregi_stack_esd_ifg_deb_dinsar_fit_sub_unw_dsp_TC` selected. The Raster menu is open, and the 'Reprojection' option is highlighted. A 'Reprojection' dialog box is open in the foreground, showing the 'Reprojection Parameters' tab. The 'Coordinate Reference System (CRS)' section is set to 'Custom CRS' with 'Geodetic datum' as 'World Geodetic System 1984' and 'Projection' as 'Geographic Lat/Lon (WGS 84)'. The 'Output Settings' section has 'Preserve resolution' and 'Reproject tie-point grids' checked, and 'Resampling method' set to 'Nearest'. The 'Output Information' section shows scene width of 2171 pixel, scene height of 2425 pixel, and CRS as WGS84(DD). The 'Run' button is visible at the bottom right of the dialog box.

Inspection of Reprojected Products

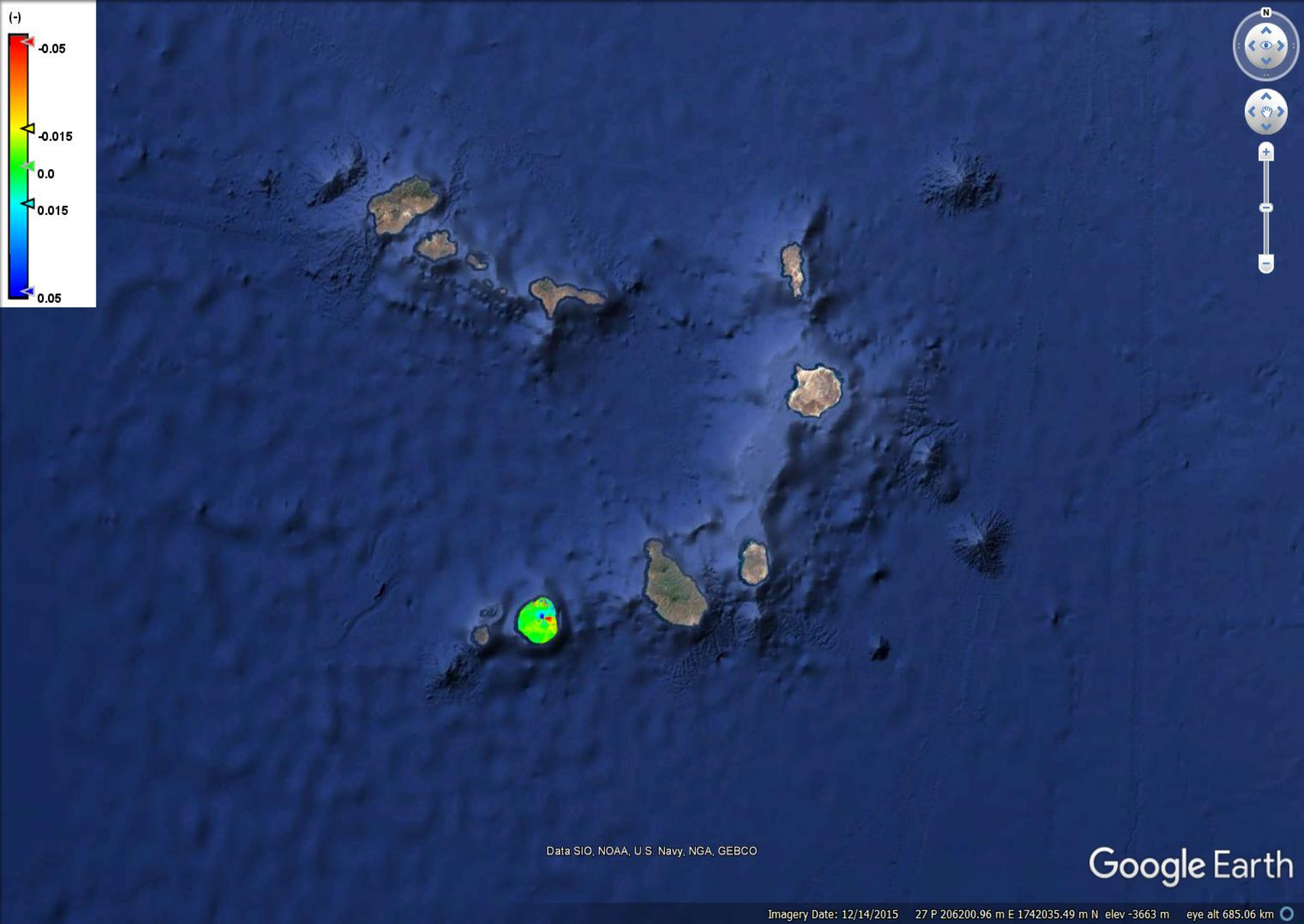
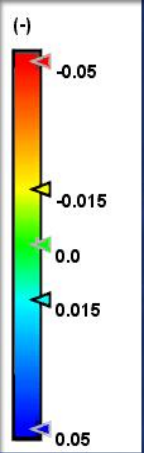


Export to Google Earth (*.kmz file)



The screenshot displays the SNAP (Scientific Data Processing) software interface. The main window shows a 3D visualization of a displacement field. A 'File' menu is open, with the 'Export' option selected, leading to a submenu where 'View as Google Earth KMZ' is highlighted. A 'SNAP - export KMZ' dialog box is open, showing a list of files to be exported, including 'coregi_stack.data', 'coregi_stack_rg.data', 'coregi_stack_rg_az.data', 'coregi_stack_rg_az_ifg.data', 'coregi_stack_rg_az_ifg_deb.data', 'coregi_stack_rg_az_ifg_deb_dinsar.data', 'coregi_stack_rg_az_ifg_deb_dinsar_fit.data', 'coregi_stack_rg_az_ifg_deb_dinsar_fit_unw.data', 'subset_coregi_stack_rg_az_ifg_deb_dinsar_fit.data', 'subset_coregi_stack_rg_az_ifg_deb_dinsar_fit_unw.data', 'subset_coregi_stack_rg_az_ifg_deb_dinsar_fit_unw_dsp.data', 'subset_coregi_stack_rg_az_ifg_deb_dinsar_fit_unw_dsp_TC.data', and 'subset_coregi_stack_rg_az_ifg_deb_dinsar_fit_unw_dsp_TC_reprojected.data'. The 'File name' field is set to 'Fogo_DInSAR' and the 'Files of type' is set to 'KMZ - Google Earth File Format (*.kmz)'. The 'Save in' location is 'outputs'.

The bottom left panel shows a histogram of the displacement data, with a color bar indicating the range from -5E-2 to 5E-2. The histogram is titled 'displacement_ref' and shows a distribution of values. The color bar is labeled with values: -5E-2, -1.5E-2, 0.0, 1.5E-2, 5E-2.



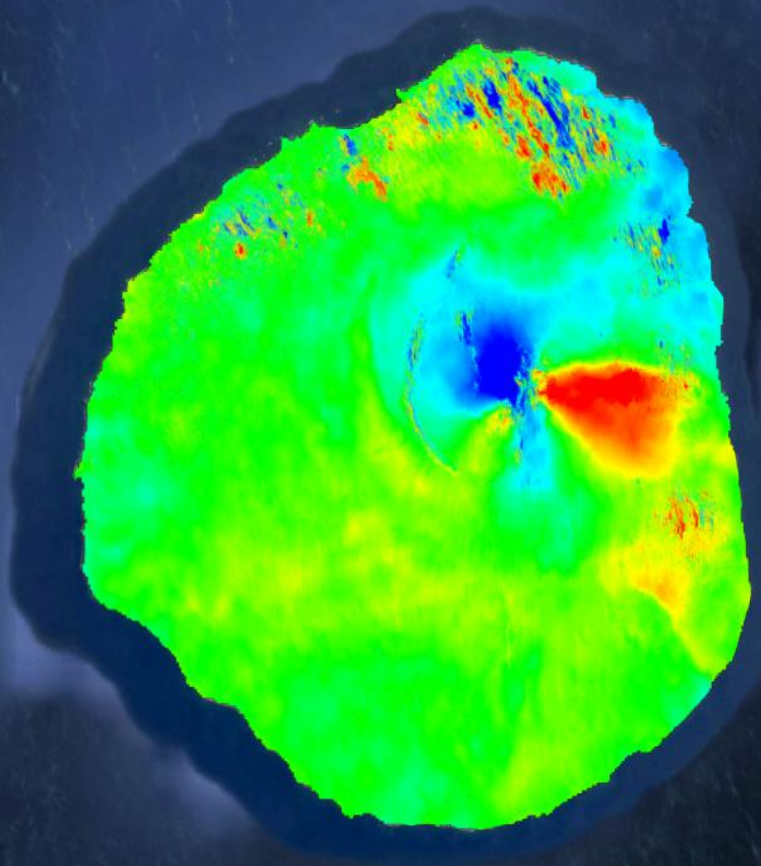
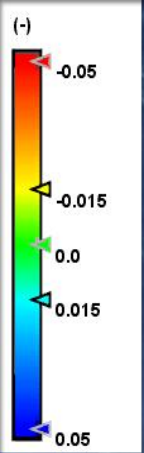
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google Earth

Imagery Date: 12/14/2015 27 P 206200.96 m E 1742035.49 m N elev -3663 m eye alt 685.06 km



European Space Agency



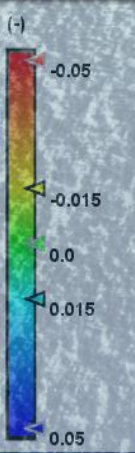
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2016 CNES / Astrium

Google Earth

Imagery Date: 2/3/2016 26 P 782116.51 m E 1652157.21 m N elev 1777 m eye alt 59.93 km



European Space Agency



Data SIO, NOAA, U.S. Navy, NGA, GEBCO

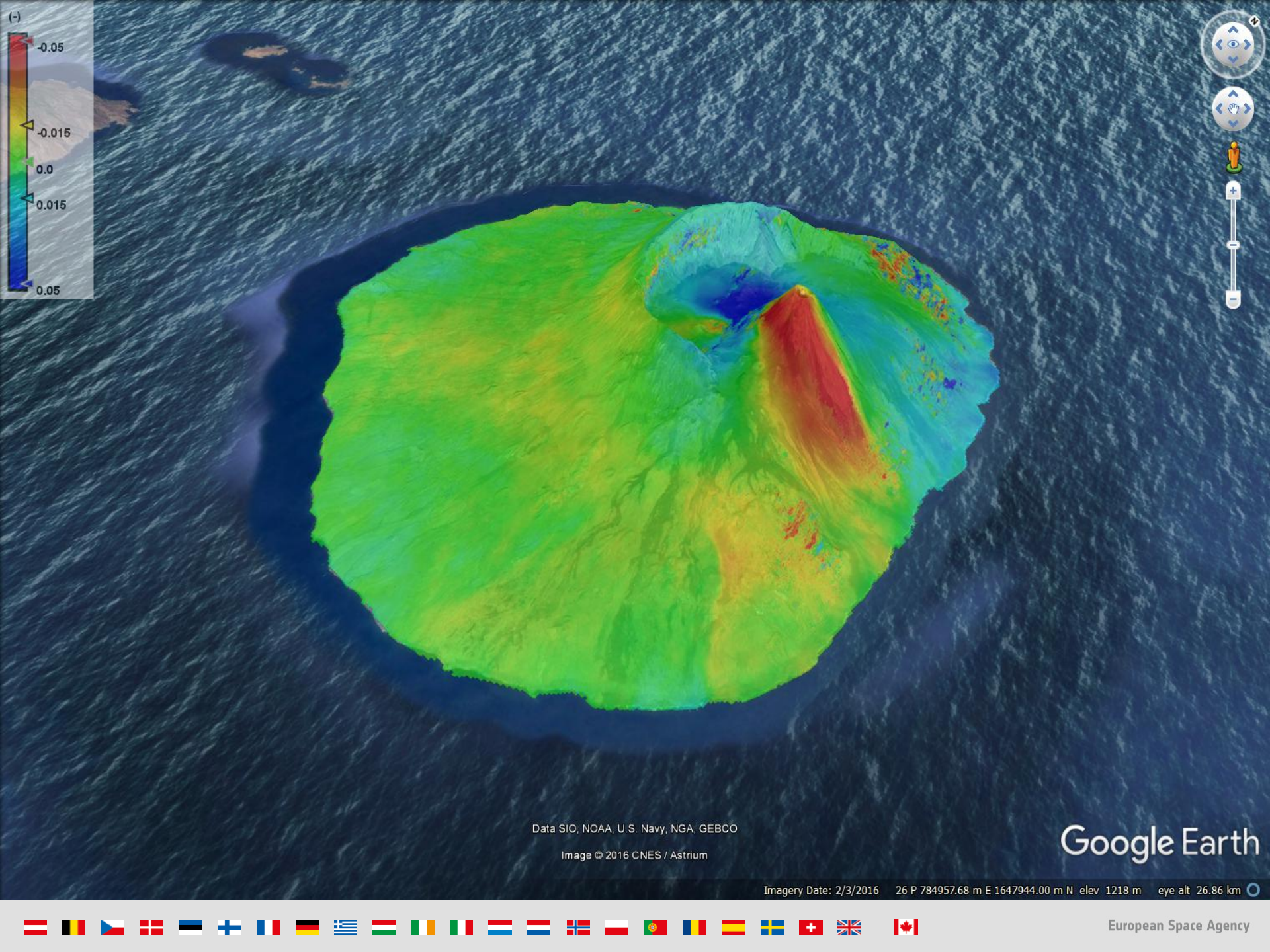
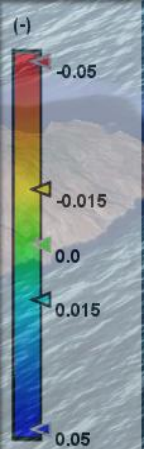
Image © 2016 CNES / Astrium

Google Earth

Imagery Date: 2/3/2016 26 P 781402.90 m E 1648118.86 m N elev 1270 m eye alt 41.53 km



European Space Agency



Data SIO, NOAA, U.S. Navy, NGA, GEBCO

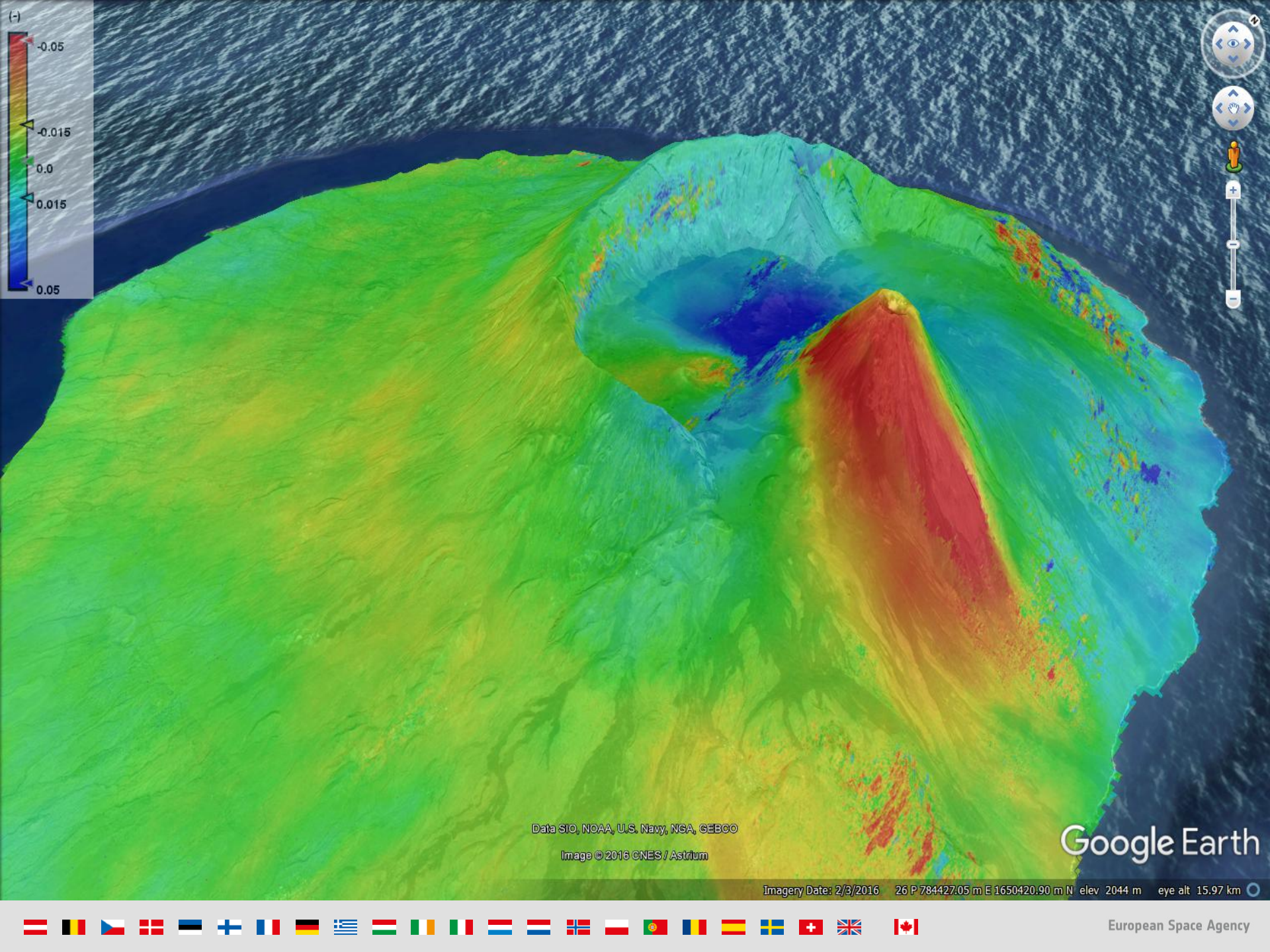
Image © 2016 CNES / Astrium

Google Earth

Imagery Date: 2/3/2016 26 P 784957.68 m E 1647944.00 m N elev 1218 m eye alt 26.86 km



European Space Agency



Data SIO, NOAA, U.S. Navy, NGA, GEBCO

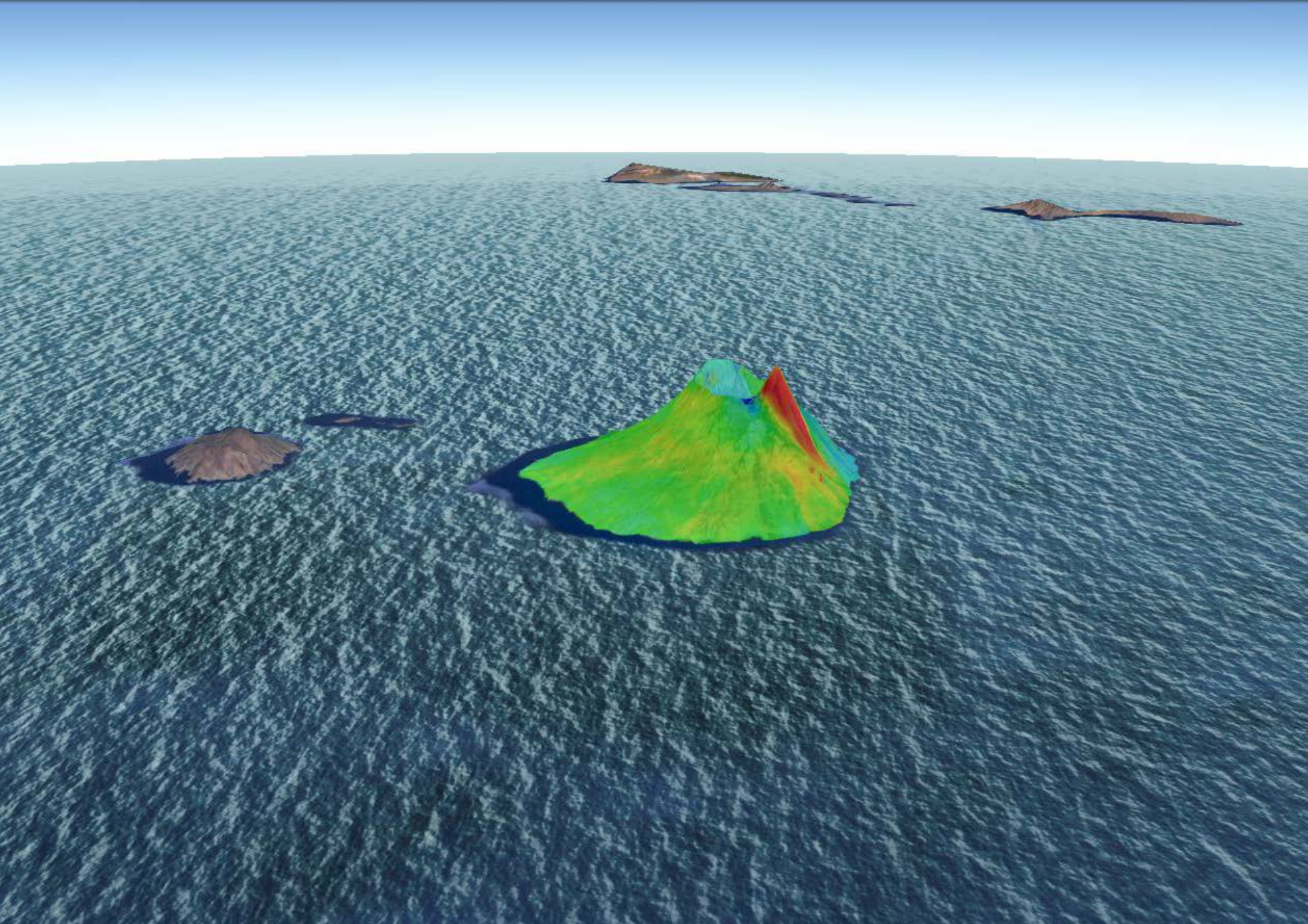
Image © 2016 CNES / Astrium

Google Earth

Imagery Date: 2/3/2016 26 P 784427.05 m E 1650420.90 m N elev 2044 m eye alt 15.97 km



European Space Agency



- SNAP/Sentinel-1 Toolbox supports **SAR interferometry (InSAR)** for multiple SAR missions (incl. acquisitions in TOPS mode).
- TOPS Interferometry requires high SAR image registration accuracy (≤ 0.005 pixel), reachable using dedicated **Enhanced Spectral Diversity (ESD)** approach.
- **Phase unwrapping** is performed using **SNAPHU** external tool (import/export to integrated in SNAP), provided via a pre-configured Virtual Machine (VM).
- End-to-end processing chains can be built using the **Graph Builder**. (*.xml file) and automated using scripts (batch, python etc.).

Would you like to know more?
Visit step.esa.int