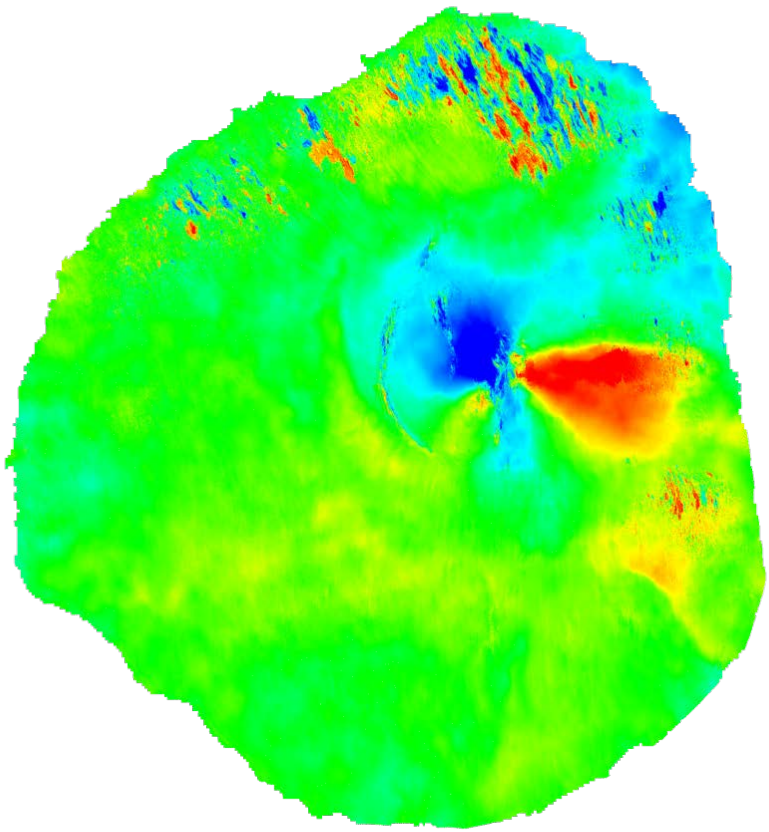
Practical Exercise

Measuring Ground Deformation

November 2016

Goals of the Exercise

- 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]

Input Dataset

- 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

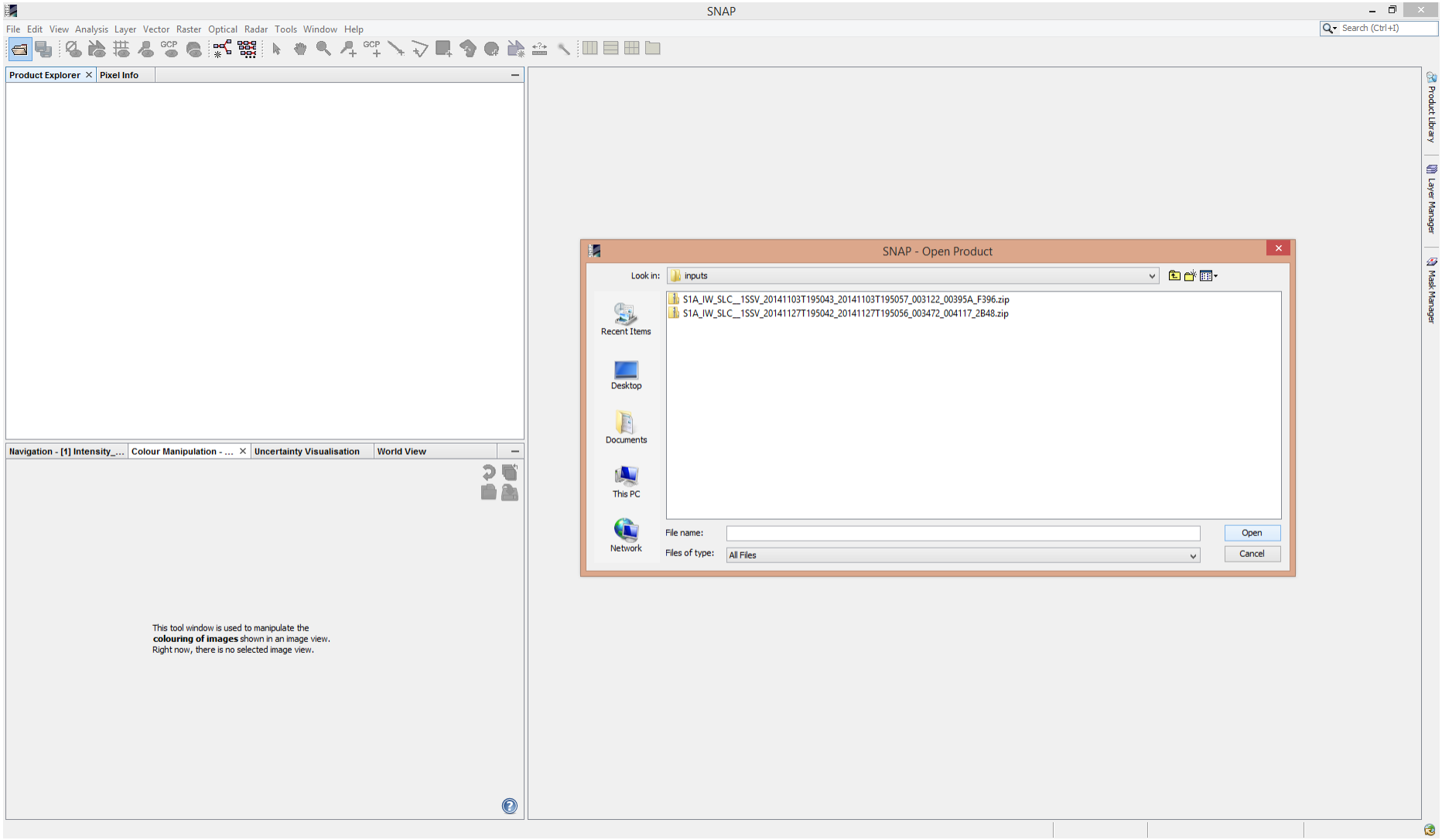
PART 1
Sentinel-1 TOPS InSAR Processing

EXERCISE Processing Steps (PART 1)

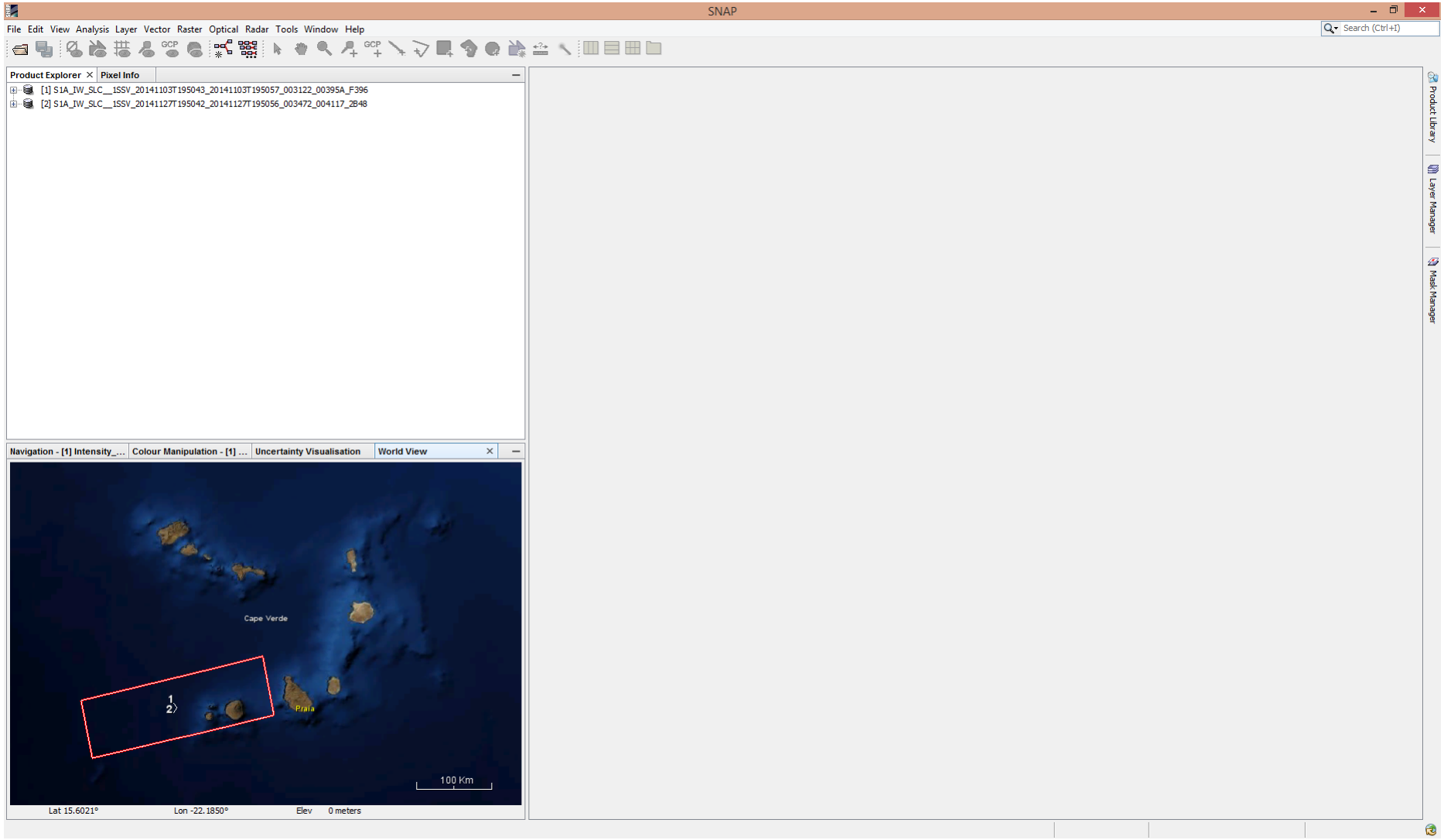
- Split IW Subswath (incl. Polarization) over AOI
- Update Orbit State Vectors
- Backgeocoding (DEM-assisted coregistration)
- Correct for Range and Azimuth Shifts (ESD algorithm)

  TOPS Coregistration
- Interferogram Generation (incl. Coherence)
- Goldstein Phase Filtering
- Phase Unwrapping (SNAPHU)
- Convert Phase to Displacement
- Terrain Correction Geocoding

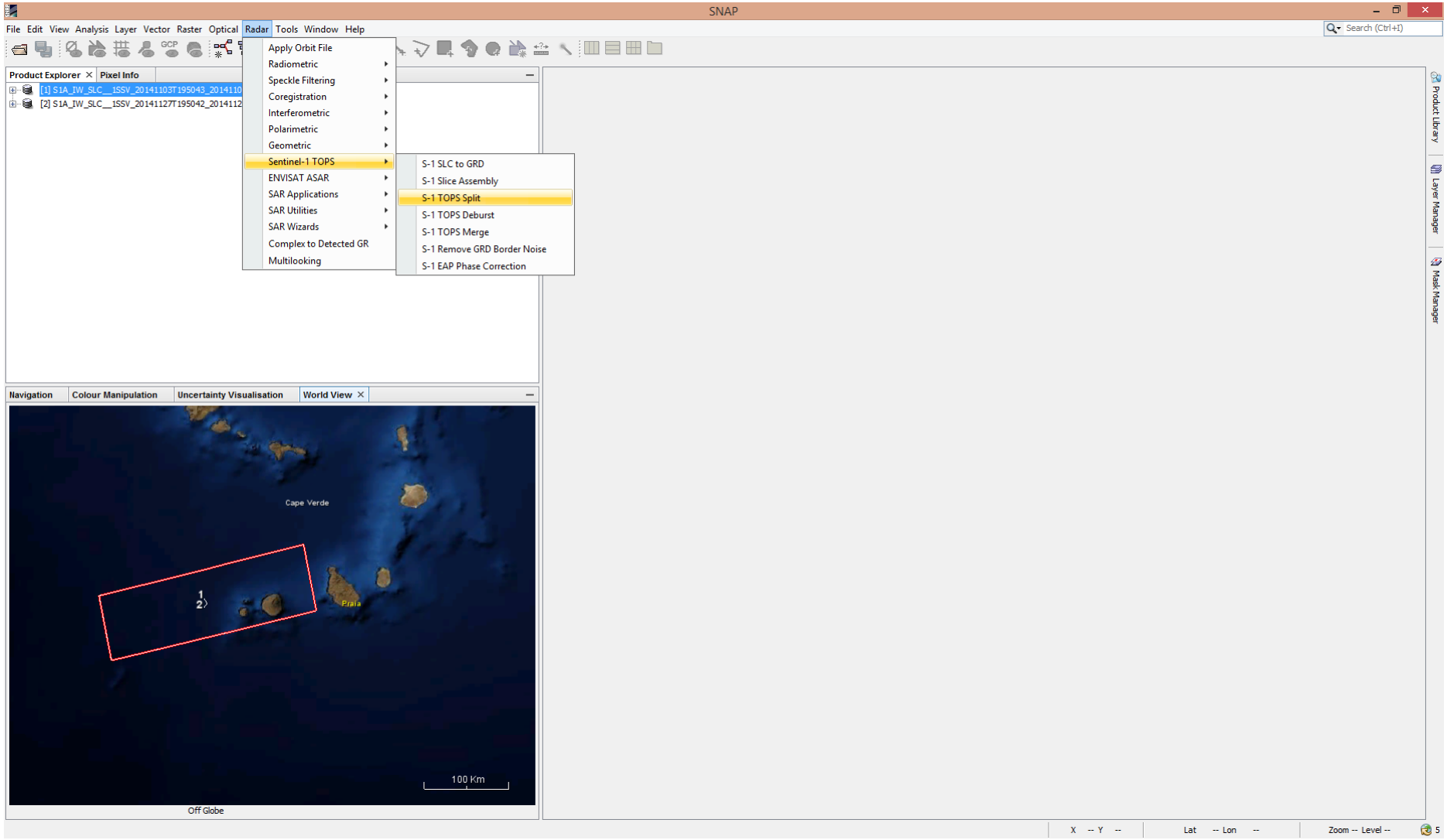
Read Sentinel-1 SLC Products (directly *.zip files)



Sentinel-1 IW TOPS (Swath of 250km)

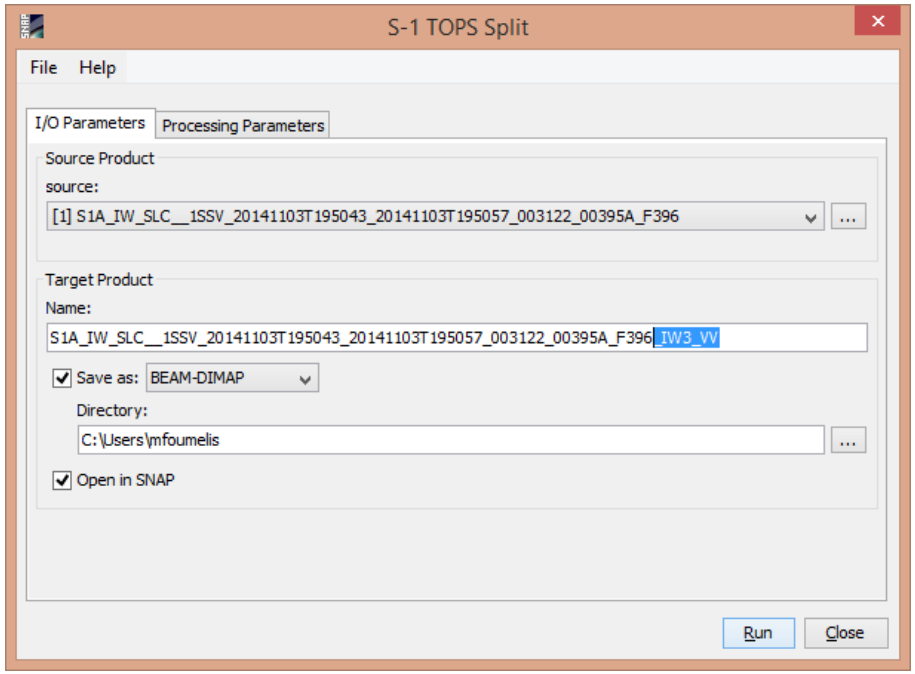


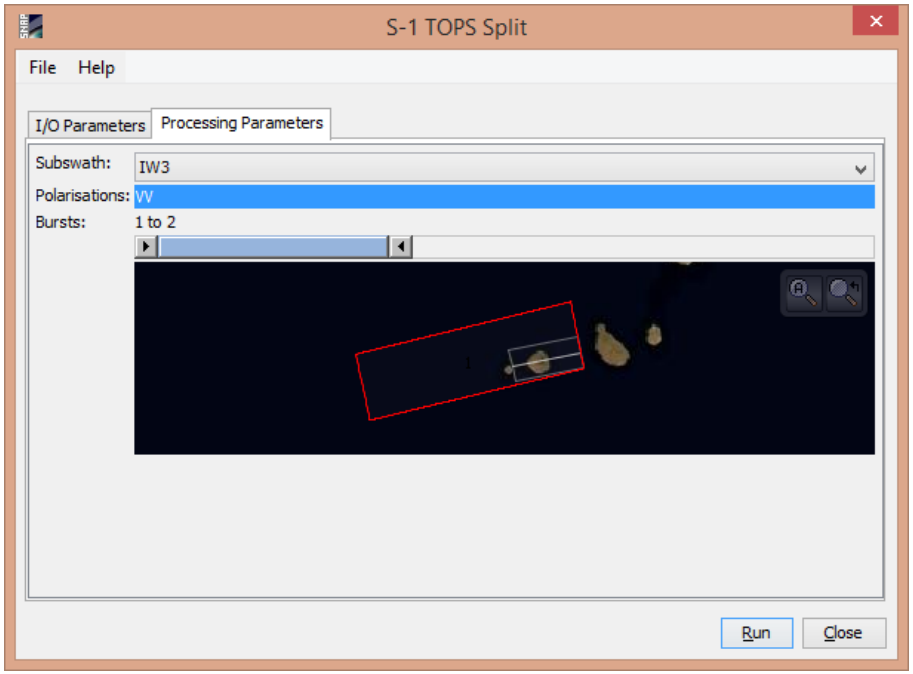
Splitting S1 SLC Products (@Subswath and Burst level)



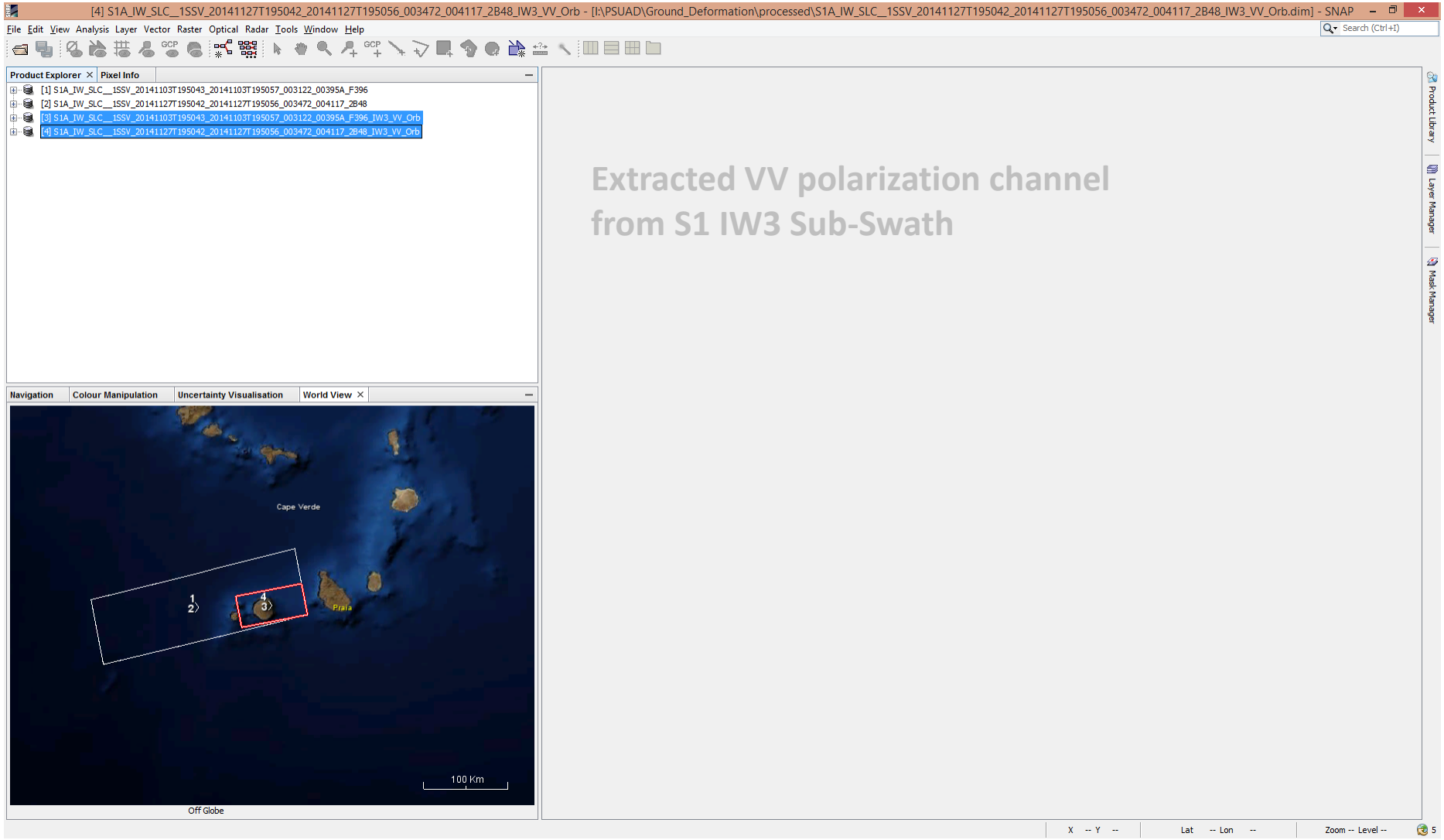
Splitting S1 SLC Products (@ Subswath and Burst level)

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

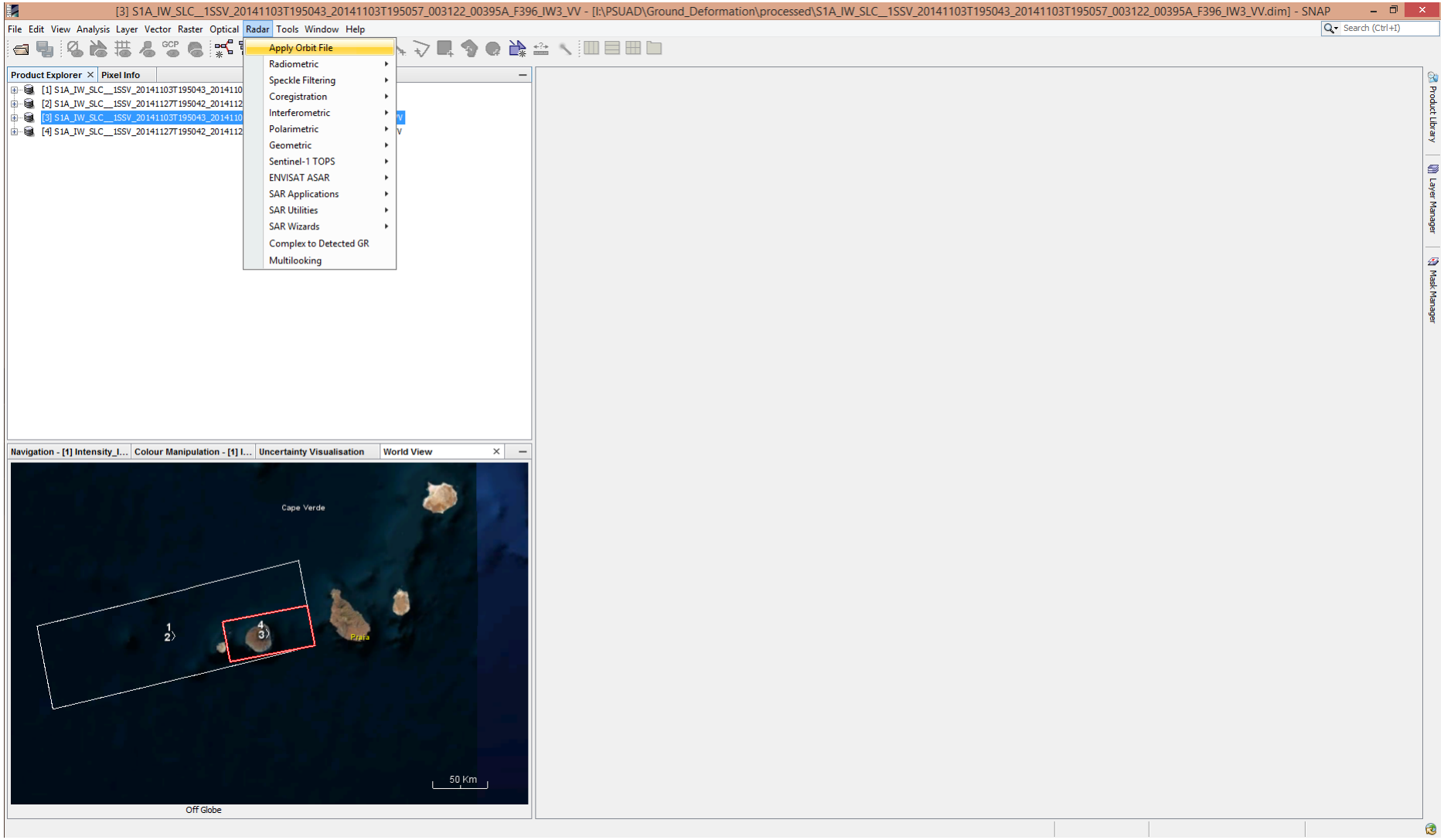




Splitting S1 SLC Products (@ Subswath and Burst level)

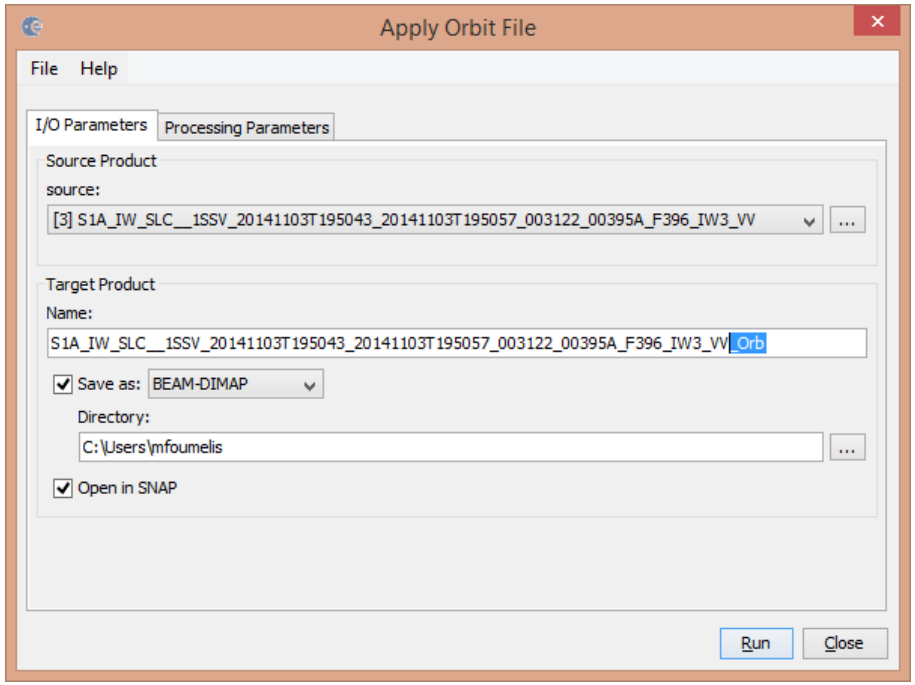


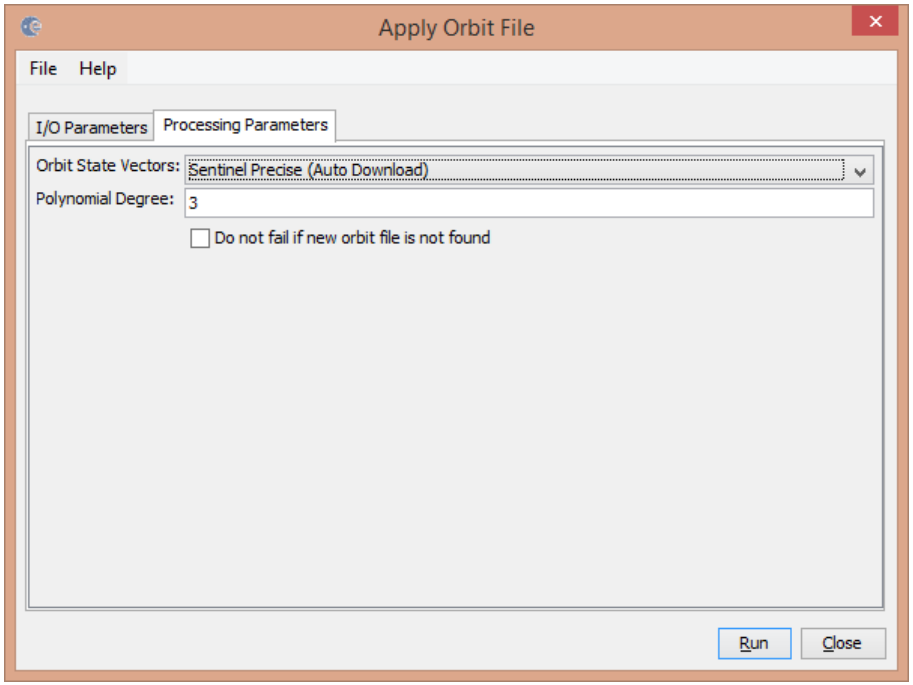
Update Orbital Information (Orbit State Vectors)



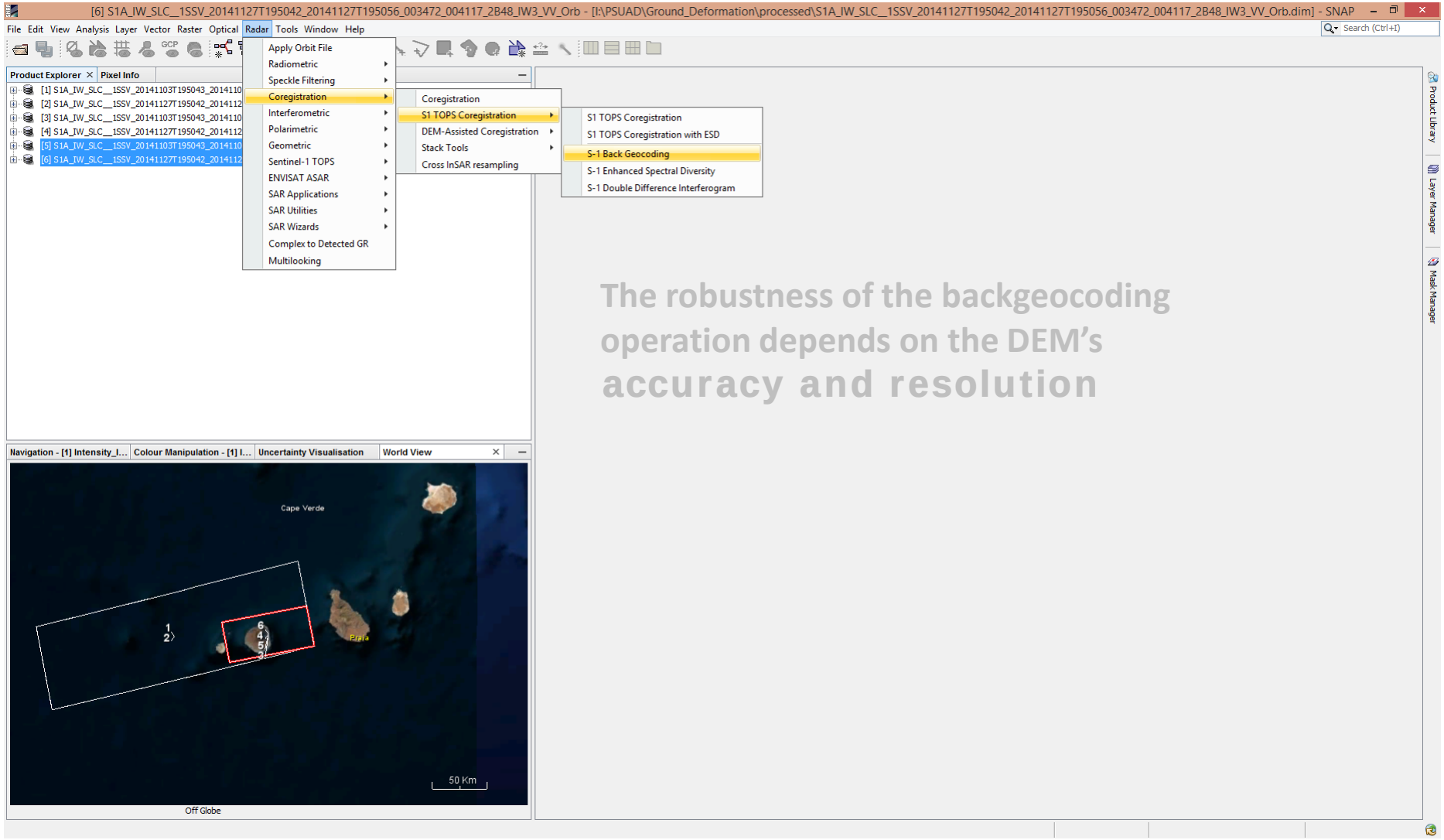
S1 Precise Orbits (https://qc.sentinel1.eo.esa.int)

Automatically adding suffixes (product_*) indicating processing implemented



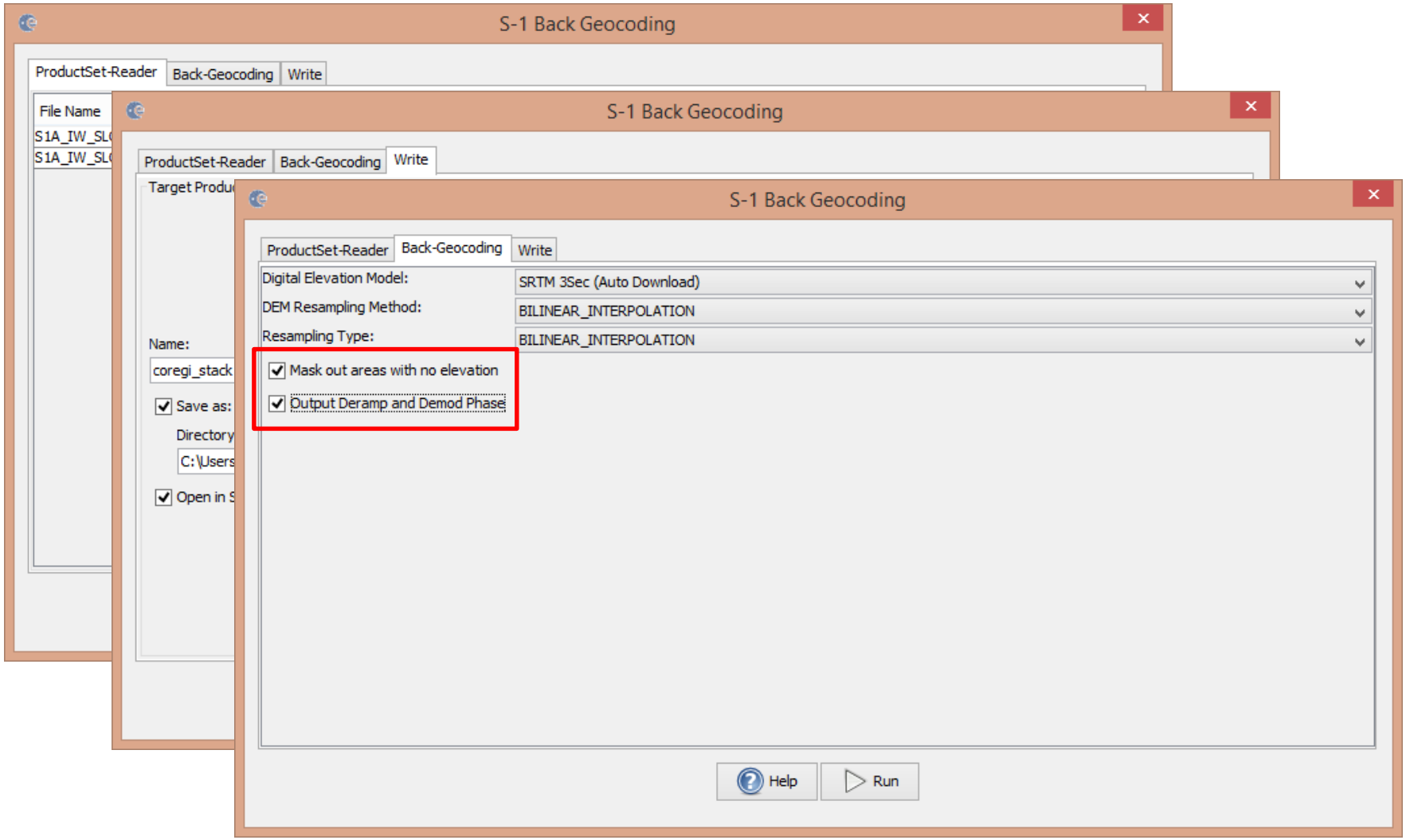


Back-geocoding TOPS SLCs (Geometric Co-registration)

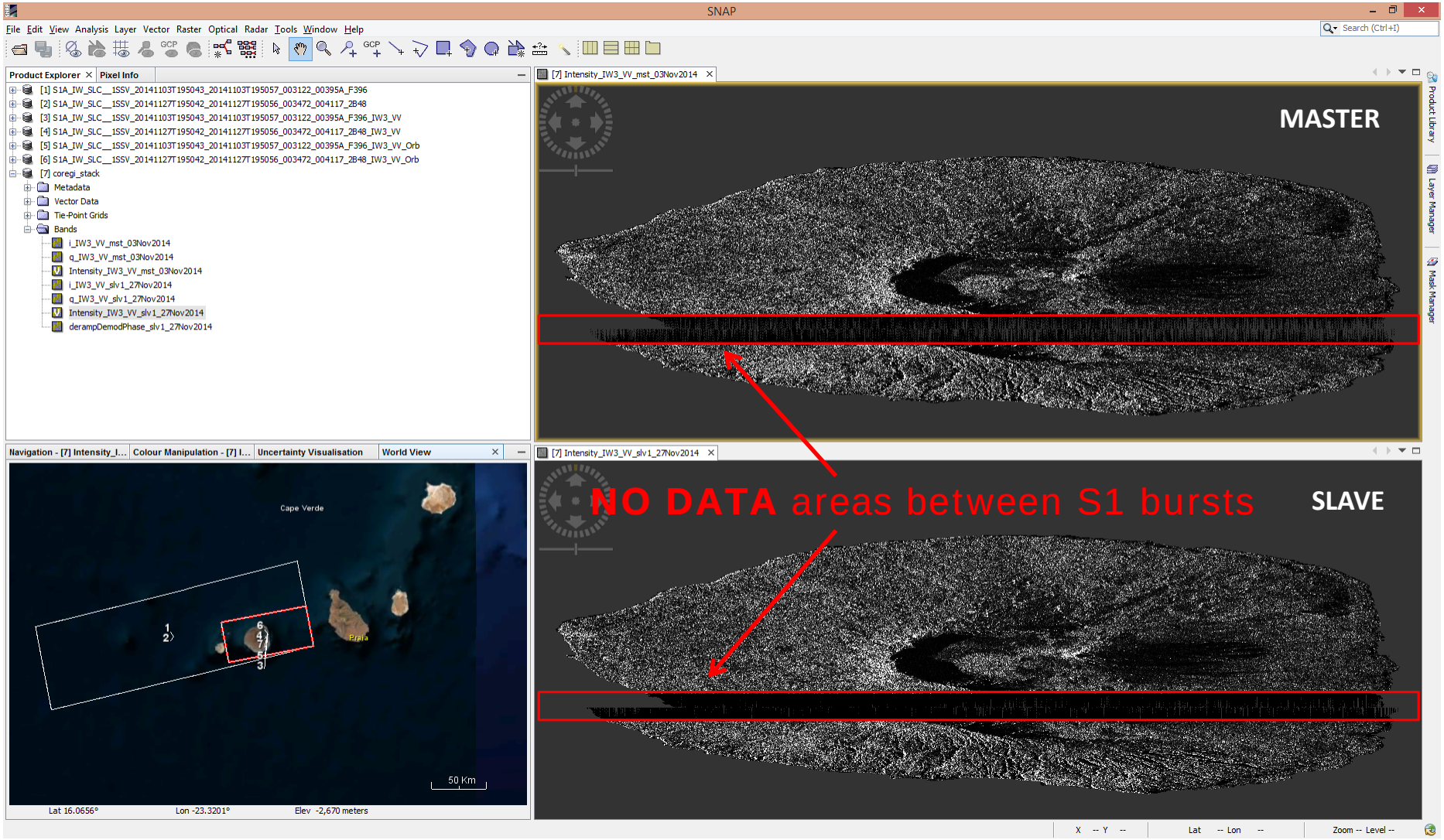


The robustness of the backgeocoding operation depends on the DEM's **accuracy and resolution**

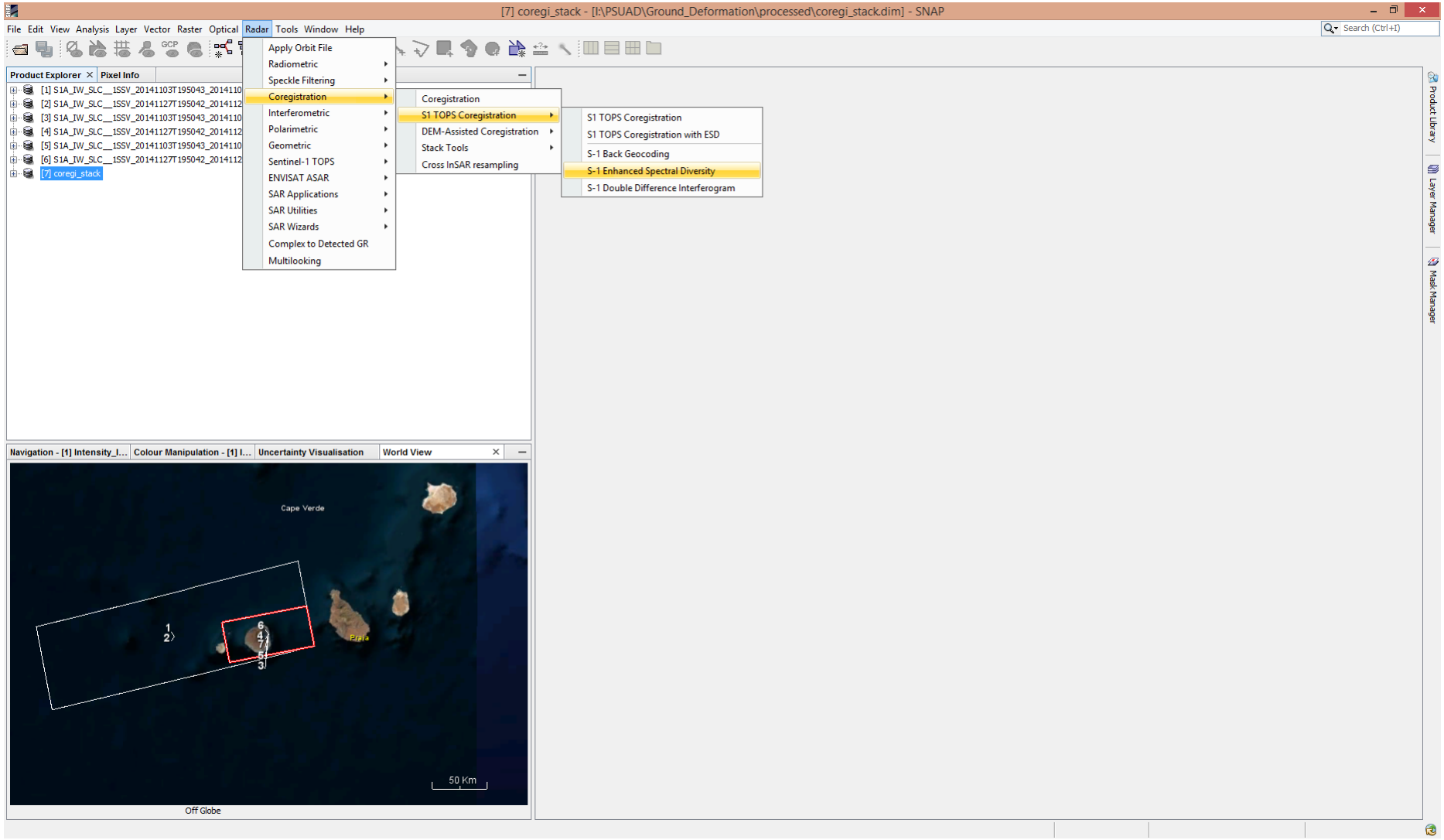
Back-geocoding TOPS SLCs (Geometric Co-registration)



S1 TOPS Co-registered Stack

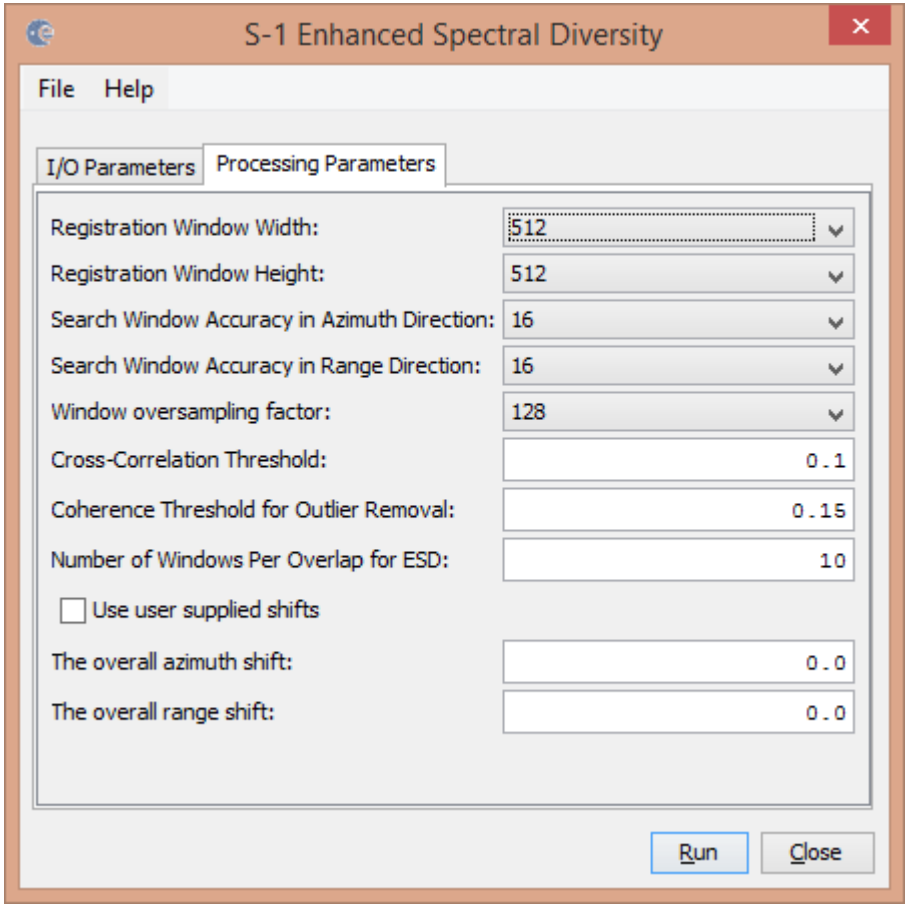


Improvement of Co-registration Accuracy
Enhanced Spectral Diversity (ESD)

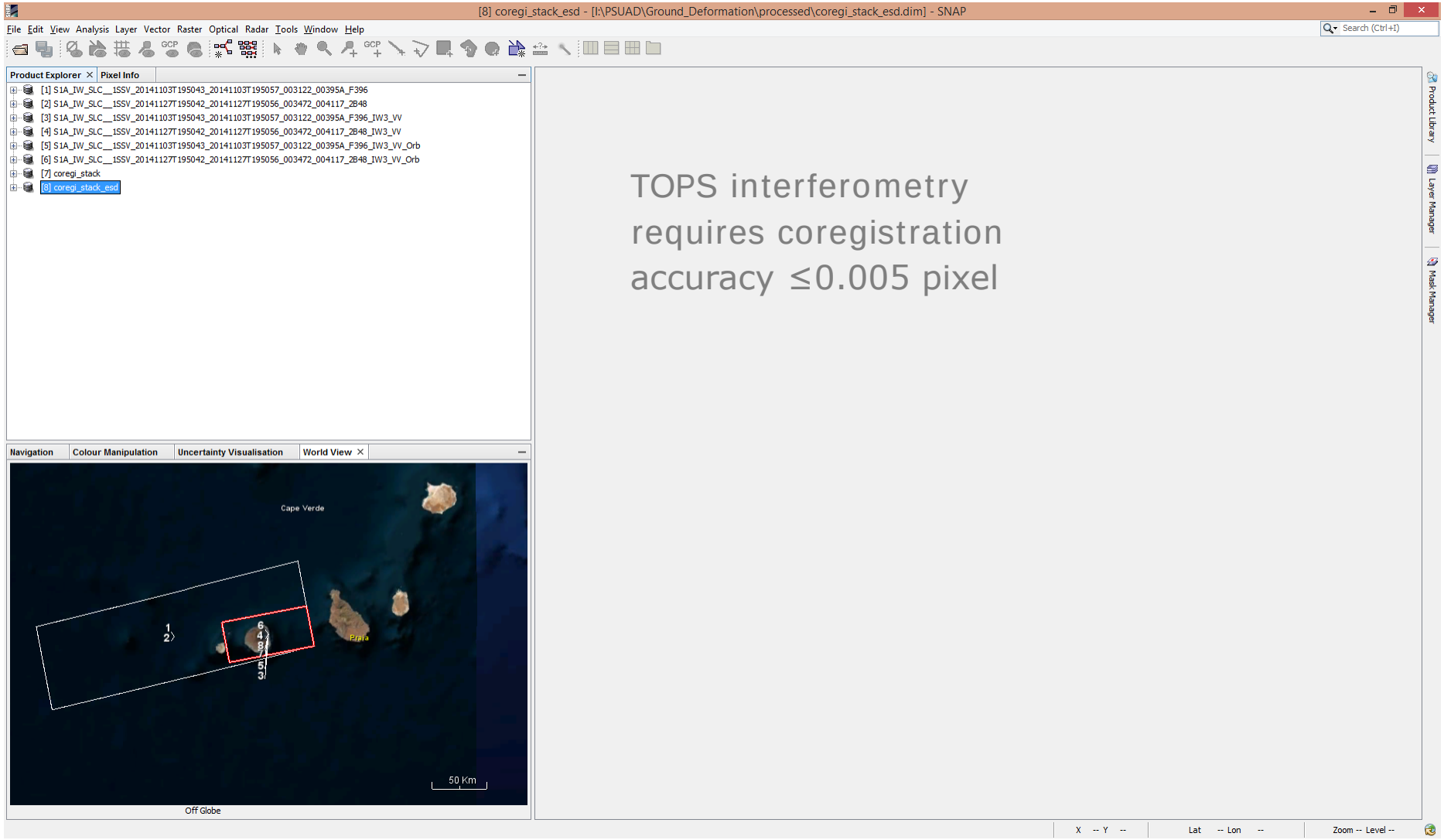


Enhanced Spectral Diversity (ESD) algorithm

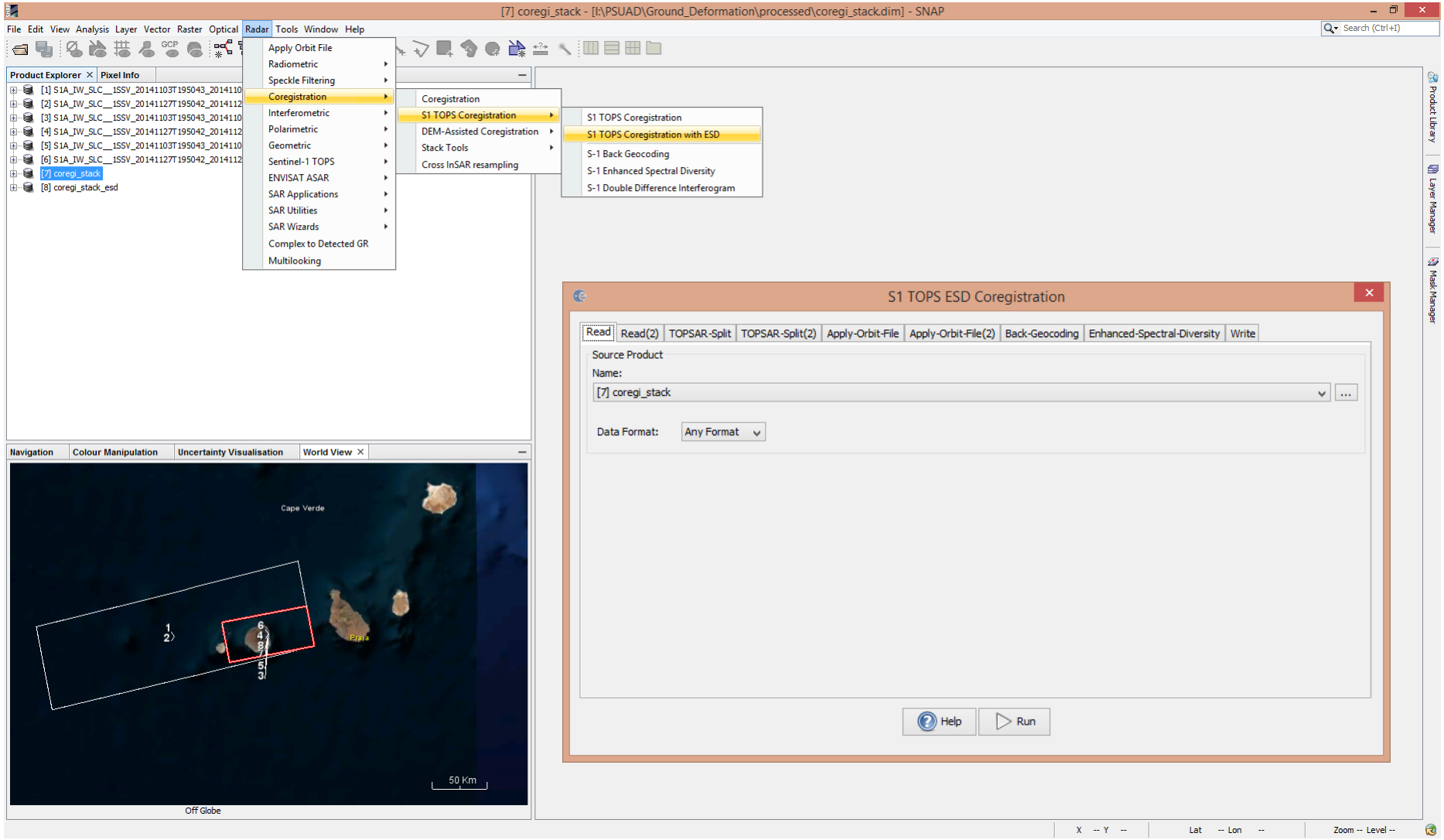
Implementation of the **Enhanced Spectral Diversity** (ESD) algorithm for correcting shifts in range and azimuth direction considering the burst overlap areas



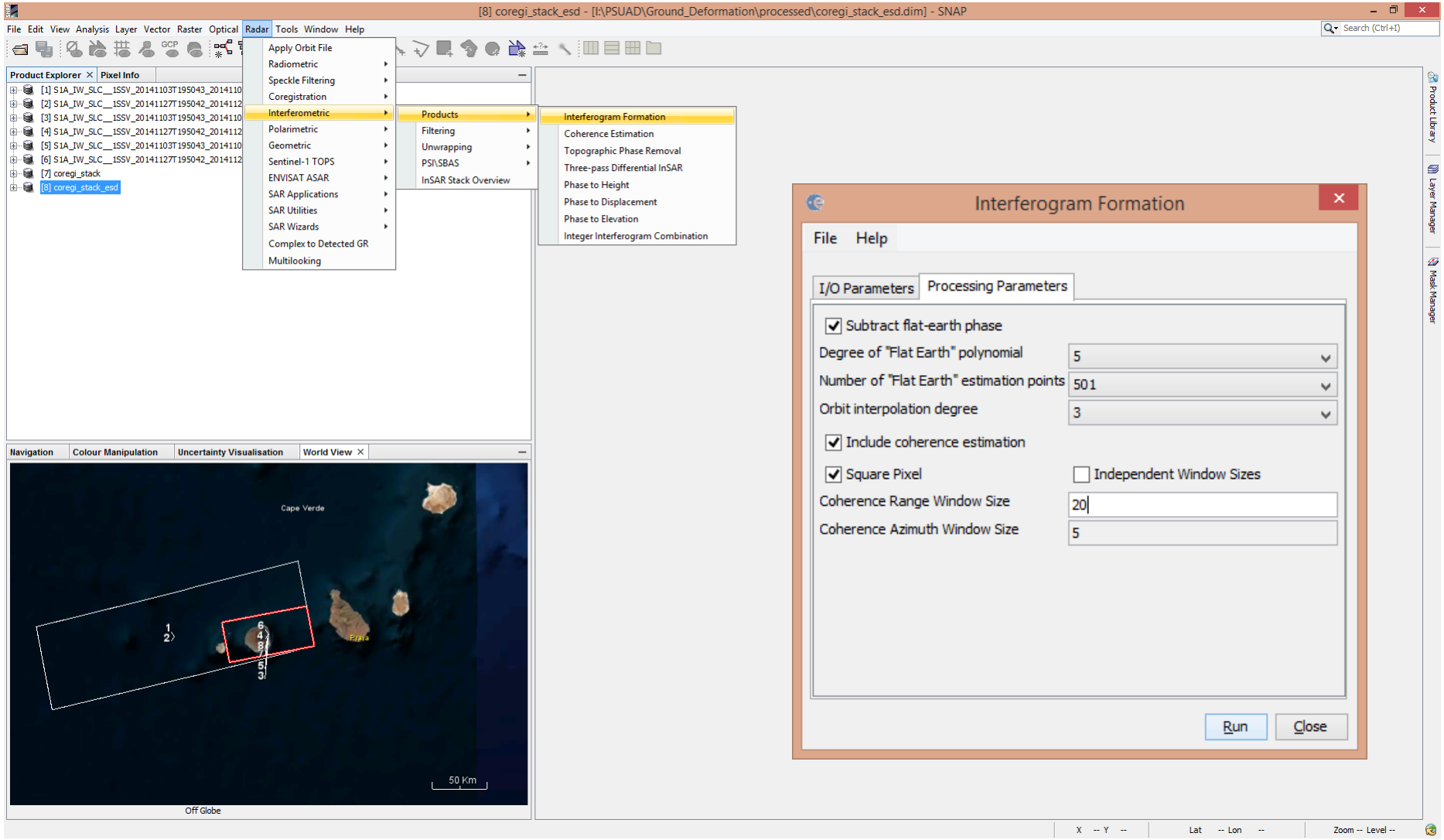
S1 TOPS ESD Co-registered Stack



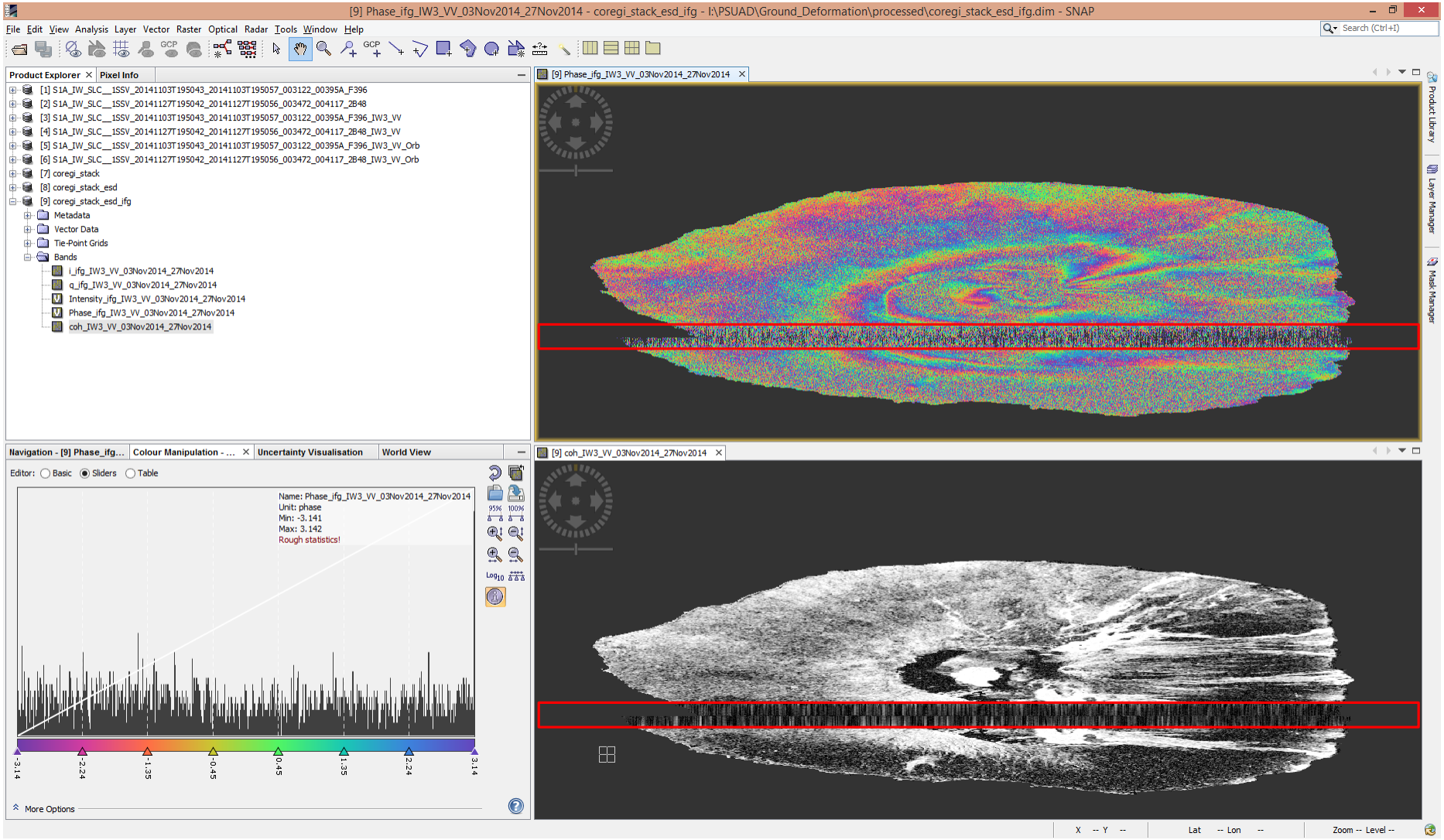
Alternative Option for TOPS Coregistration (all-in-one)



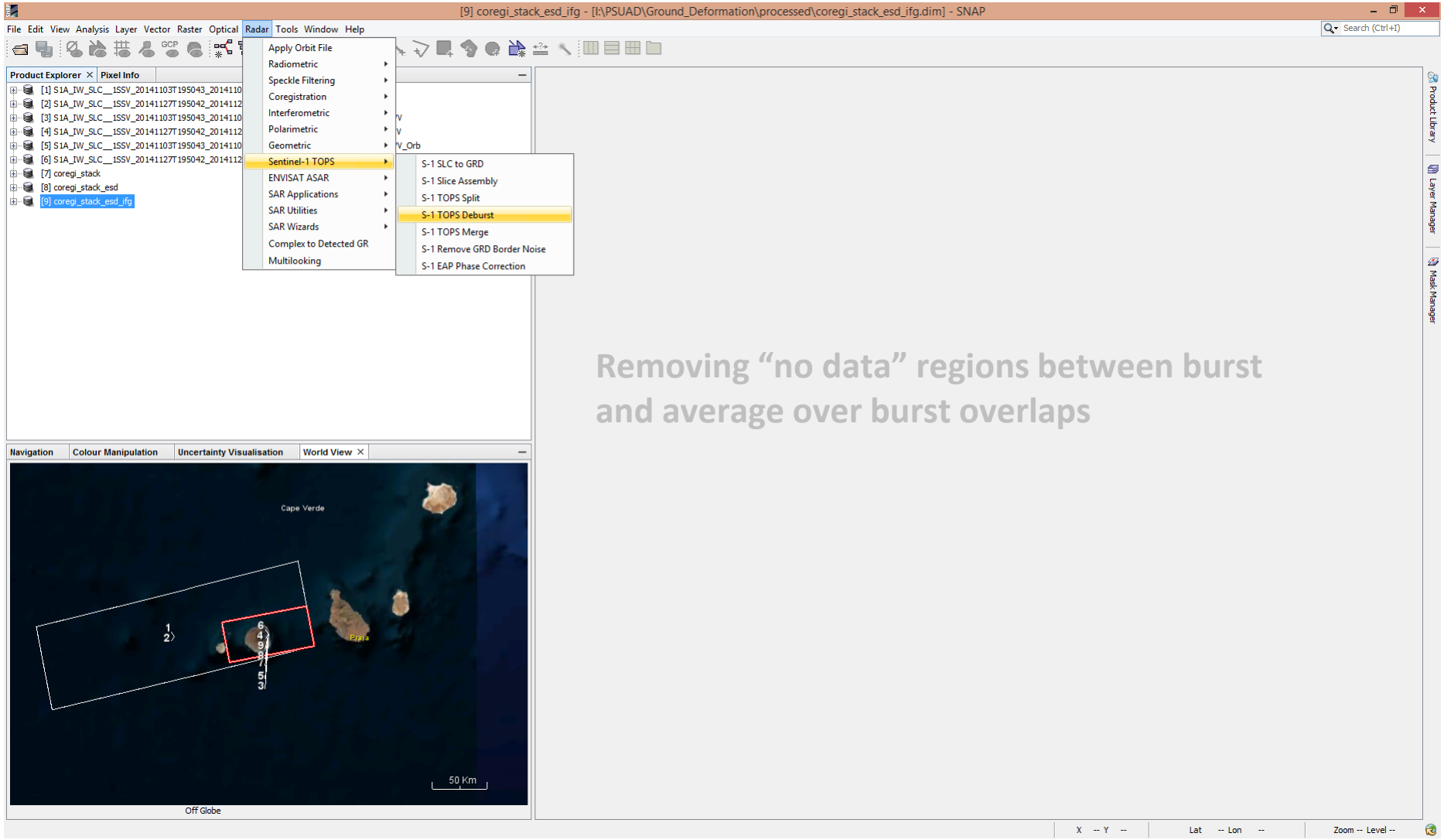
Sentinel-1 TOPS Interferogram Generation



Sentinel-1 TOPS InSAR (InSAR Phase & Coherence)

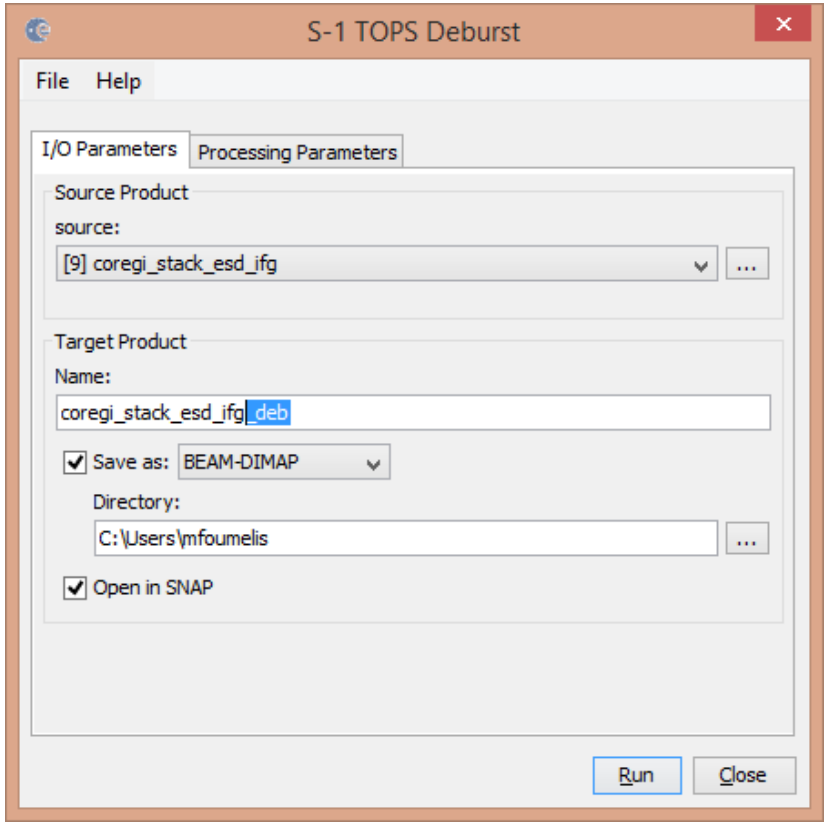


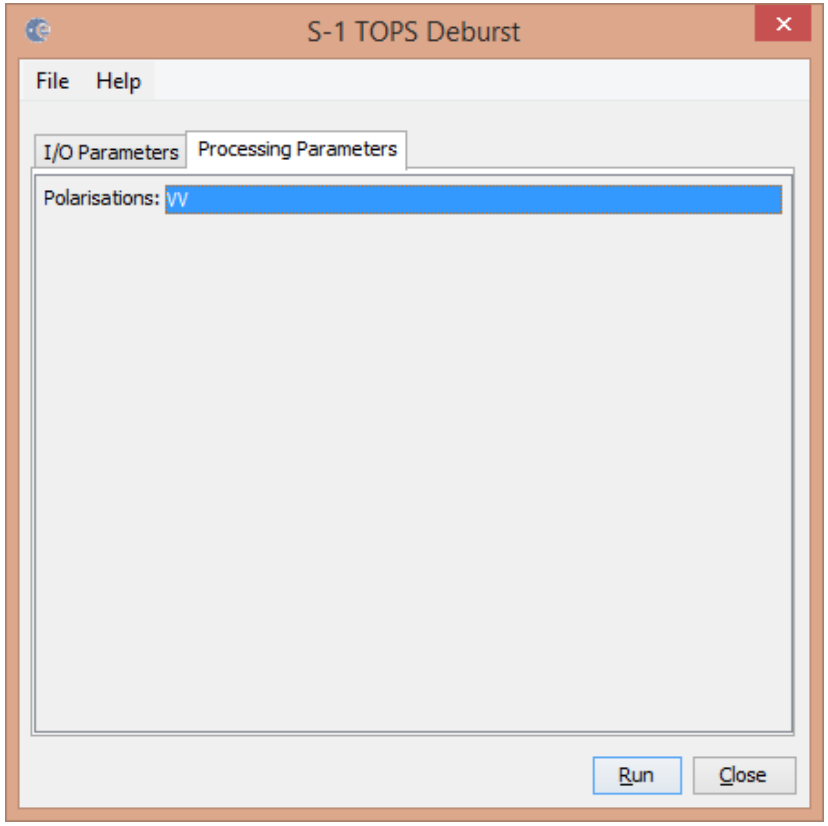
Sentinel-1 TOPS Deburst



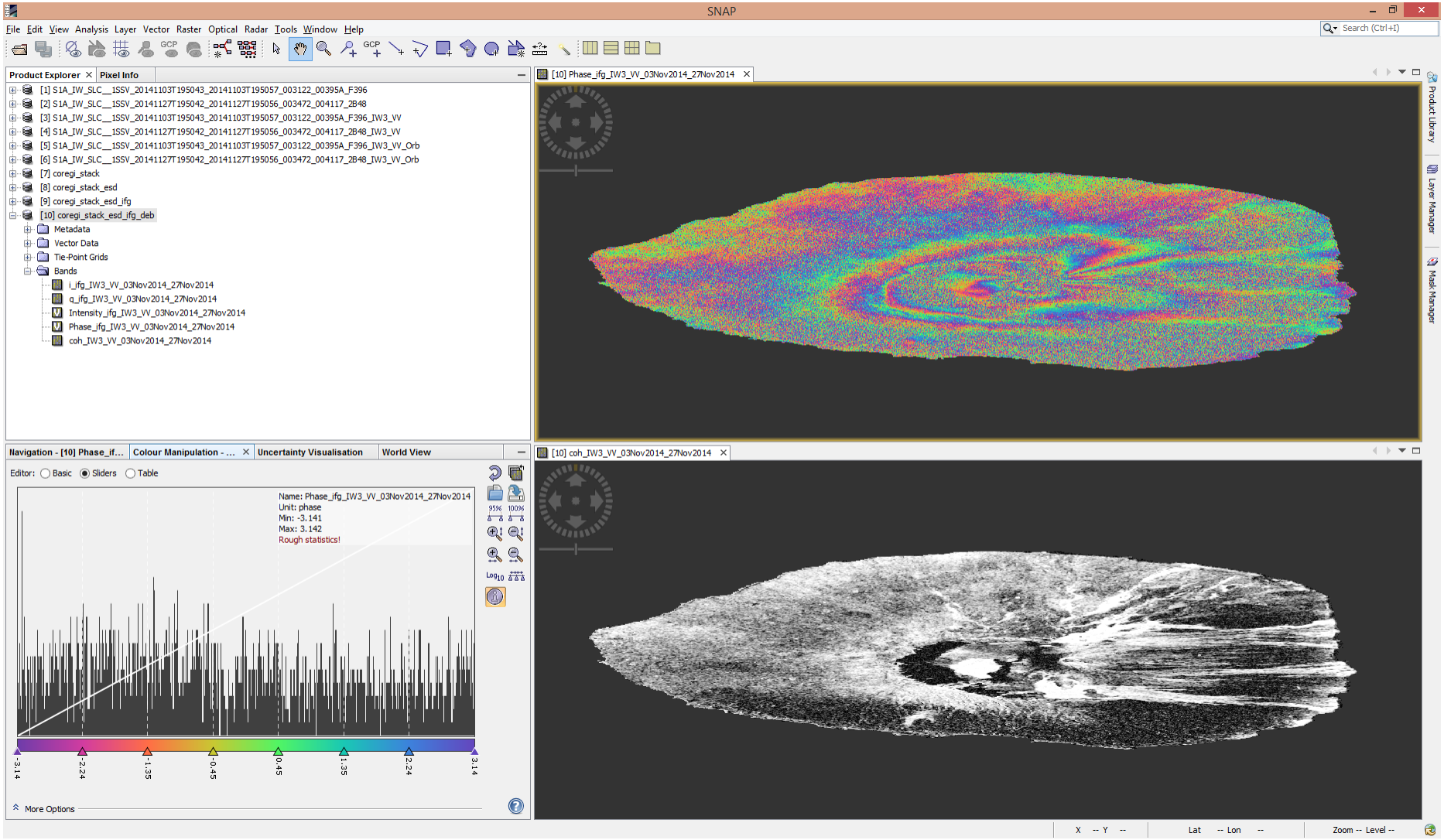
Removing “no data” regions between burst and average over burst overlaps

Sentinel-1 TOPS Deburst

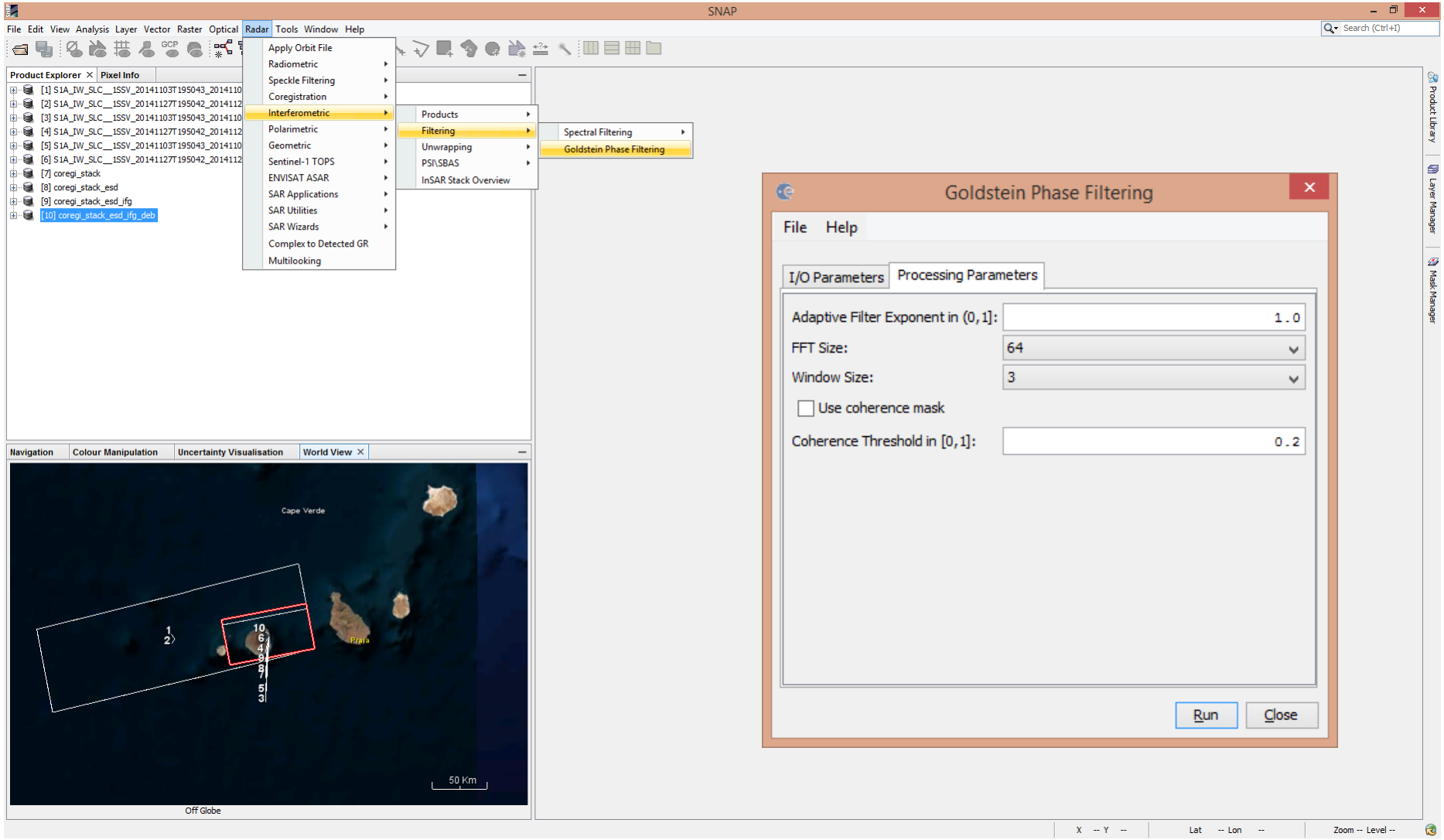




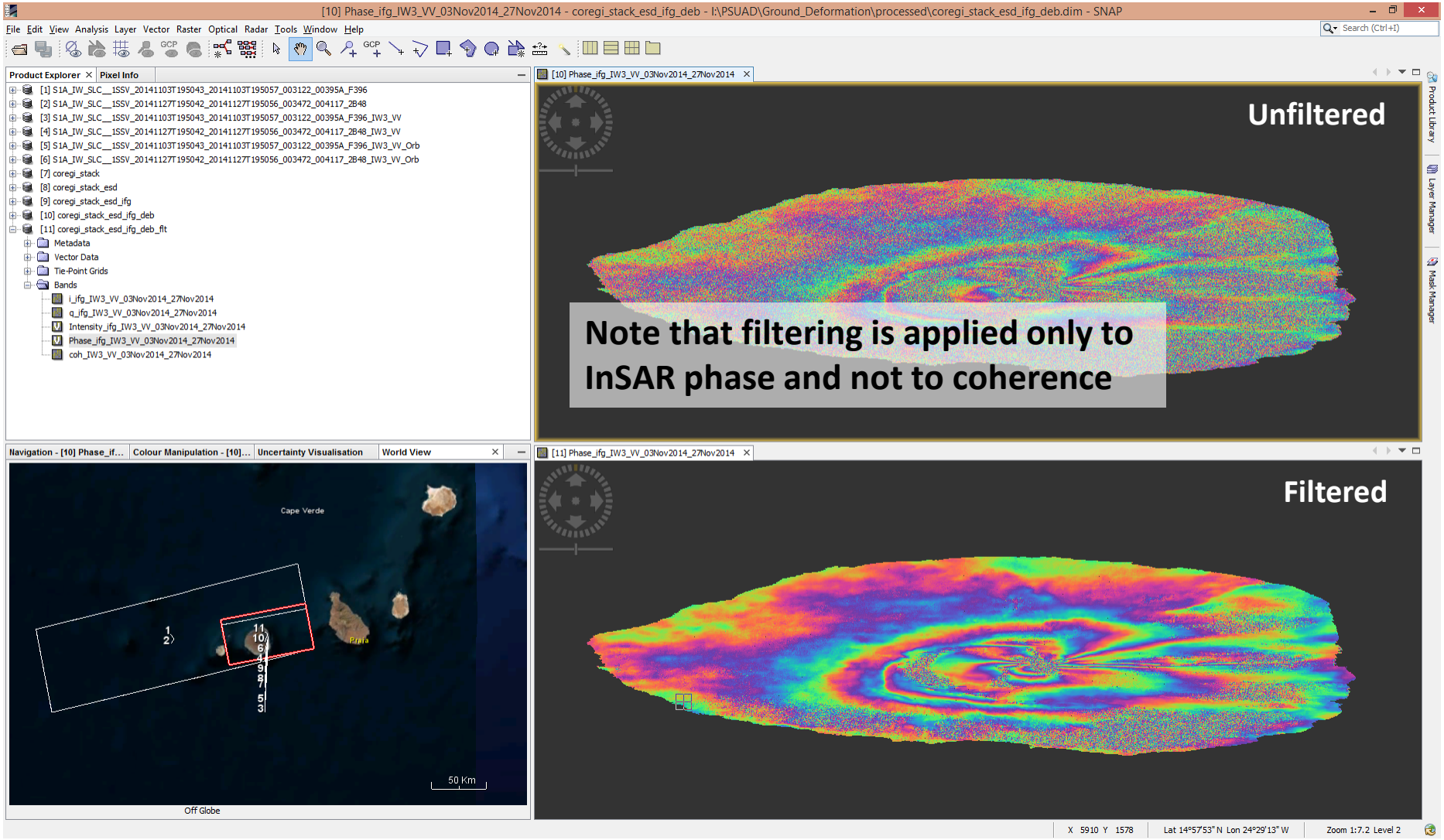
S1 Debursted Products (InSAR Phase & Coherence)



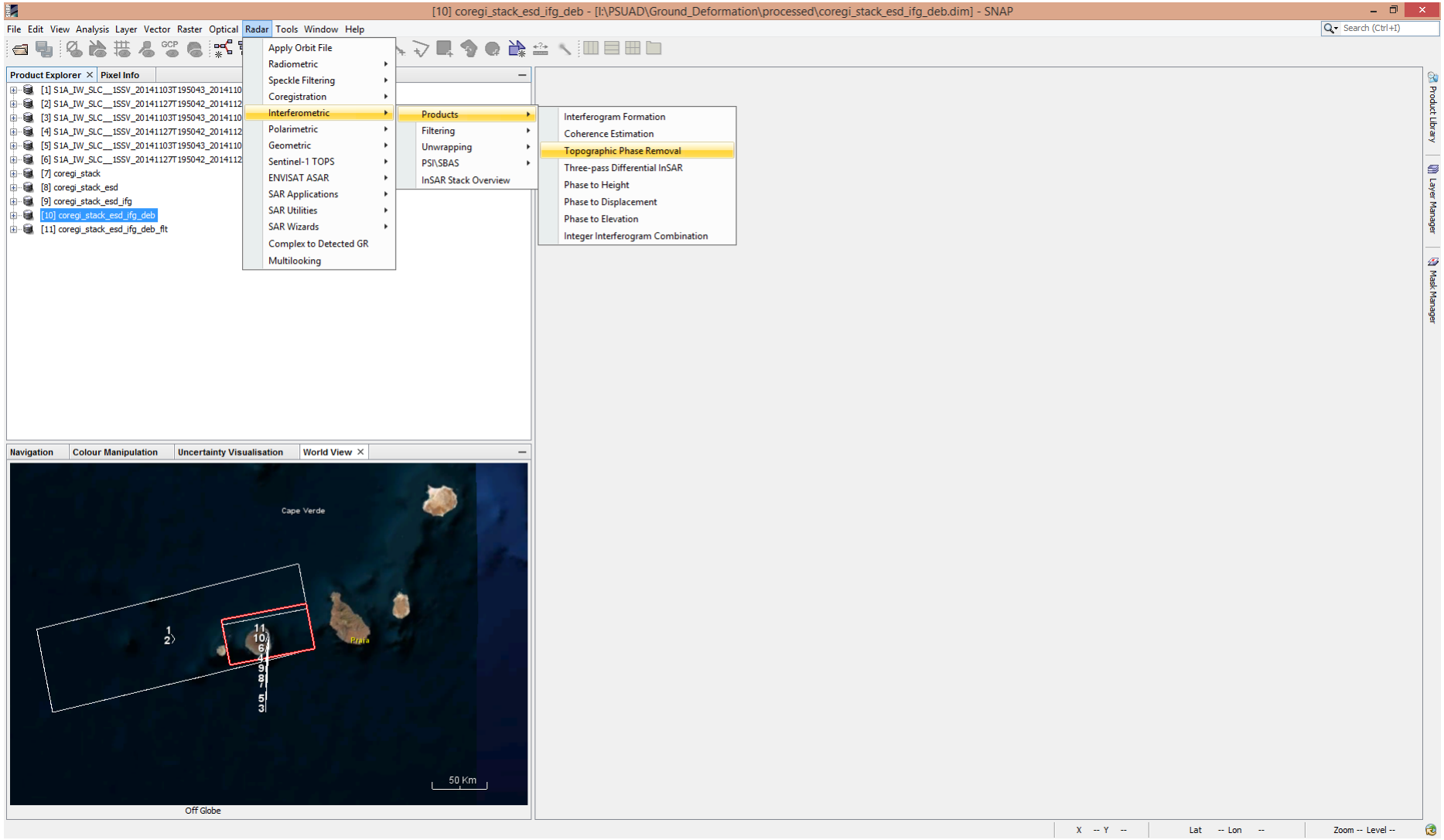
Goldstein Phase Filtering (Adaptive Filter)



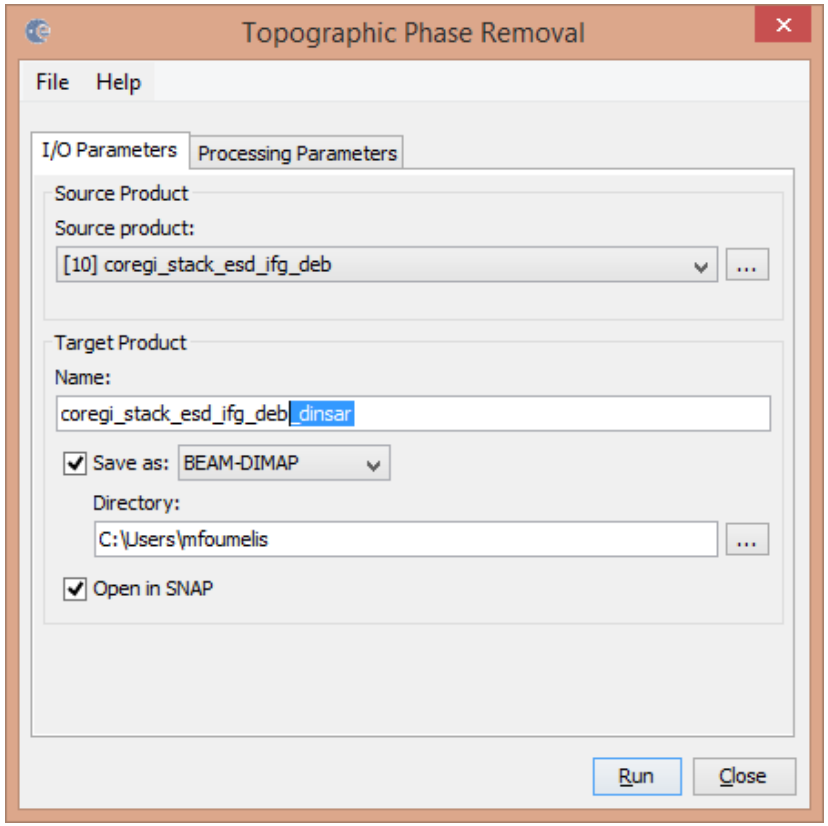
S1 Filtered InSAR Phase

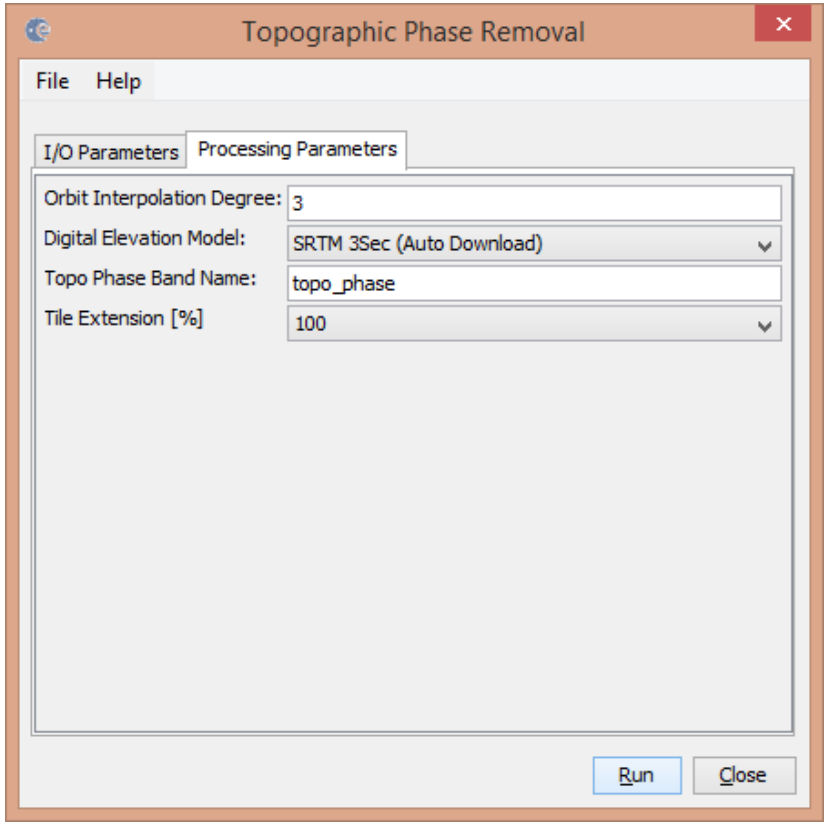


Topographic Phase Removal (Differential InSAR Phase)

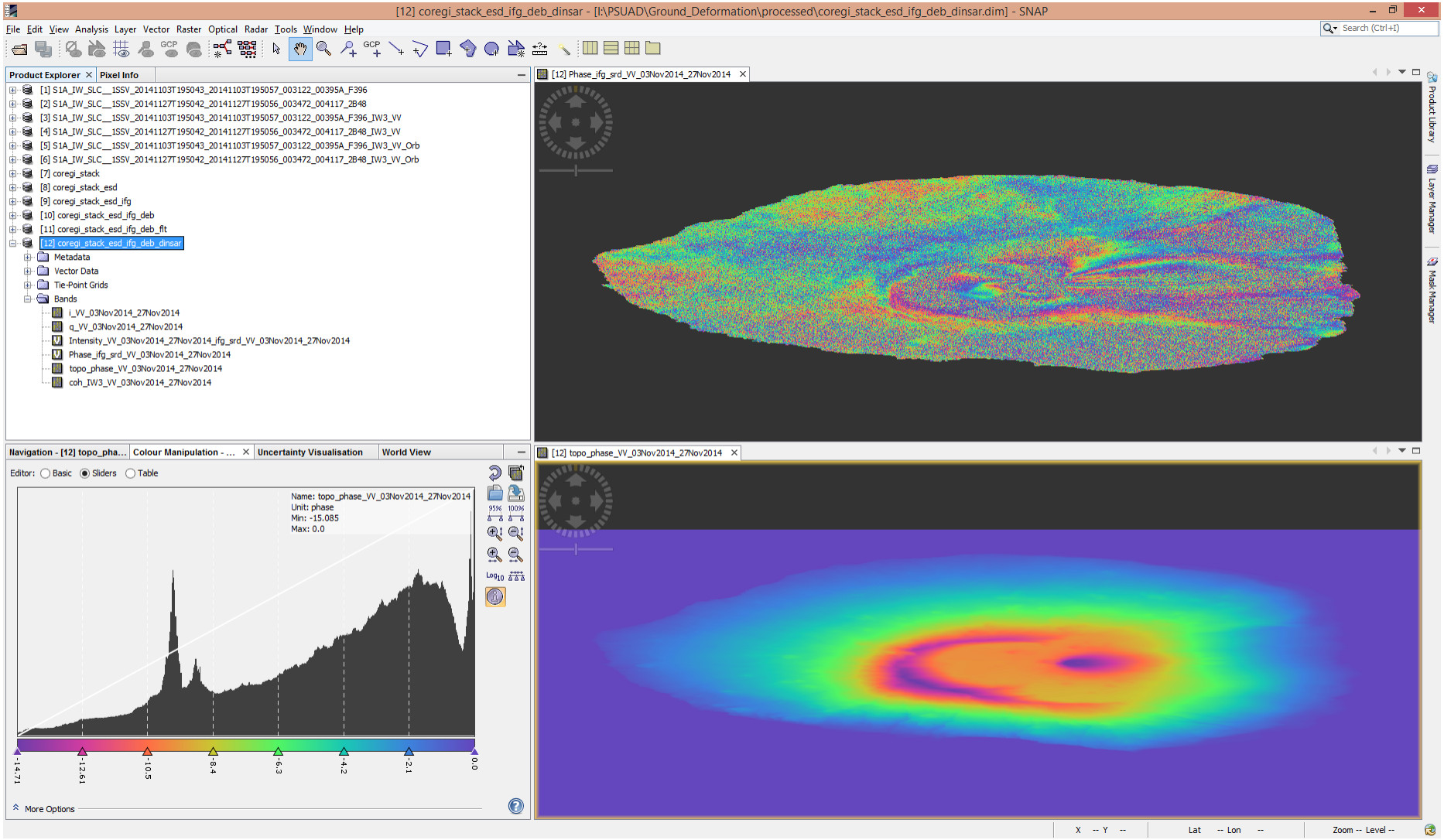


Topographic Phase Removal (Differential InSAR Phase)

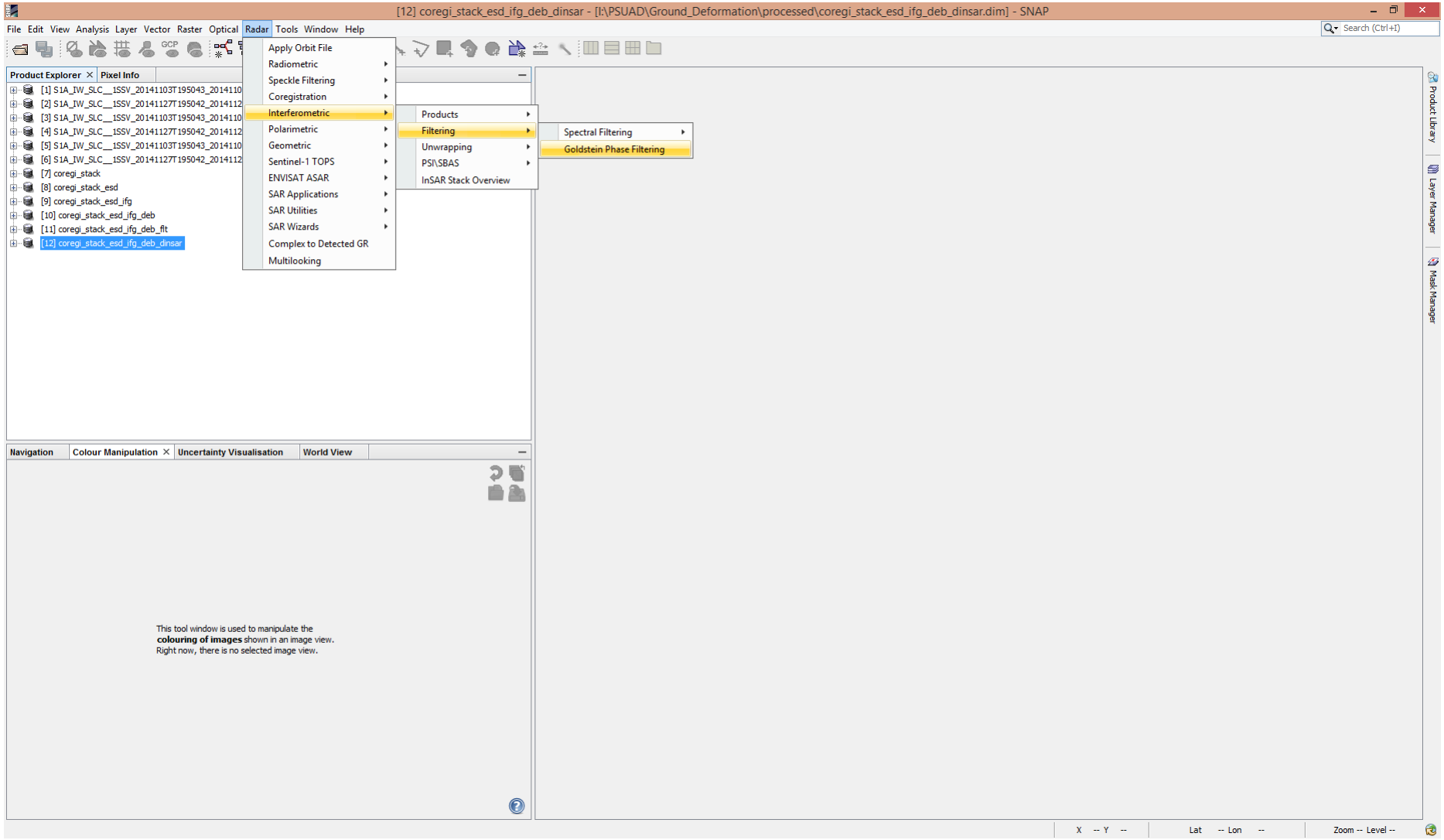




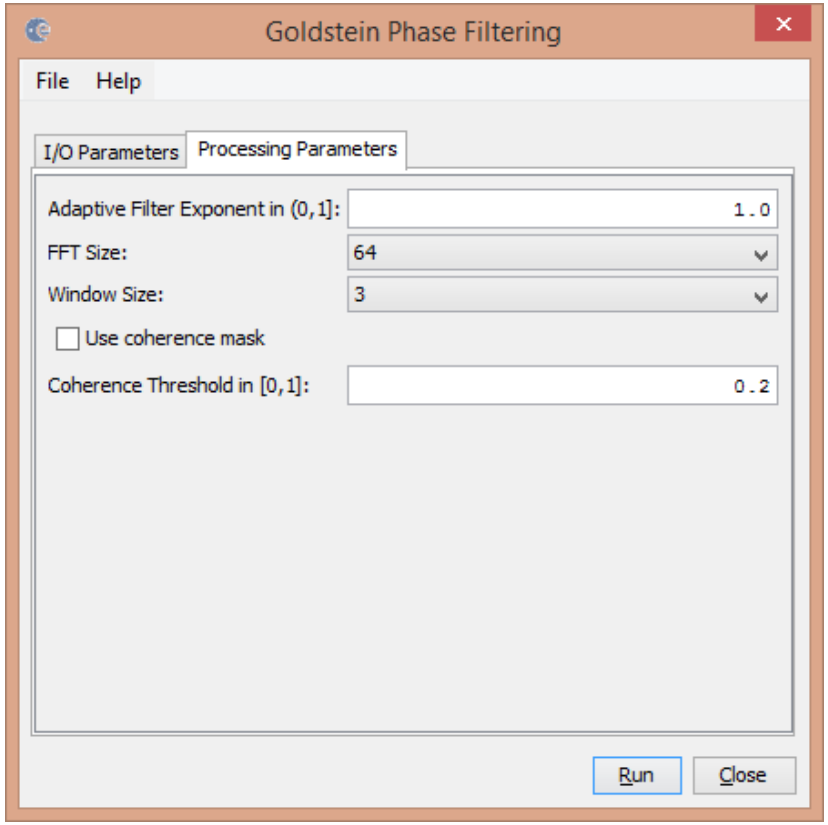
Differential Interferogram & Simulated Topo Phase



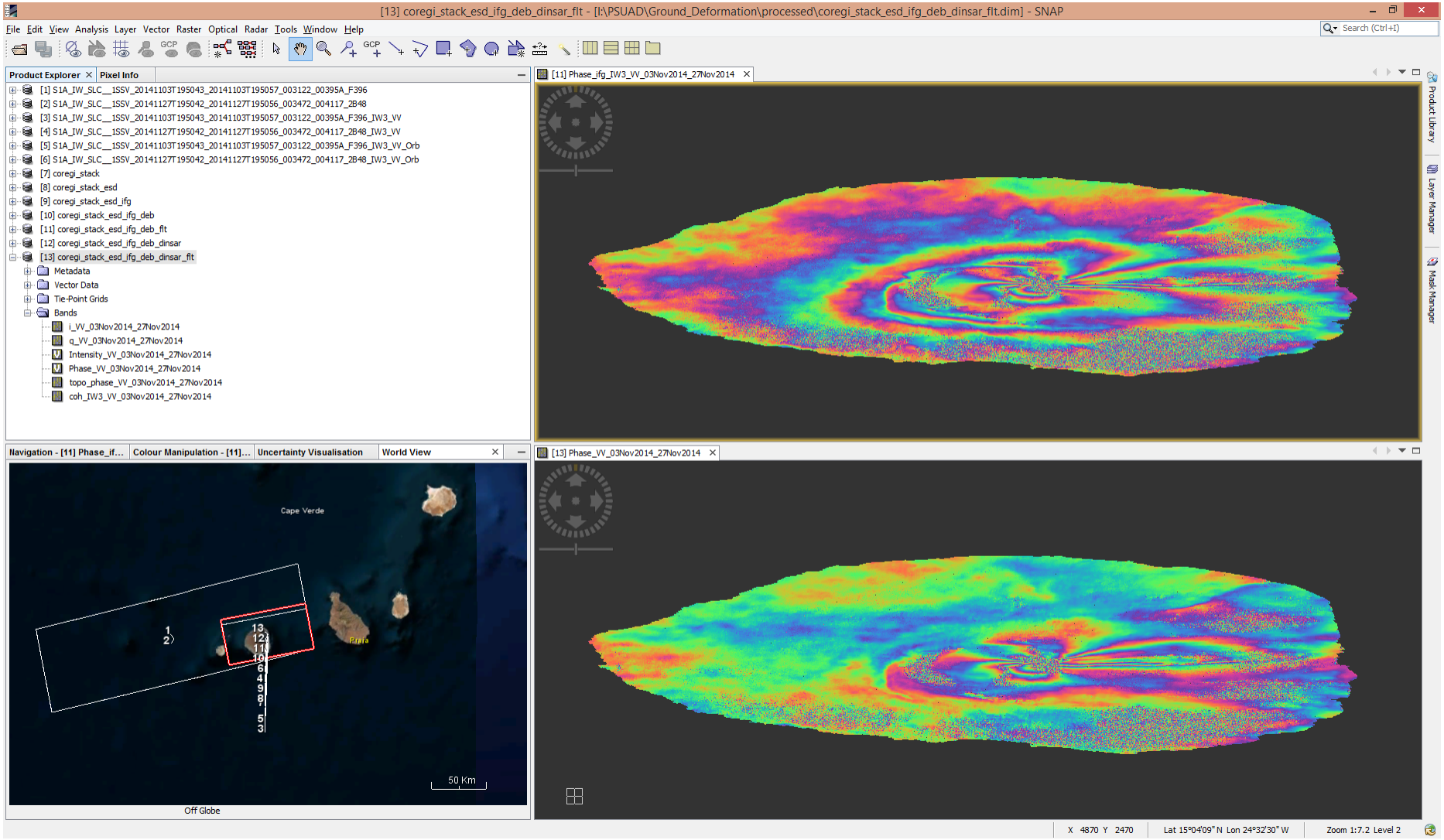
Differential Phase Filtering (Goldstein Filter)



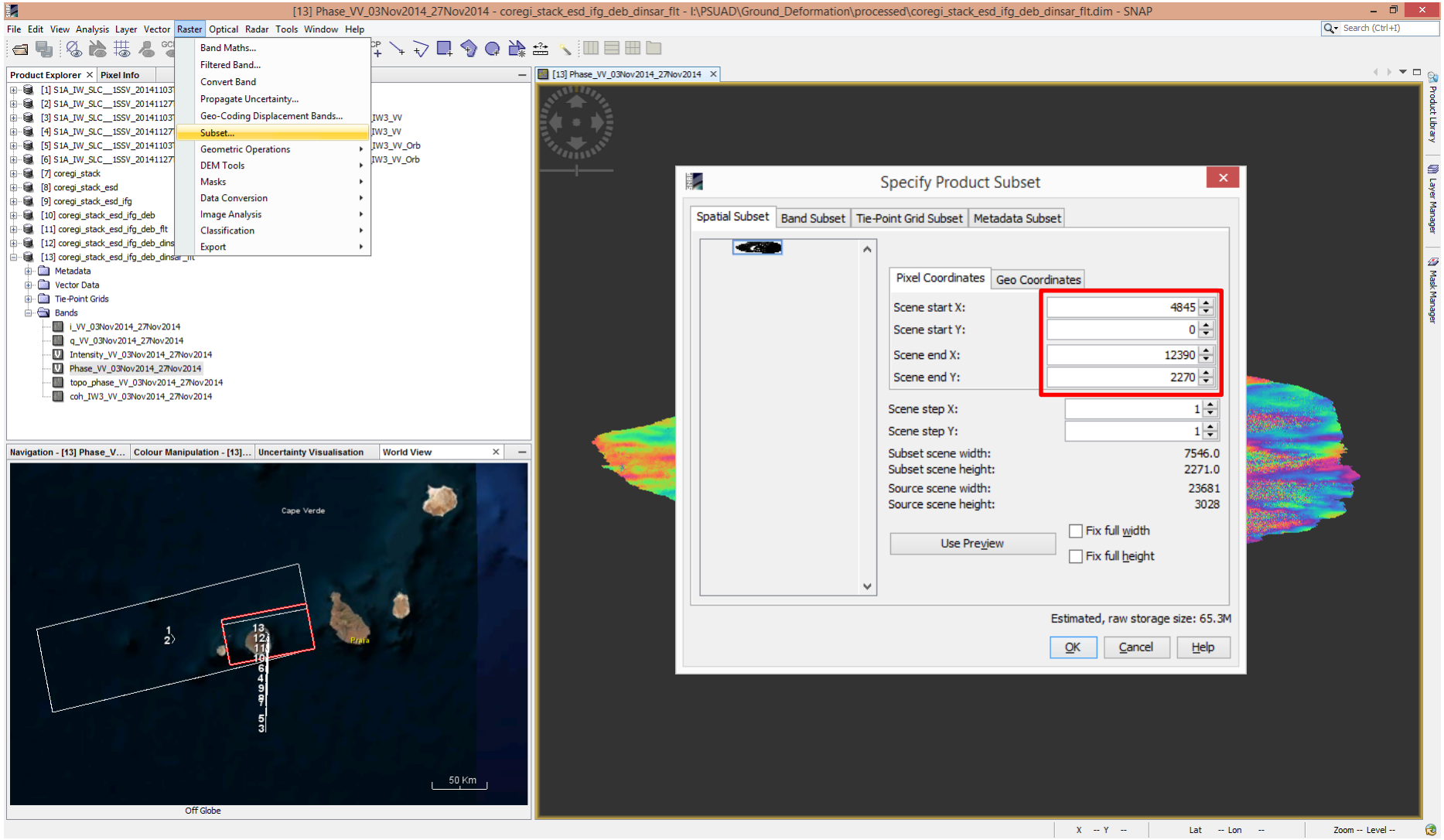
Differential Phase Filtering



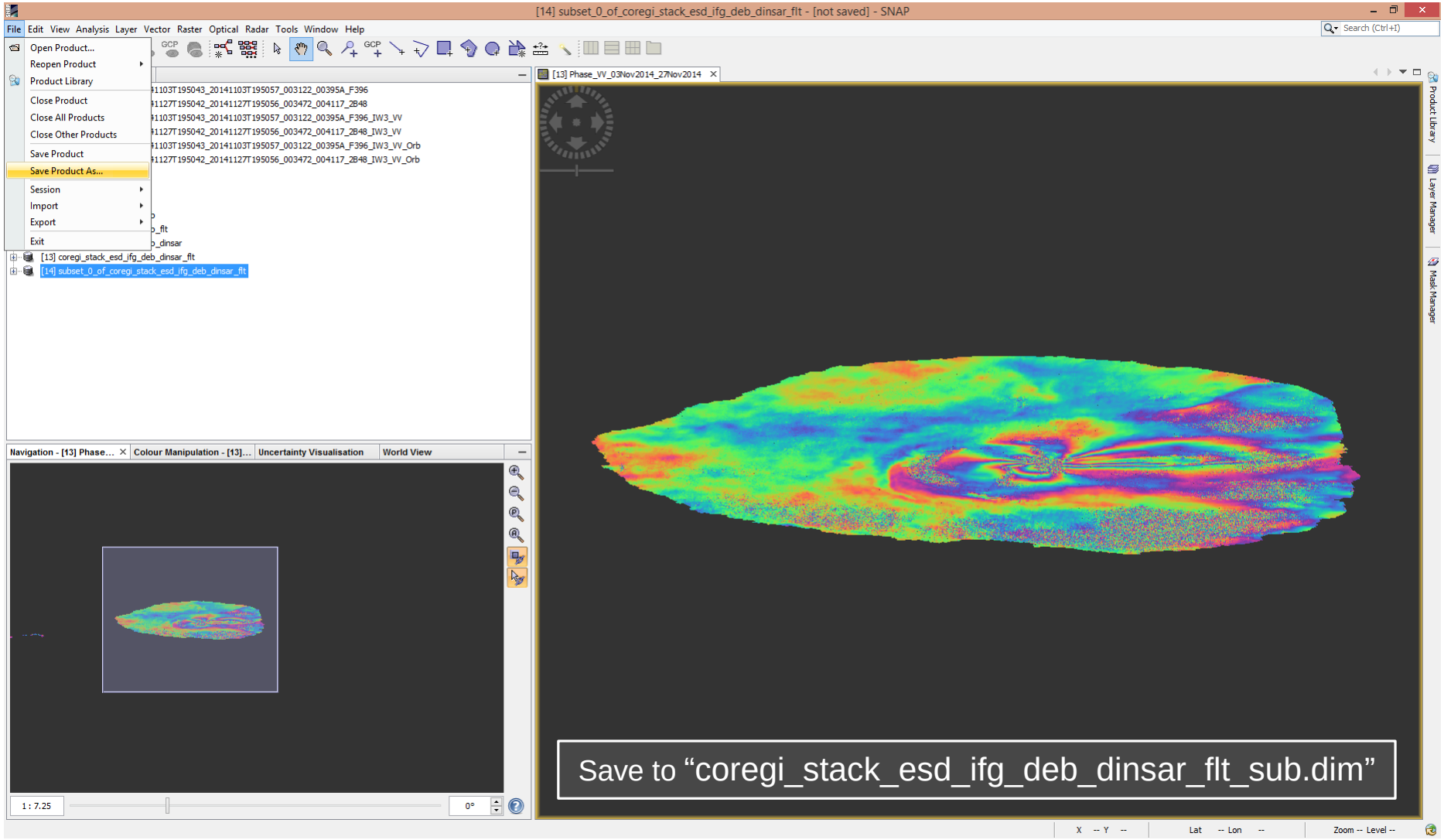
S1 Filtered DInSAR Phase



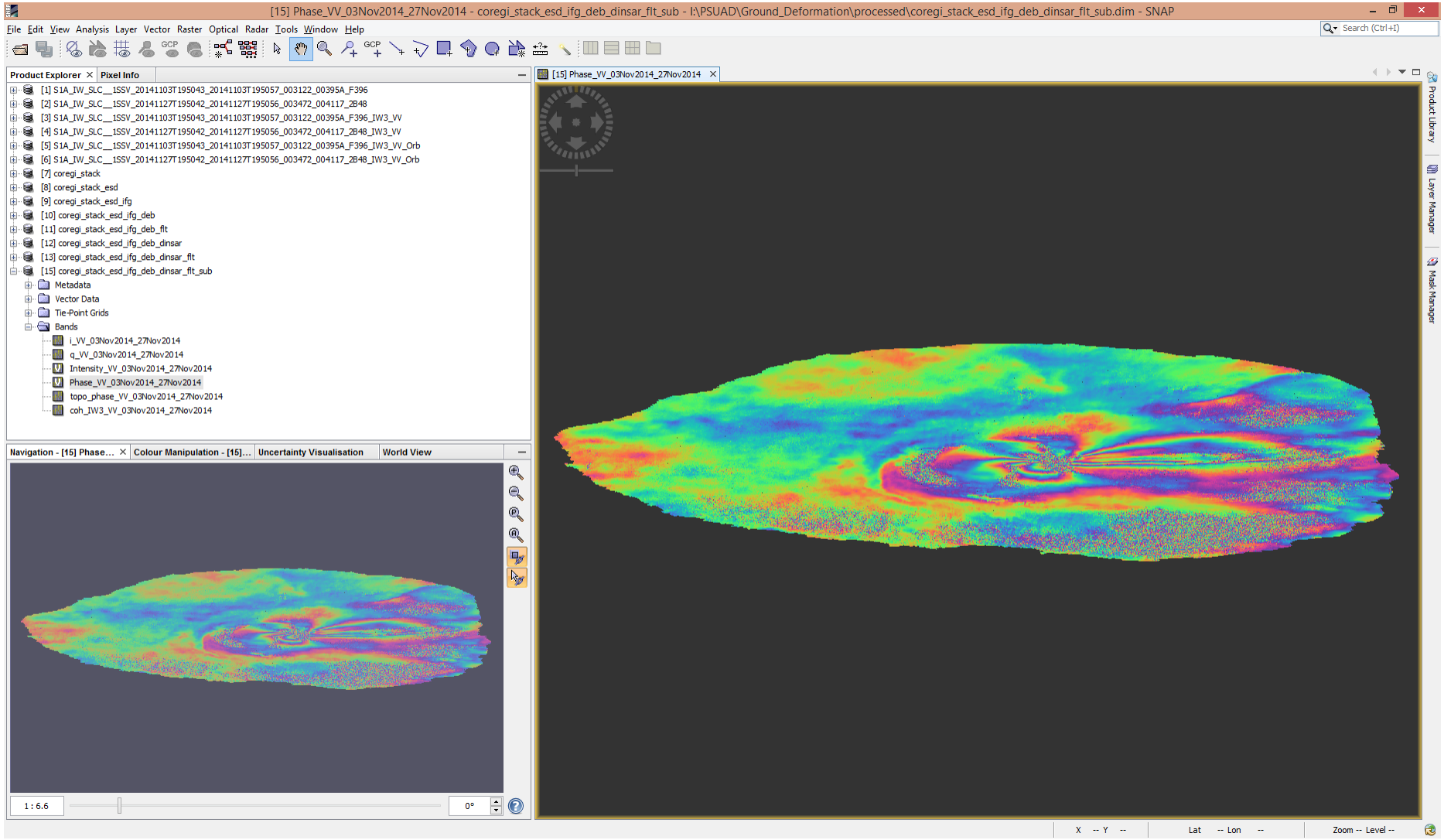
Spatial Subset over AOI



Spatial Subset over AOI

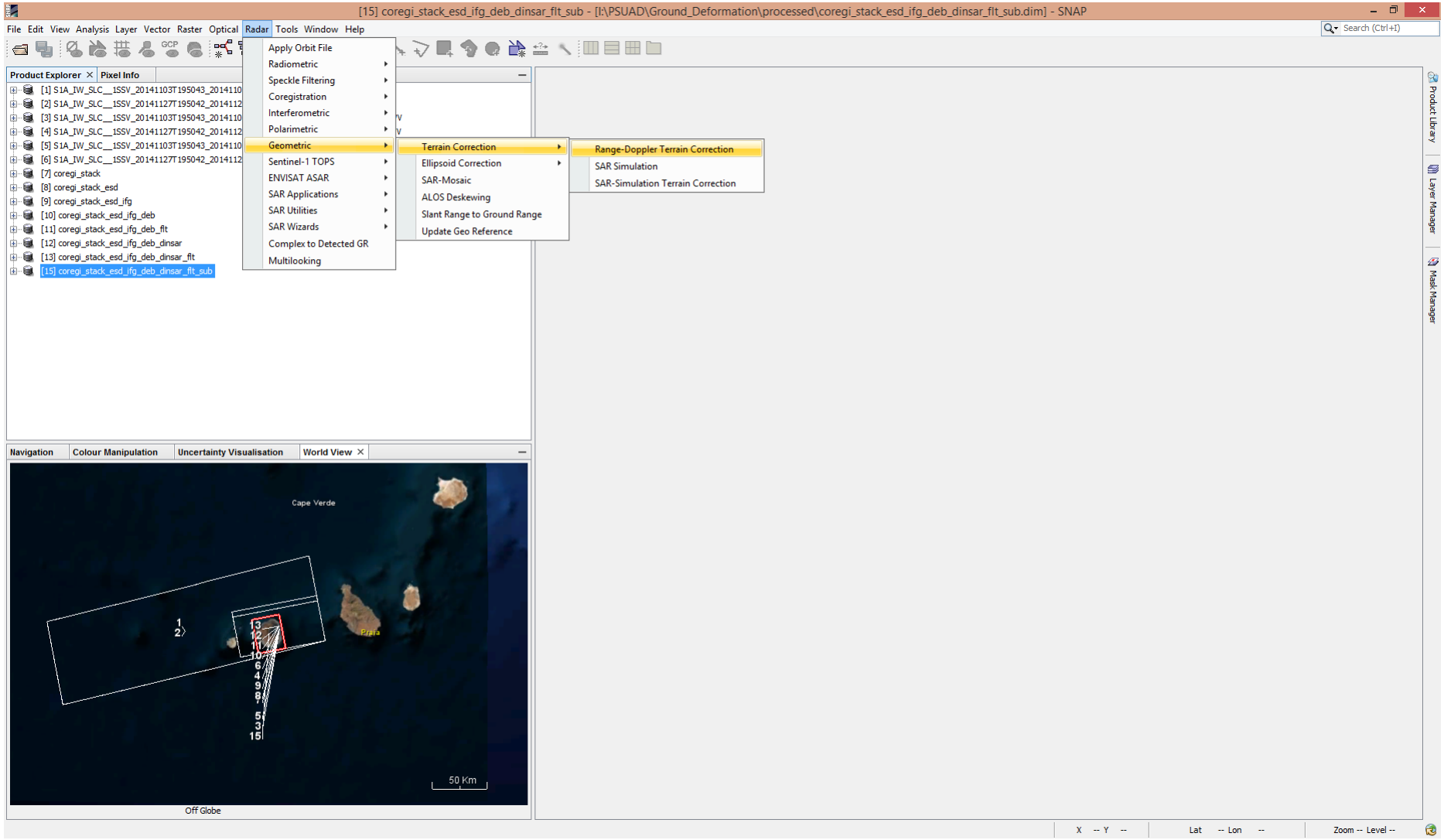


S1 TOPS Filtered DInSAR Phase (Wrapped)

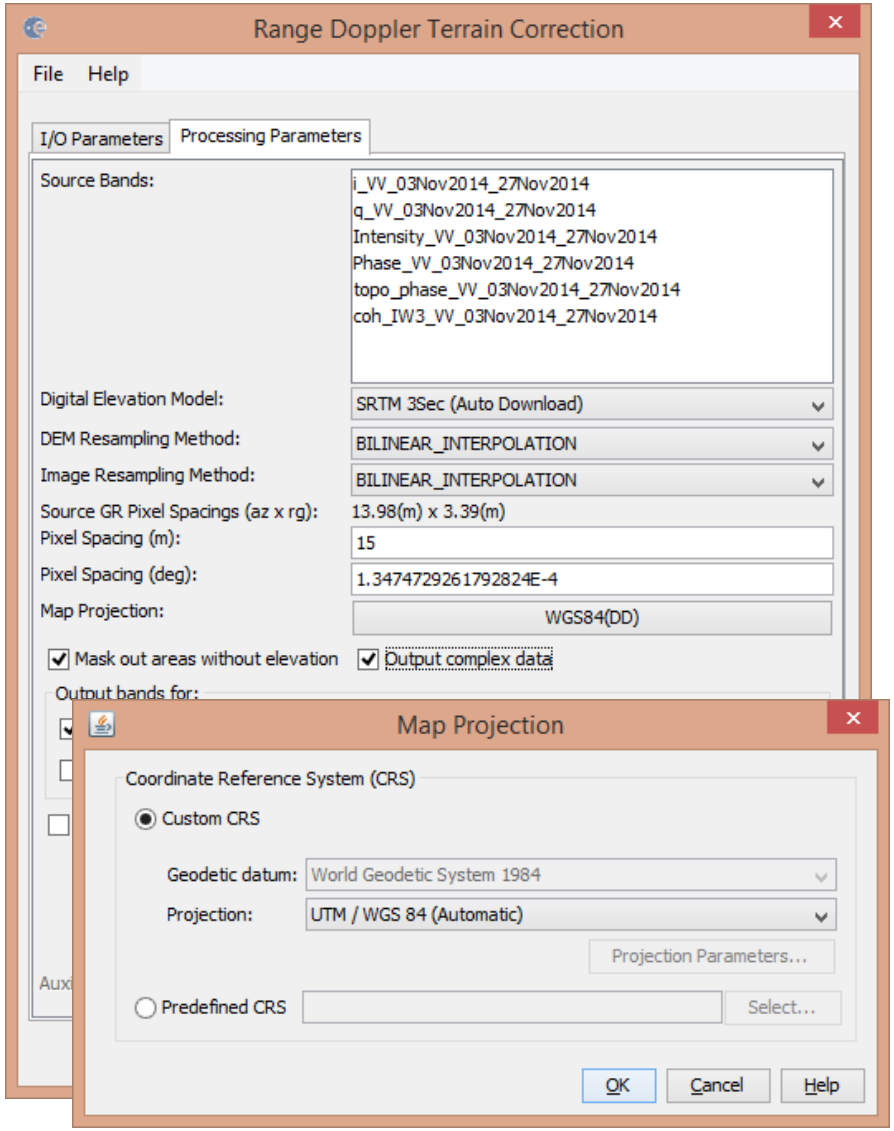


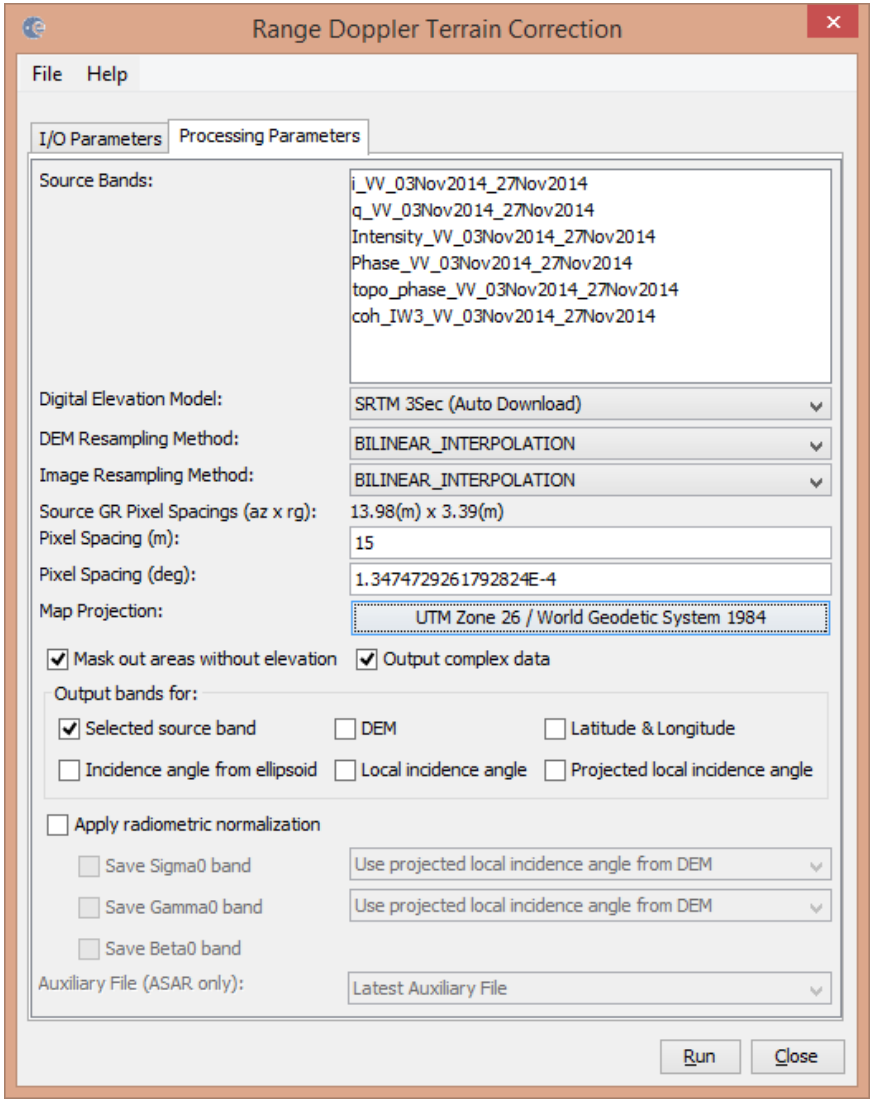
Geocoding of Wrapped DInSAR Phase & Coherence

Range-Doppler Terrain Correction approach

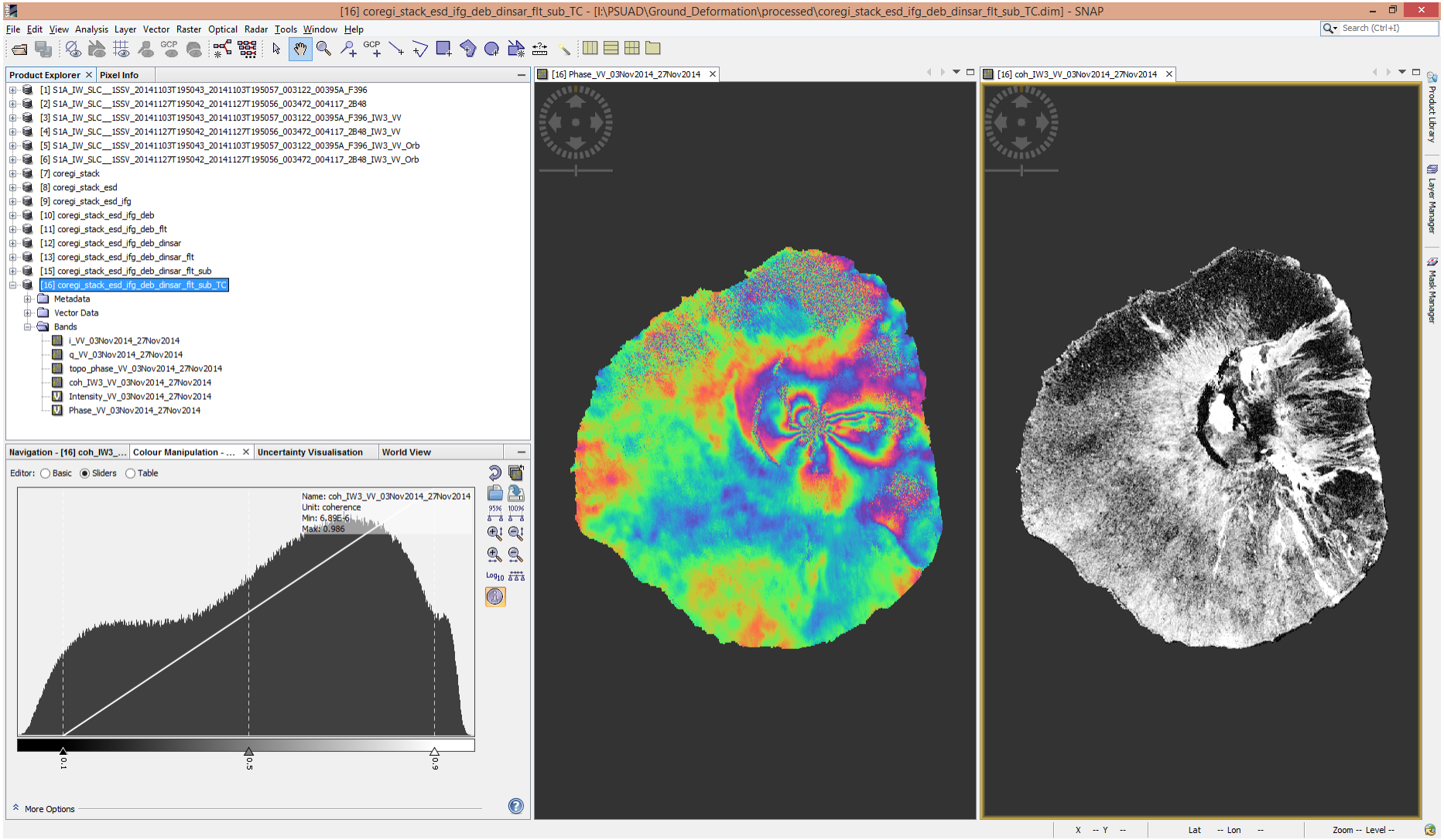


Range-Doppler Terrain Correction





Terrain Corrected
S1 TOPS Differential Interferogram & Coherence Levels



EXERCISE

PART 2
Unwrapping using SNAPHU

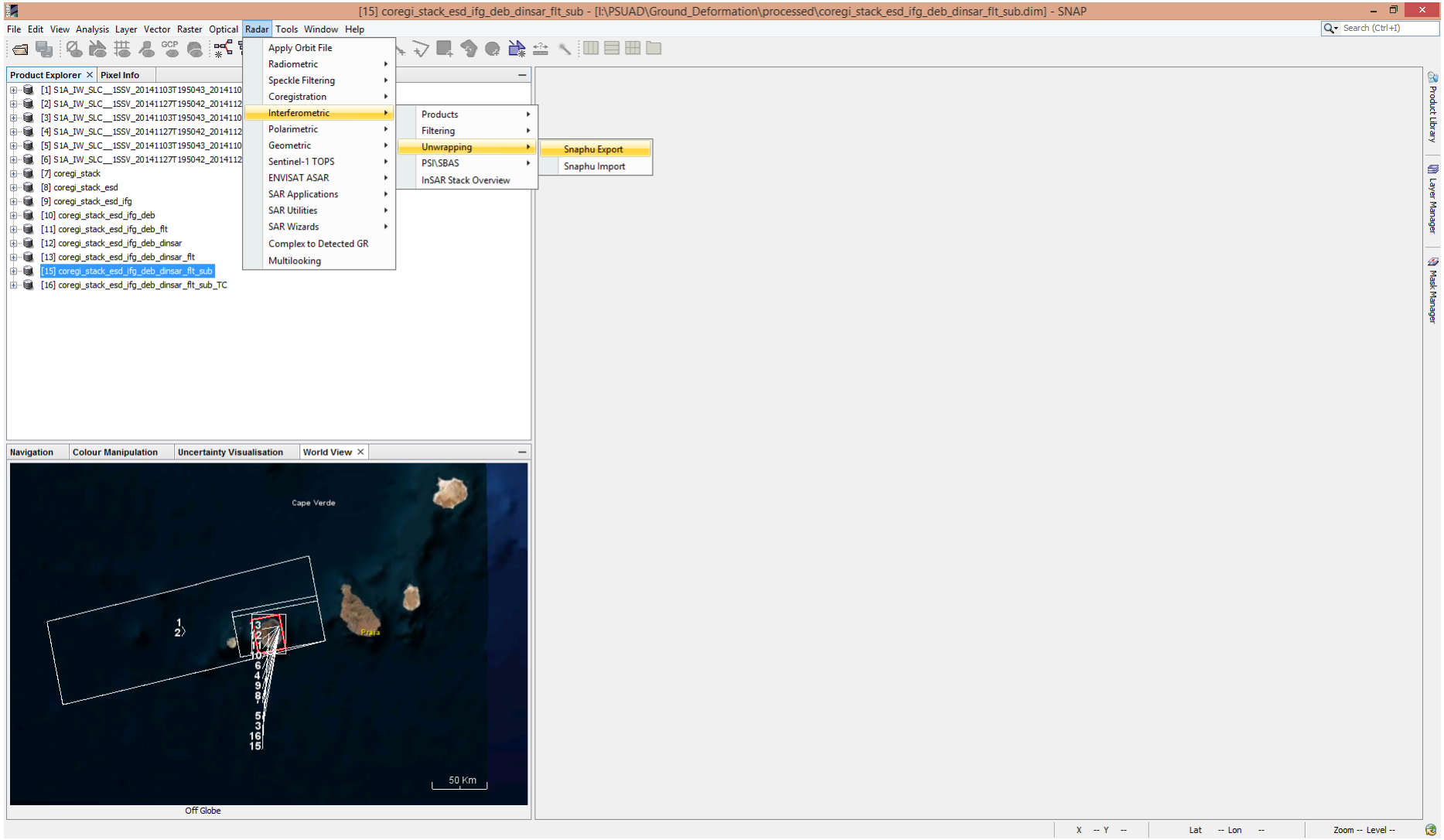
EXERCISE Processing Steps (PART 2)

- Split IW Subswath (incl. Polarization) over AOI
- Update Orbit State Vectors
- Backgeocoding (DEM-assisted coregistration)
- Correct for Range and Azimuth Shifts (ESD algorithm)

  TOPS Coregistration
- Interferogram Generation (incl. Coherence)
- Goldstein Phase Filtering
- Phase Unwrapping (SNAPHU)
- Convert Phase to Displacement
- Terrain Correction Geocoding

Phase Unwrapping

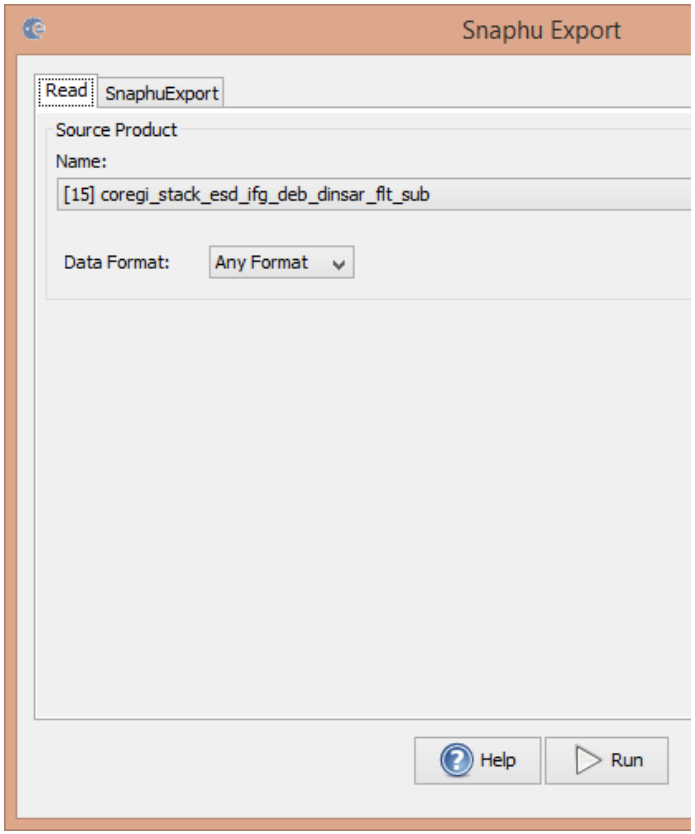
Statistical-cost Network-flow Algorithm for Phase Unwrapping (**SNAPHU**)

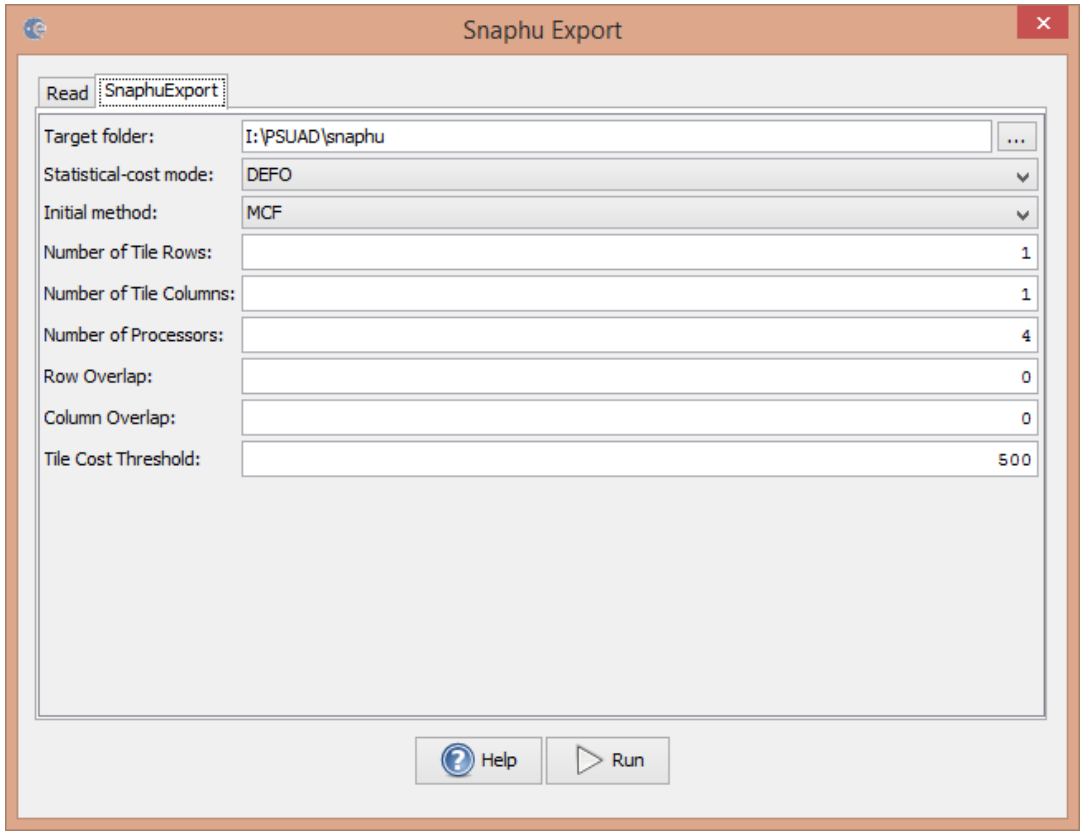


Export to SNAPHU format

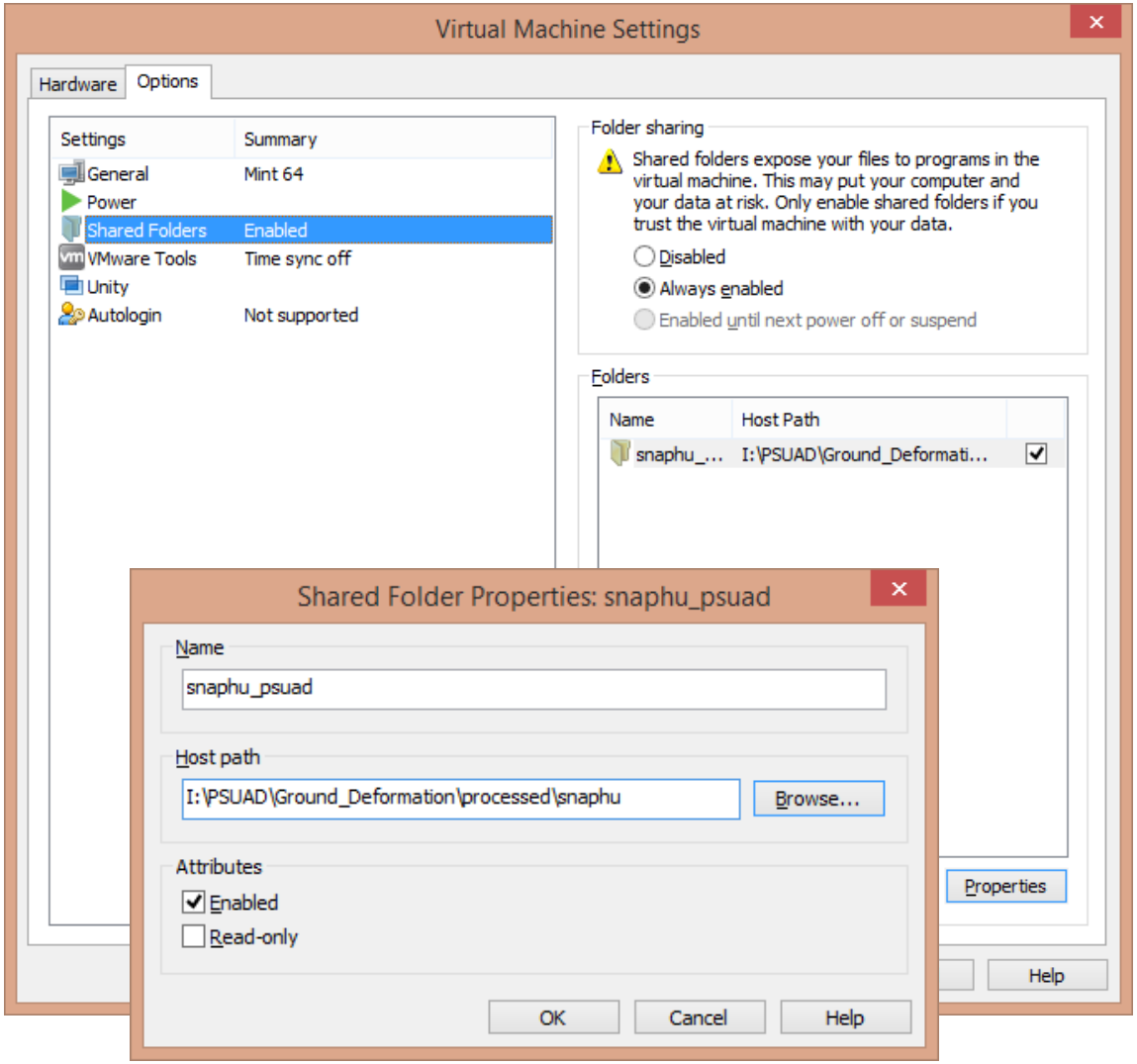
Export files required by SNAPHU to “…\outputs\snaphu” folder

Copy wrapped phases to “…\outputs\snaphu”





Virtual Machine (VM) Setup



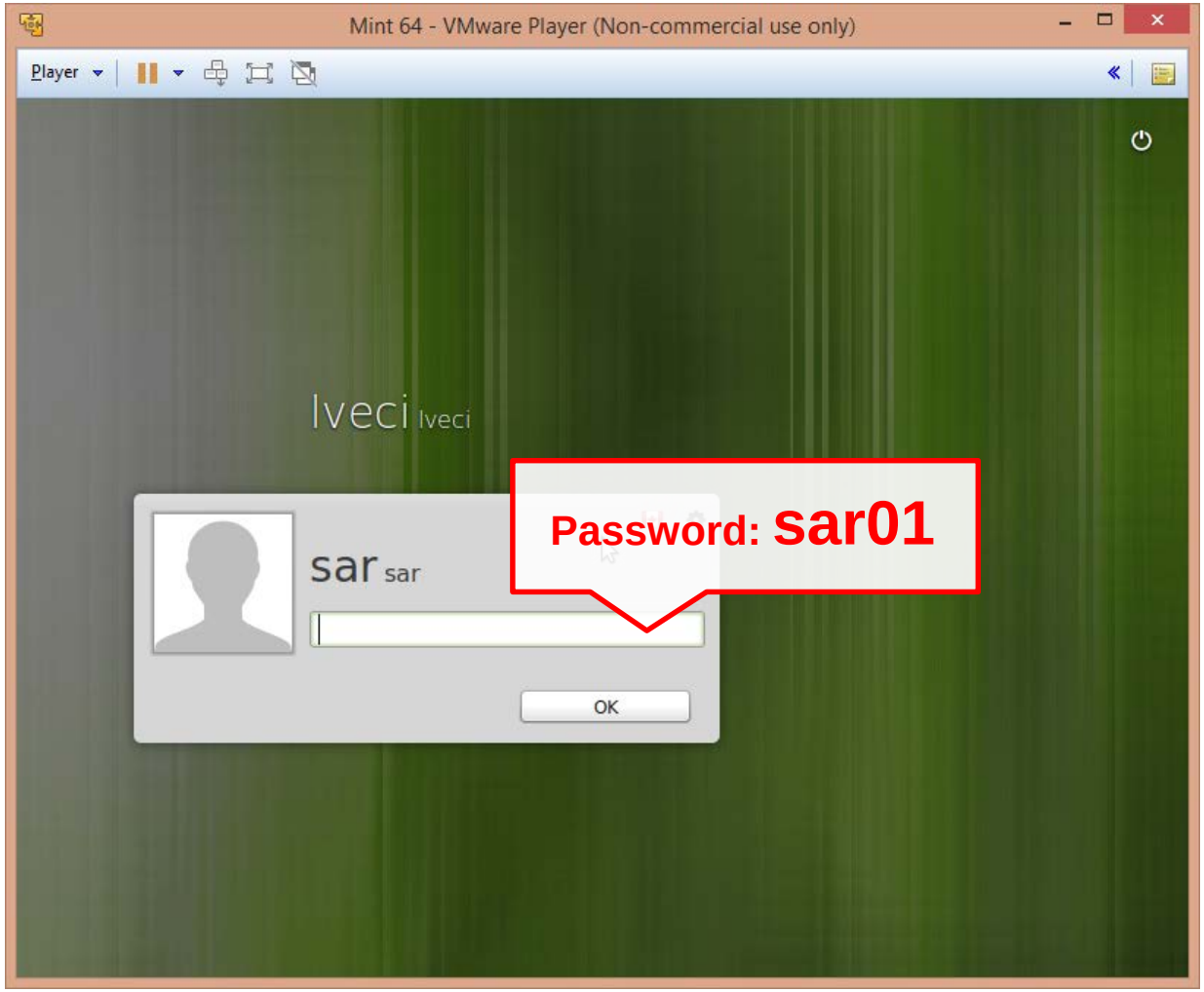
Download and install the dedicated Linux VM on Windows to run SNAPHU and apply phase unwrapping

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

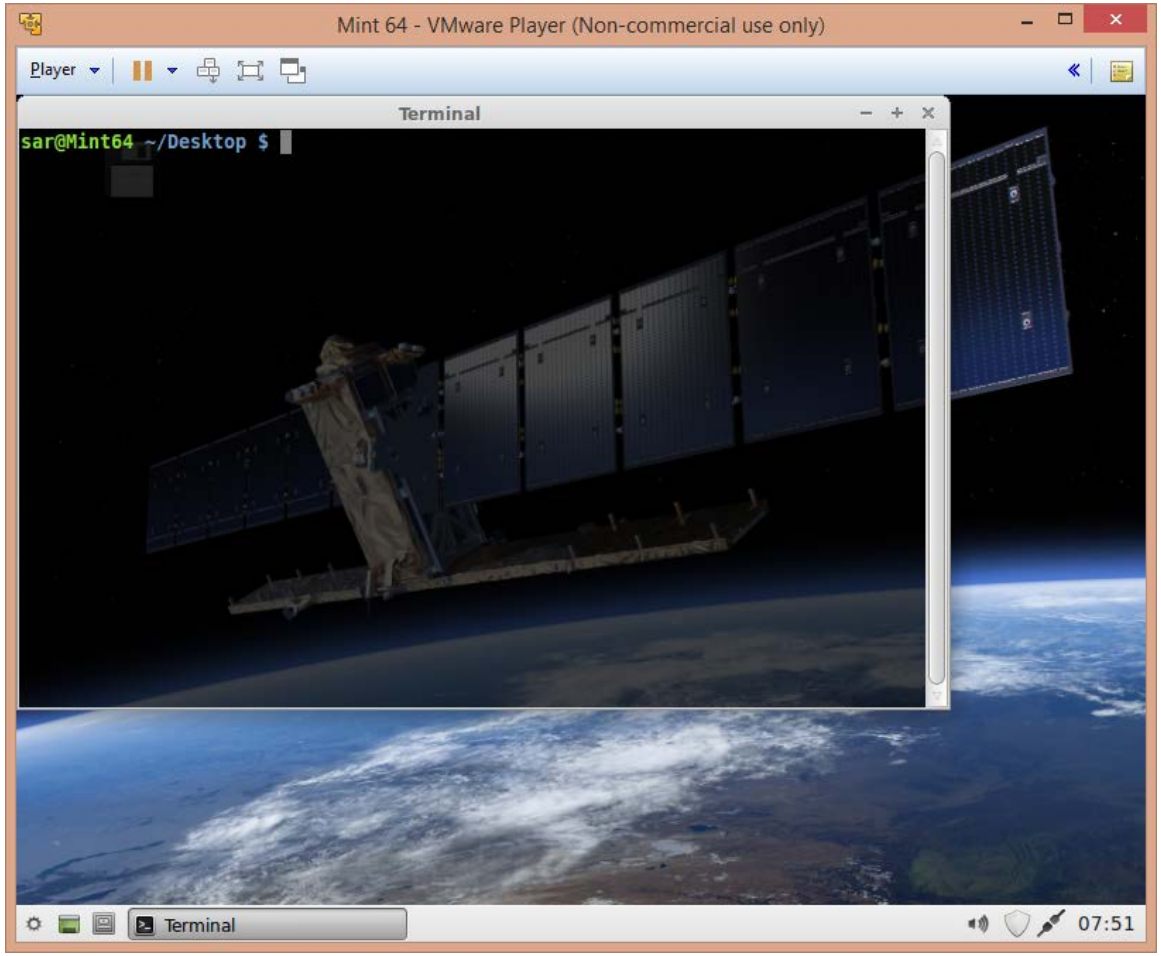
Open the VMware player and browse for the virtual machine

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

VM Initialization



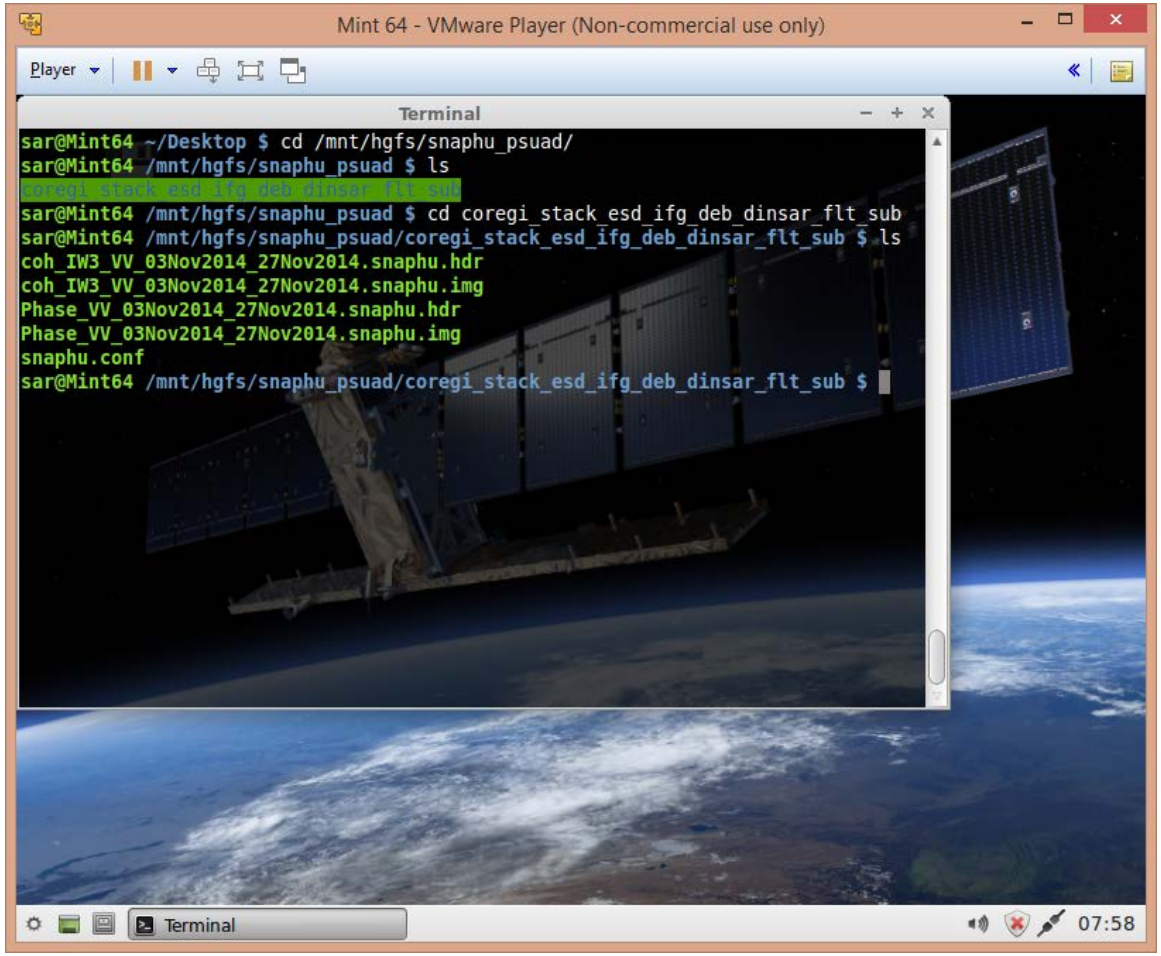
Working in Linux Terminal



Right Click and select

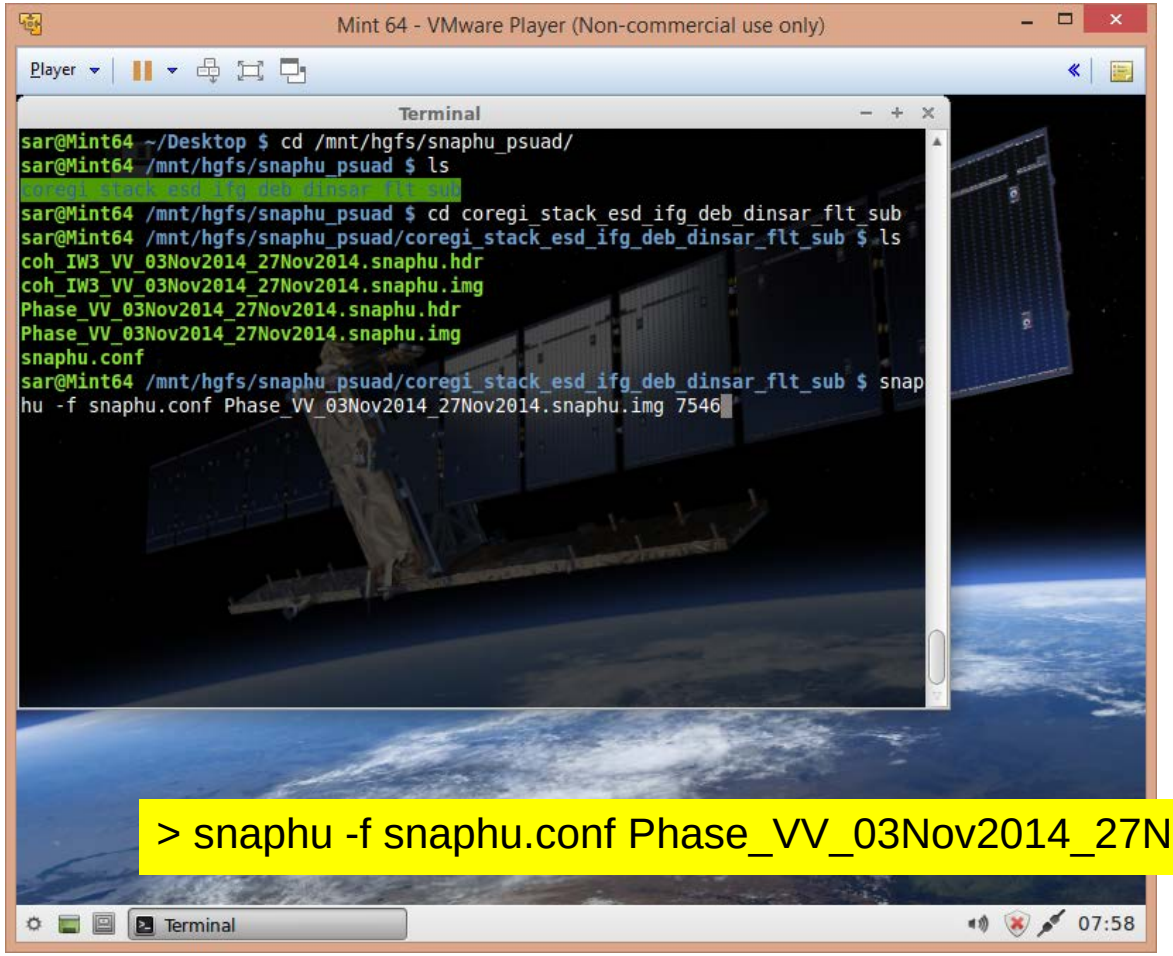
“Open Terminal Here”

NAVigating to Processing Folder



> cd /mnt/hgfs/snaphu/

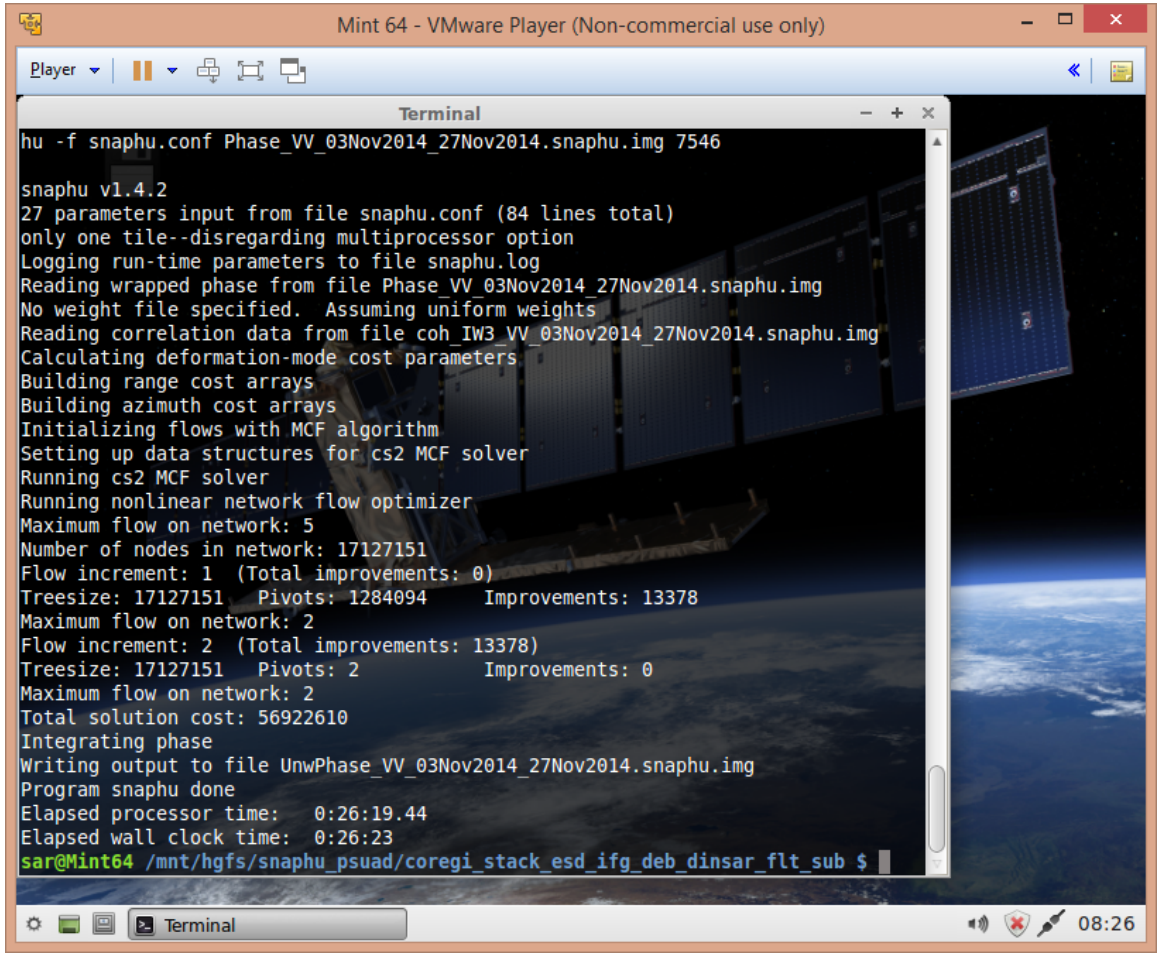
Running Predefined Unwrapping Command



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

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

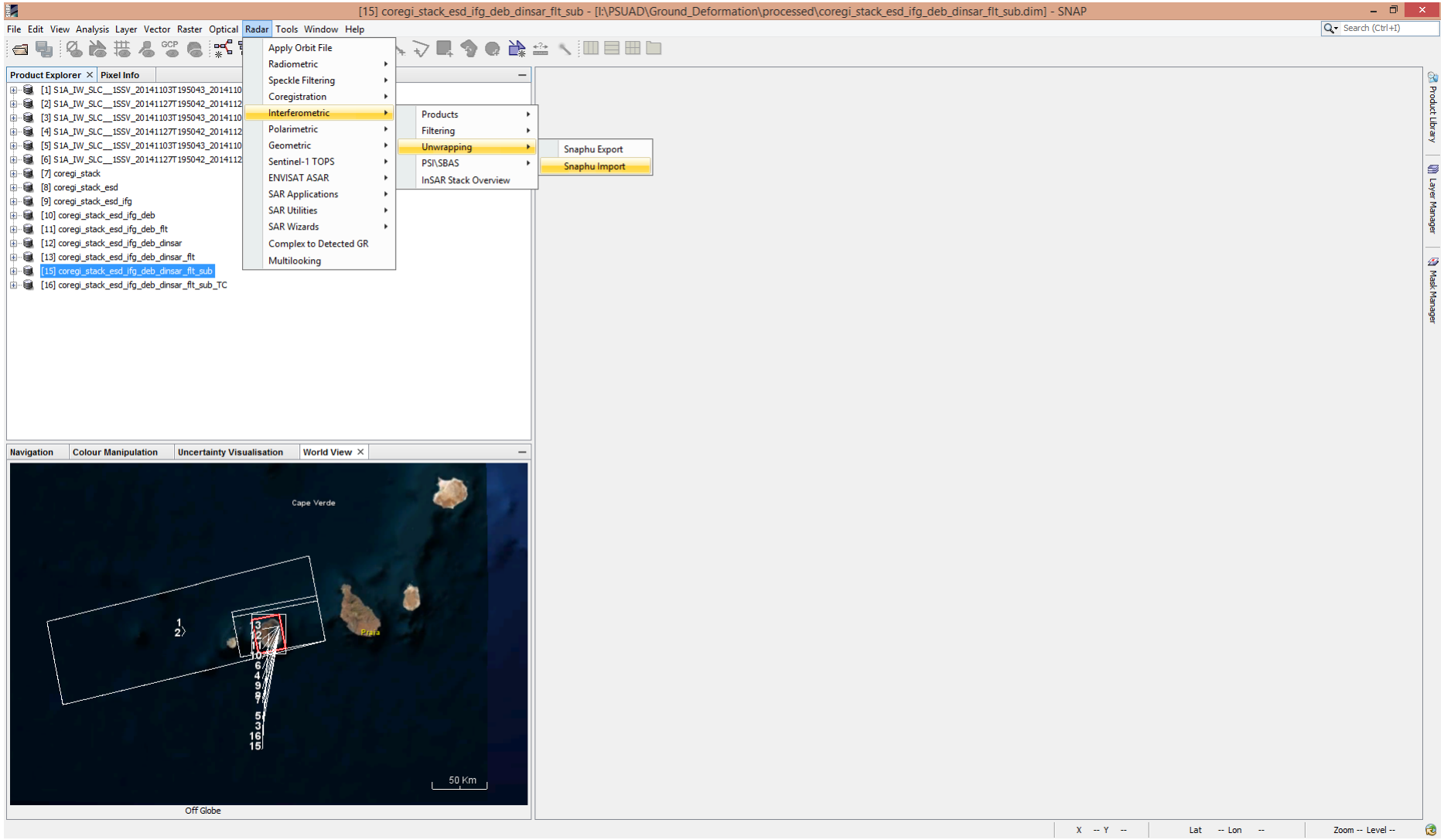
SNAPHU Processing



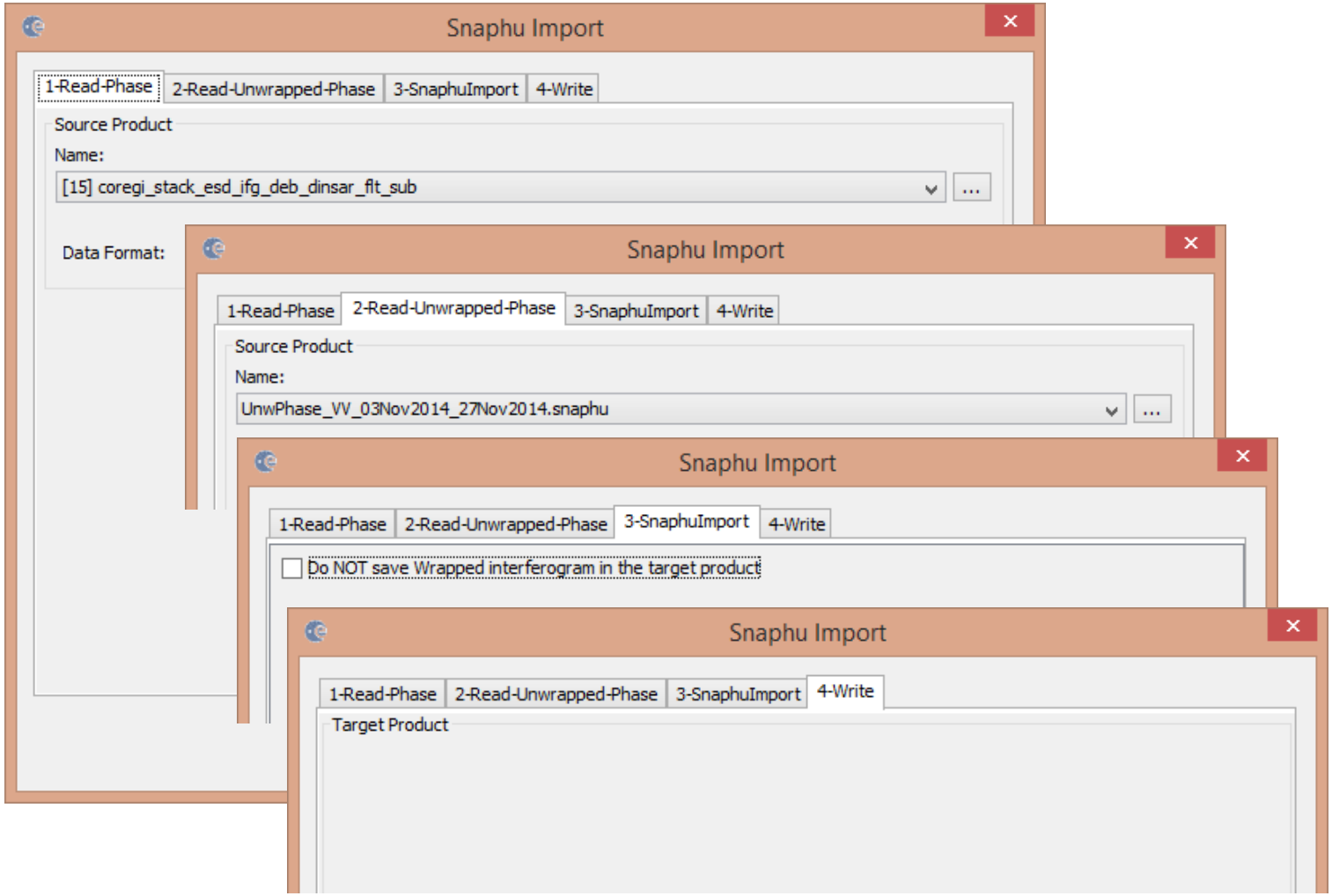
Elapsed Time

00:26:23

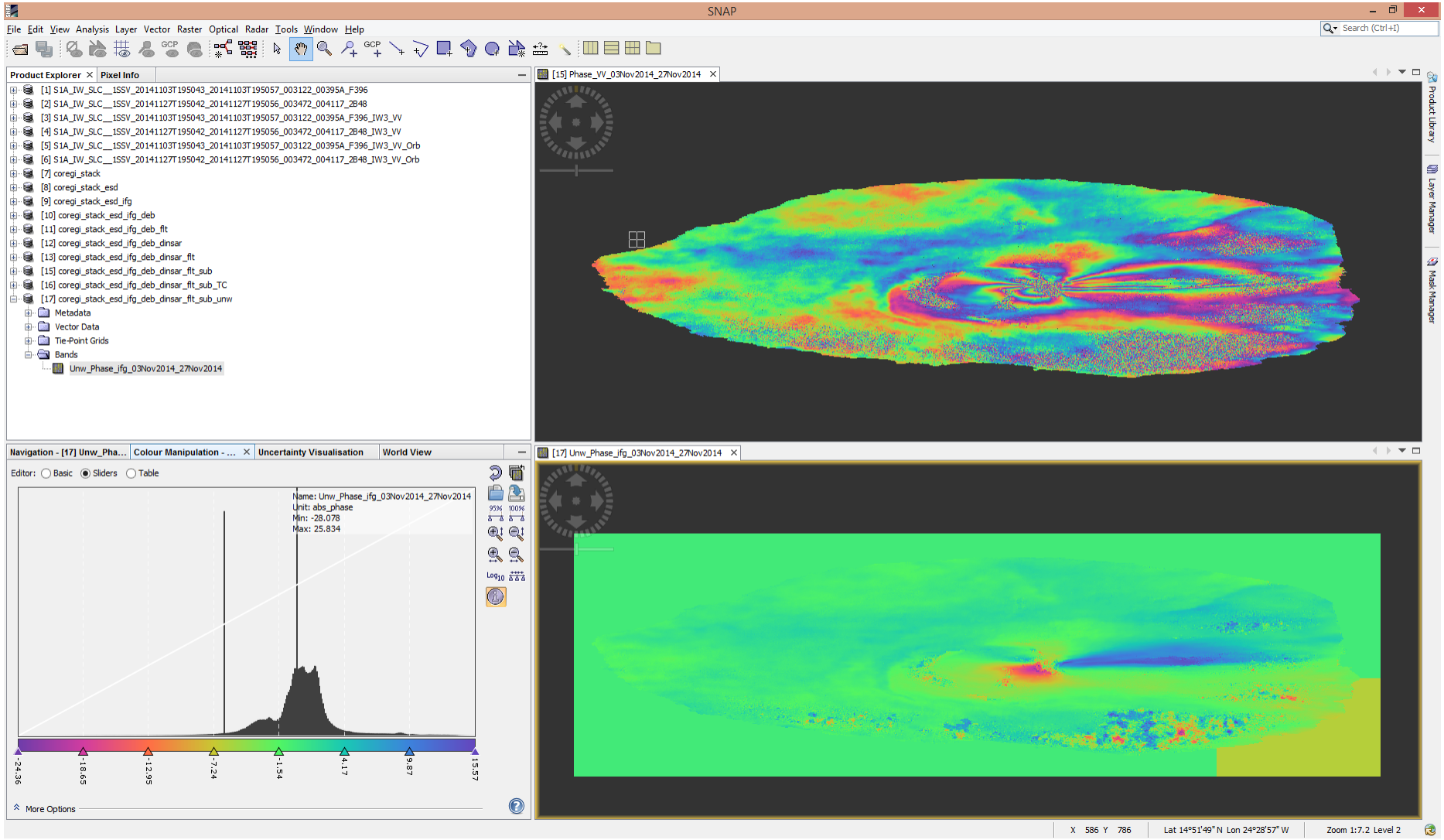
Phase Unwrapping
Import from SNAPHU format



Import from SNAPHU format



Unwrapped Differential Phase (in radians)



EXERCISE

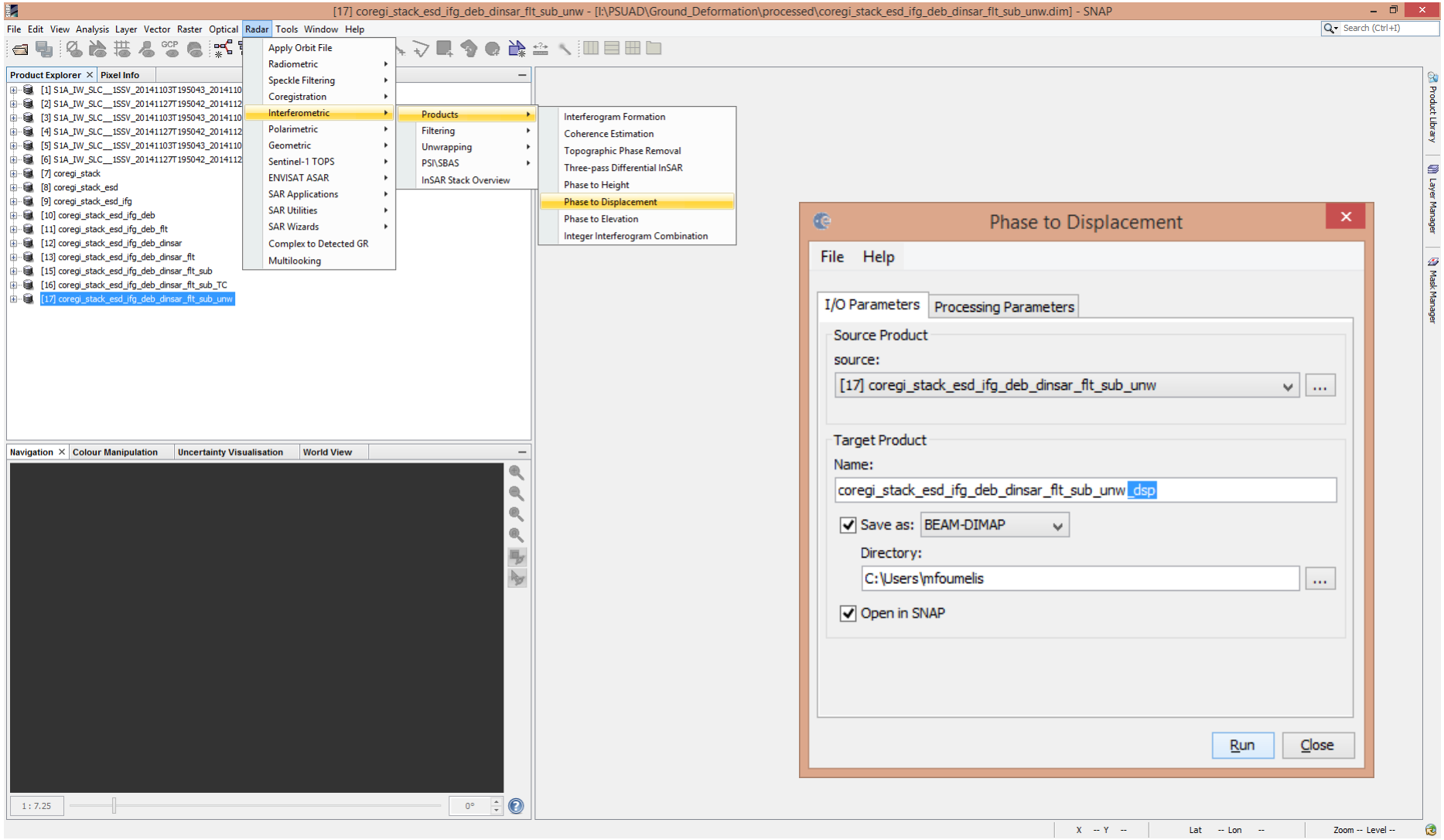
PART 3
Displacement Measurements & Terrain Geocoding

EXERCISE Processing Steps (PART 3)

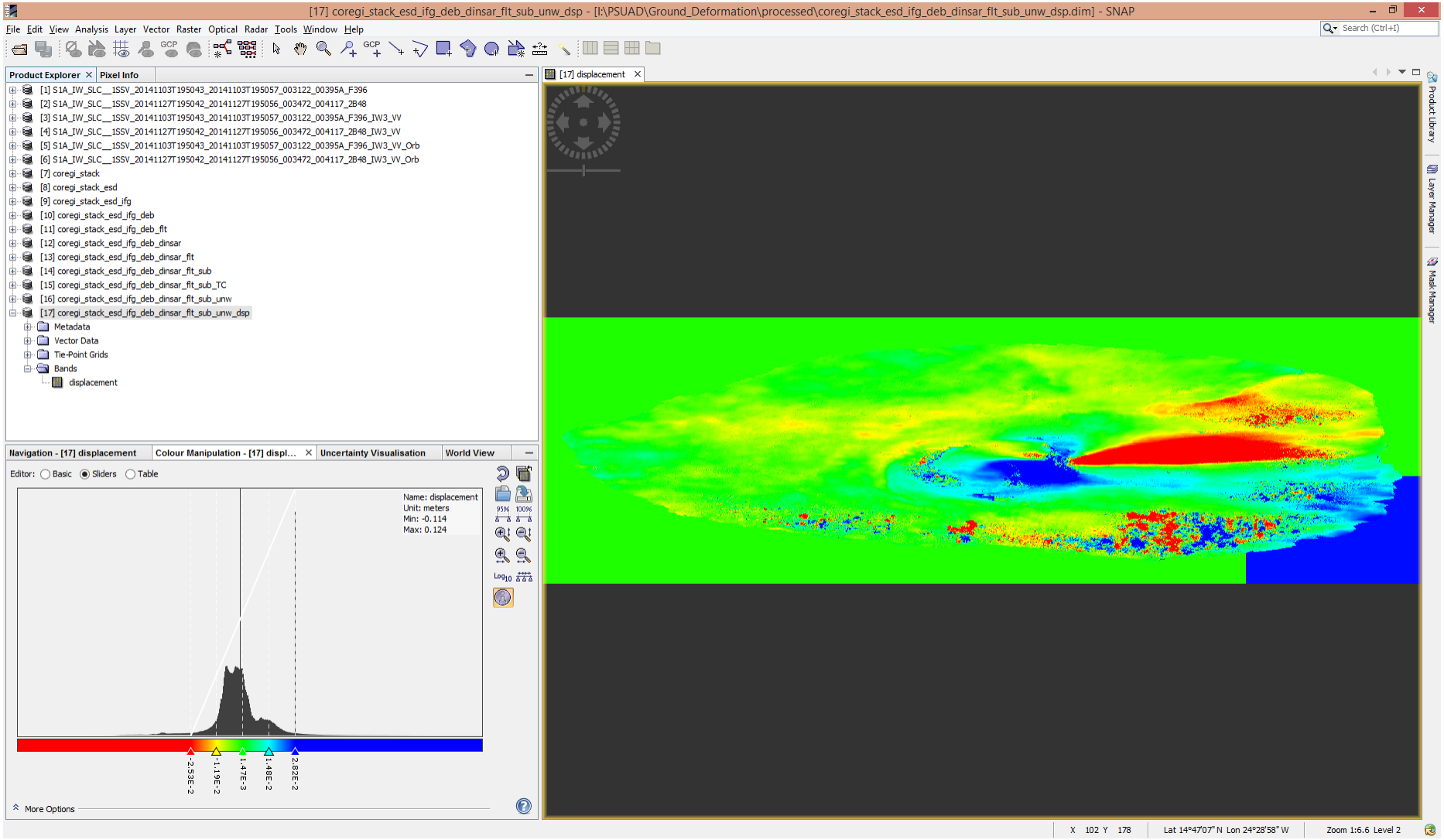
- Split IW Subswath (incl. Polarization) over AOI
- Update Orbit State Vectors
- Backgeocoding (DEM-assisted coregistration)
- Correct for Range and Azimuth Shifts (ESD algorithm)

  TOPS Coregistration
- Interferogram Generation (incl. Coherence)
- Goldstein Phase Filtering
- Phase Unwrapping (SNAPHU)
- Convert Phase to Displacement
- Terrain Correction Geocoding

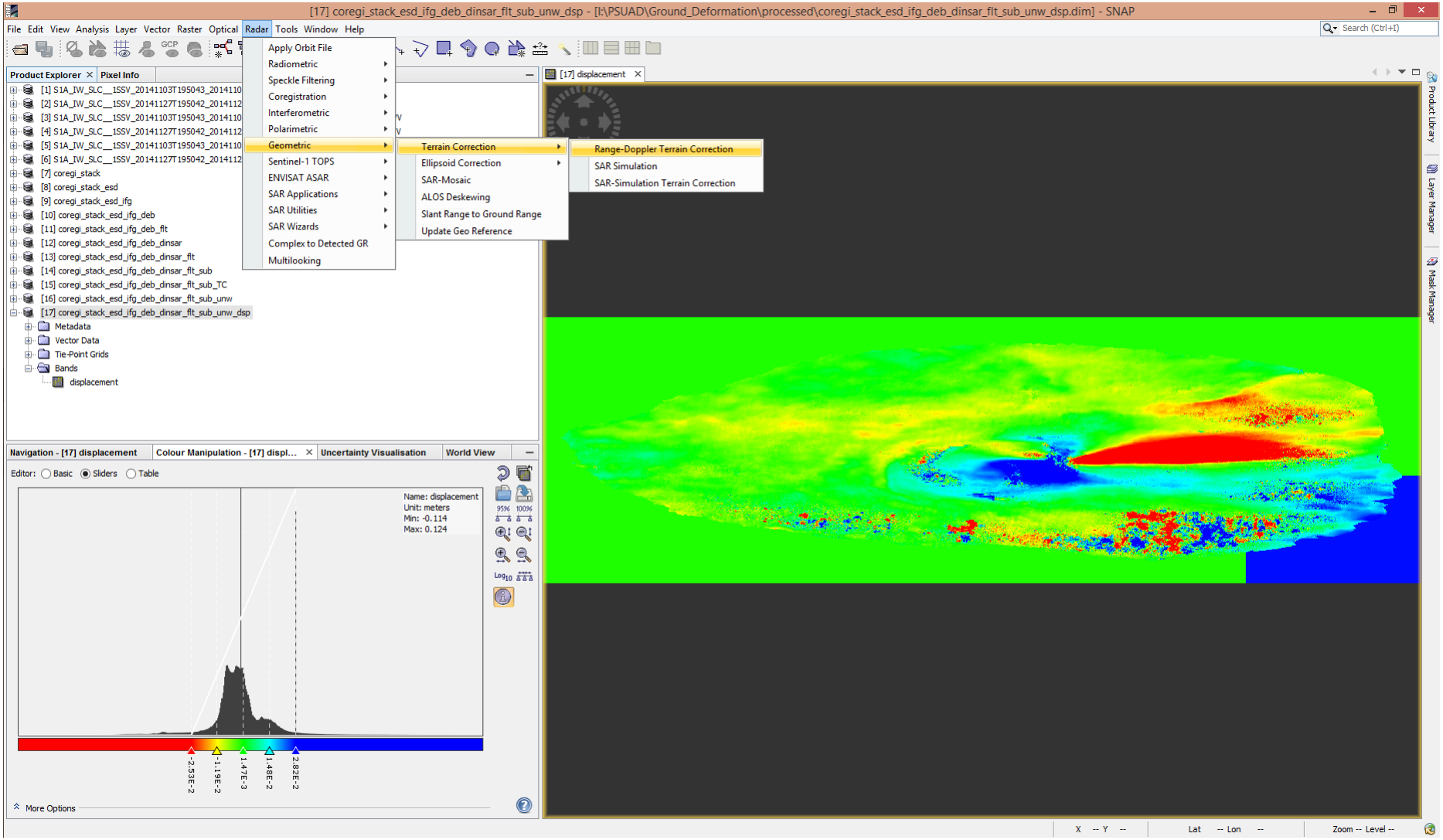
Conversion of Unwrapped Phase to Displacement



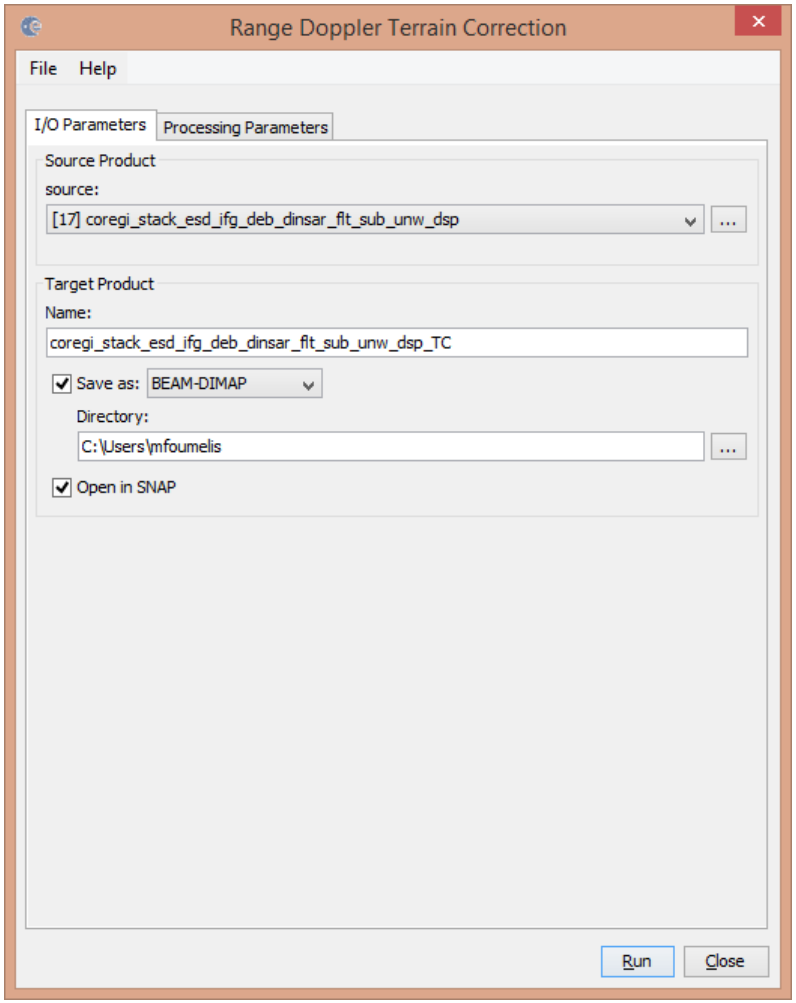
Ground Displacement along the Line-of-Sight (LOS)

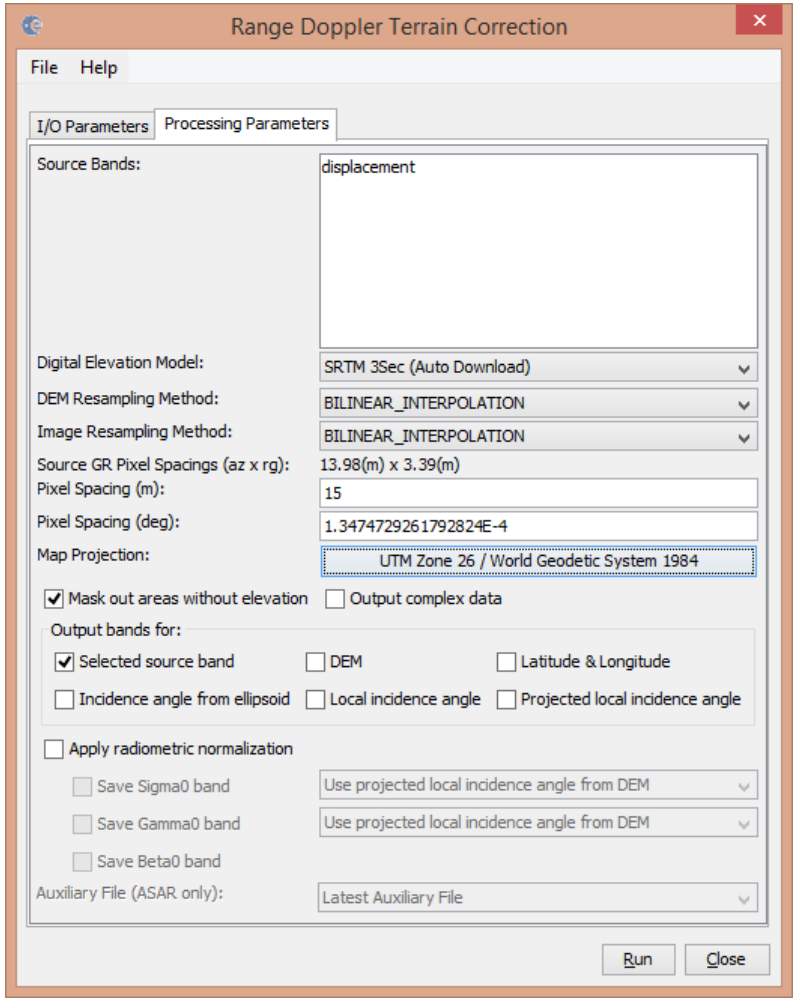


Geocoding of Sentinel-1 Ground Displacements

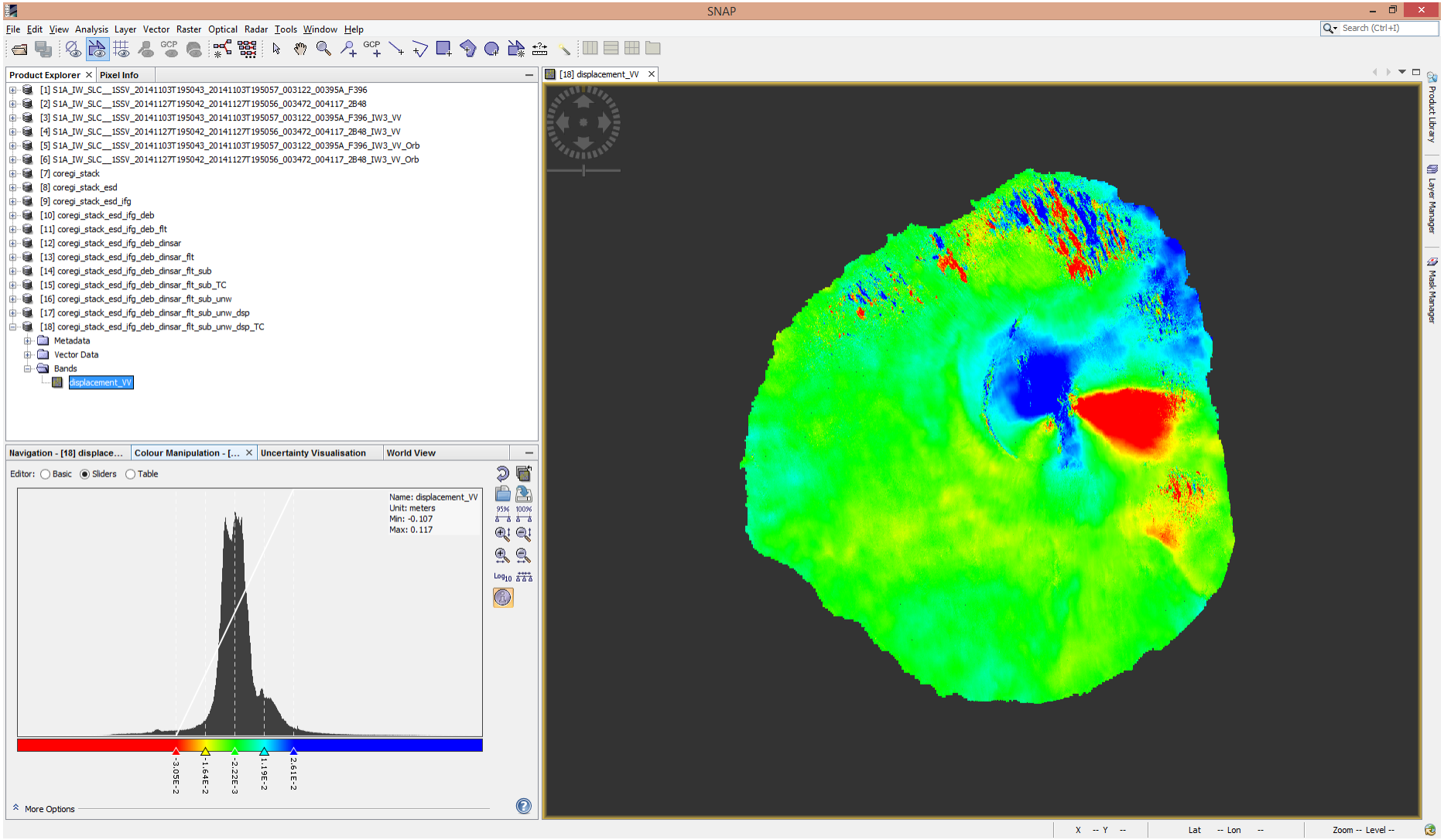


Geocoding of Sentinel-1 Ground Displacements

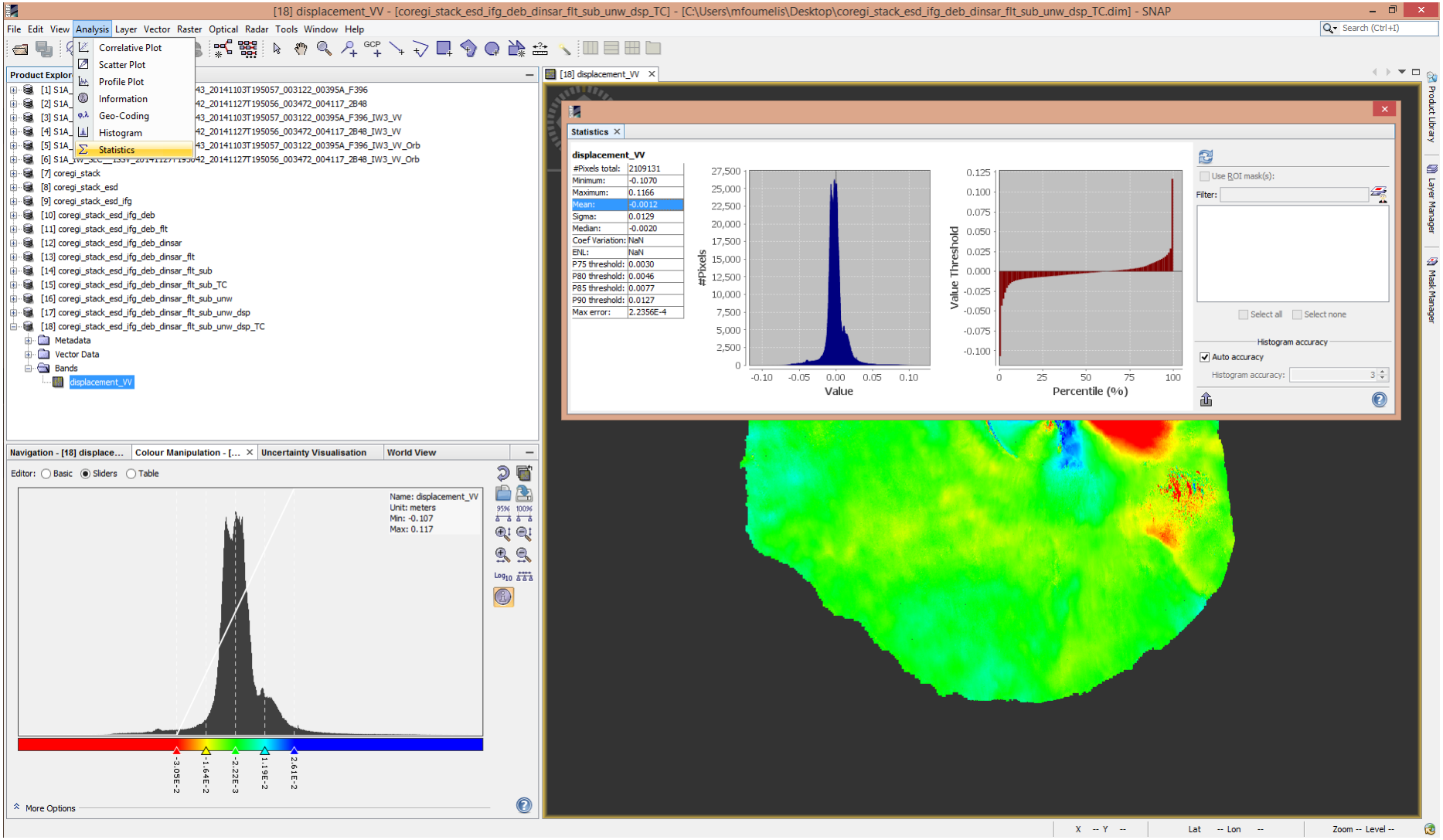




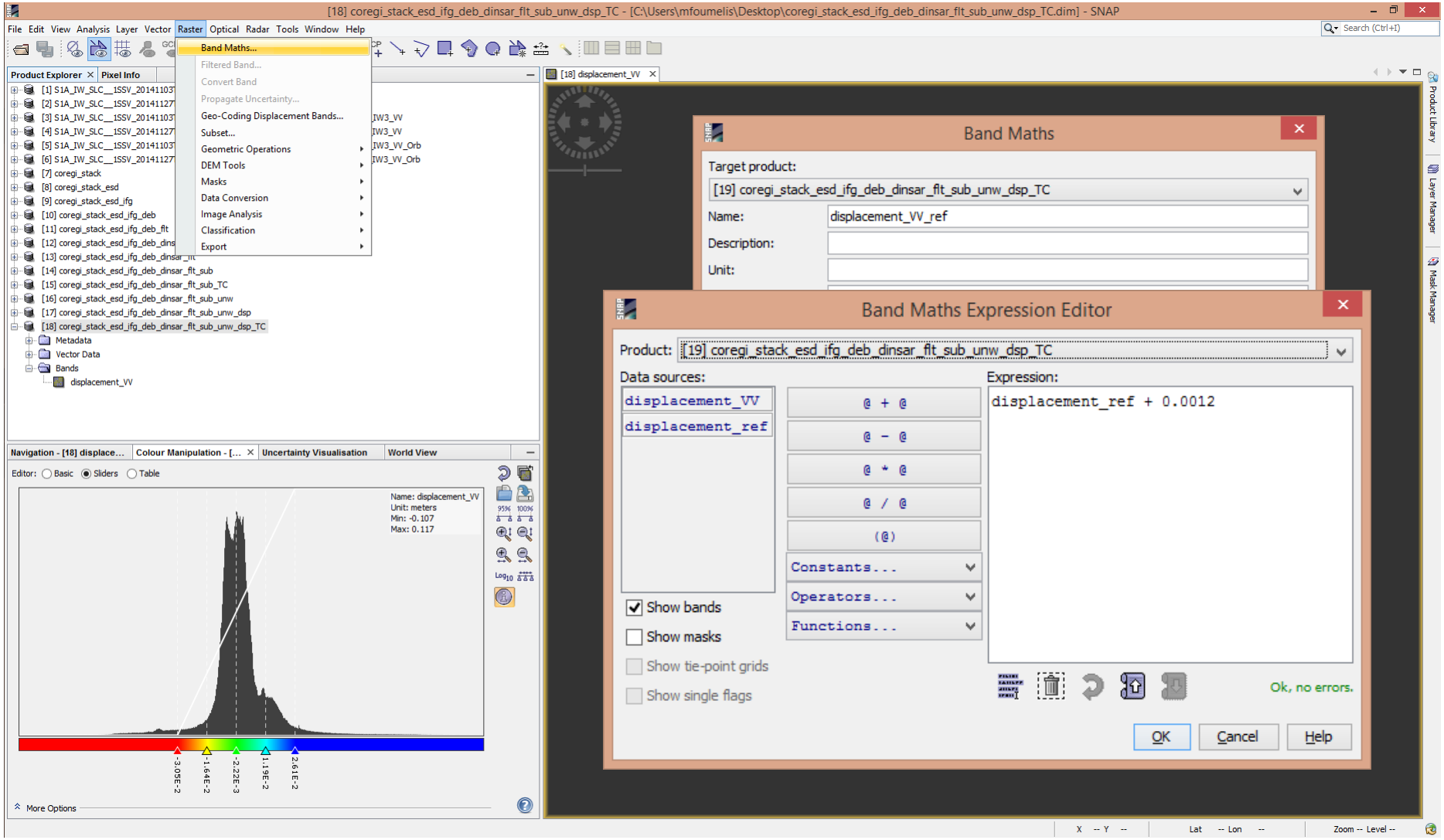
Terrain Corrected
S1 TOPS Ground Displacements



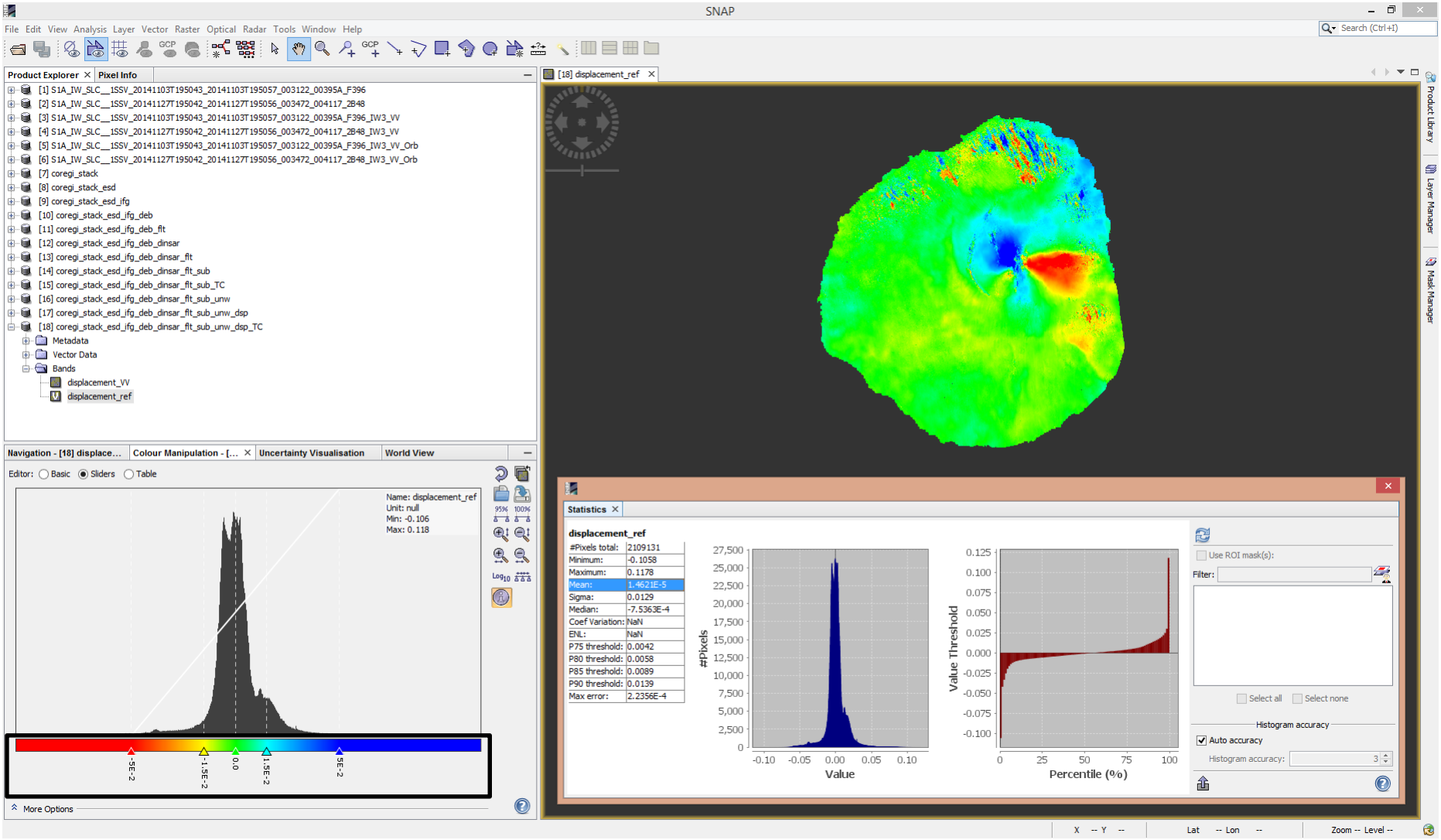
Post-processing
Selection of Local Reference



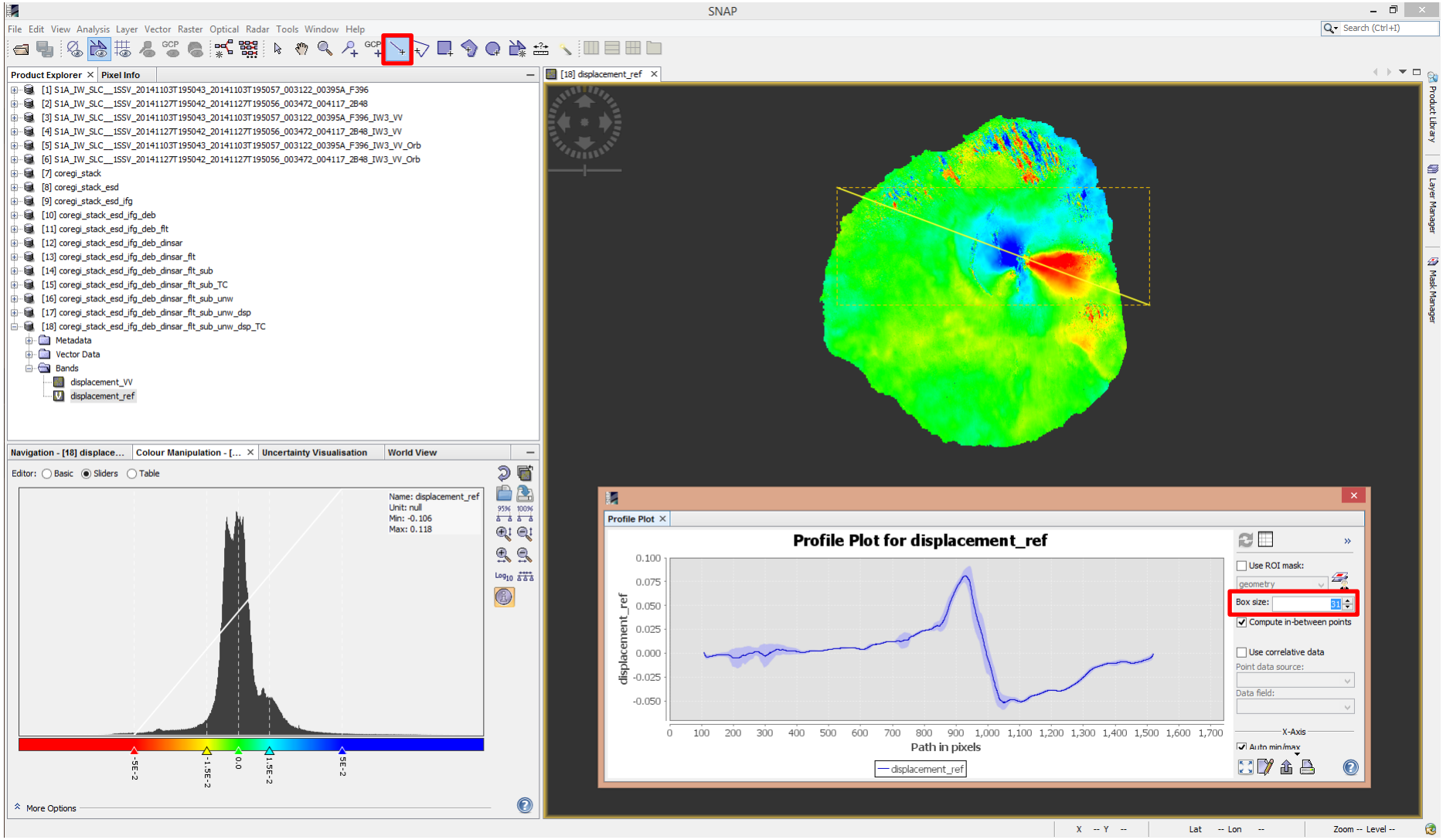
Post-processing
Referencing Displacements



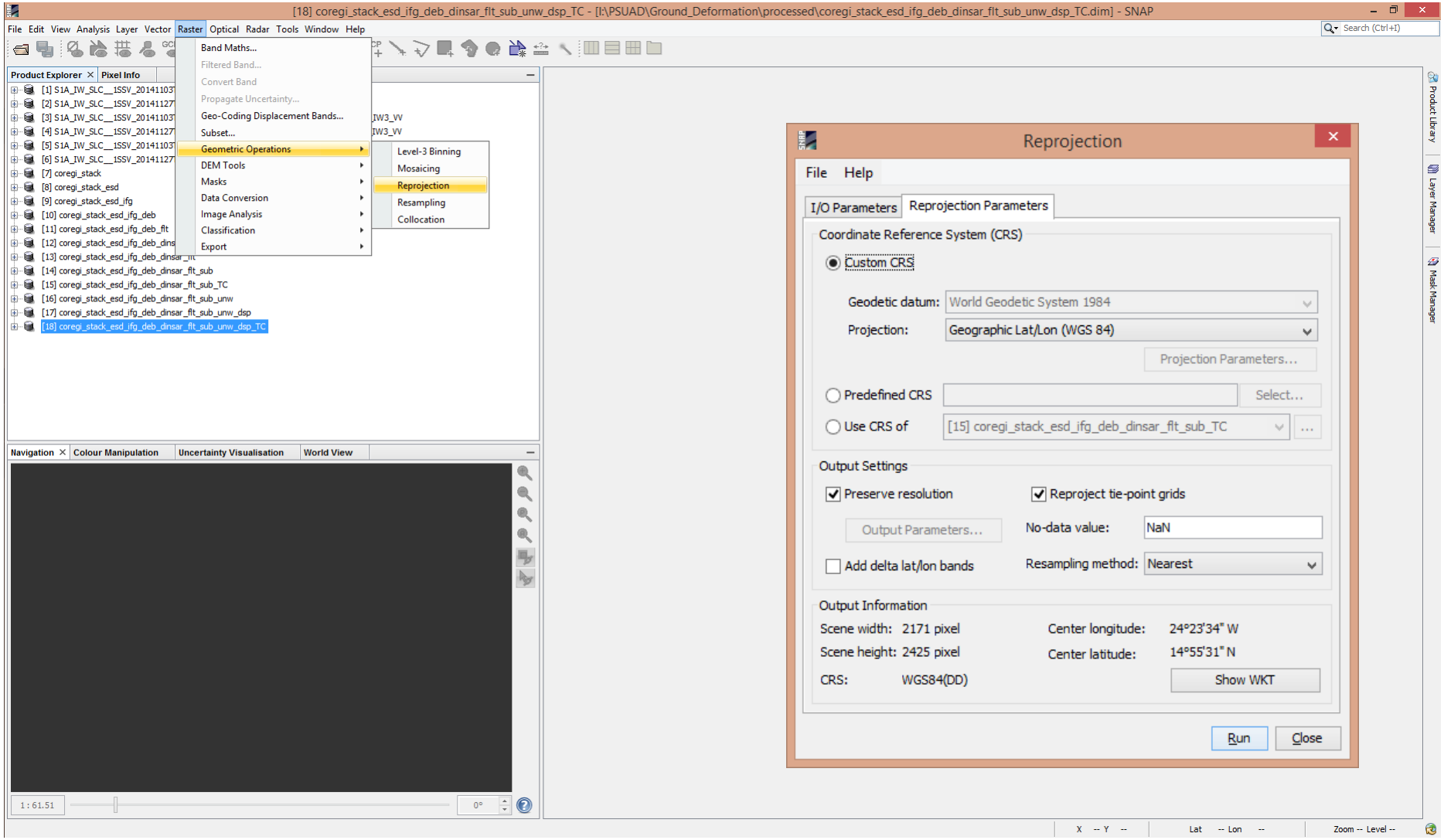
Post-processing
Arranging Colour Ramps



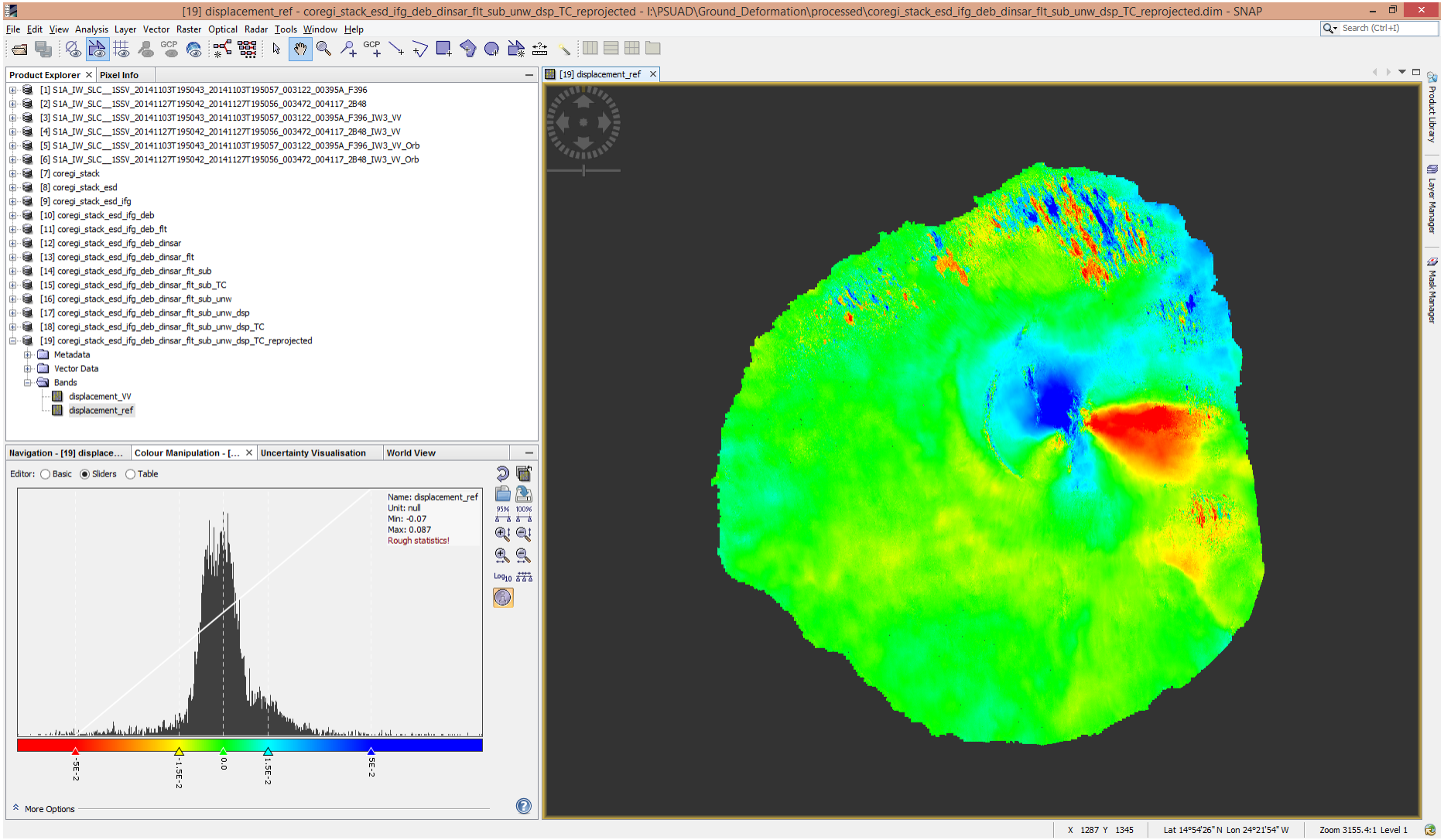
Post-processing
Spatial Profile Plots



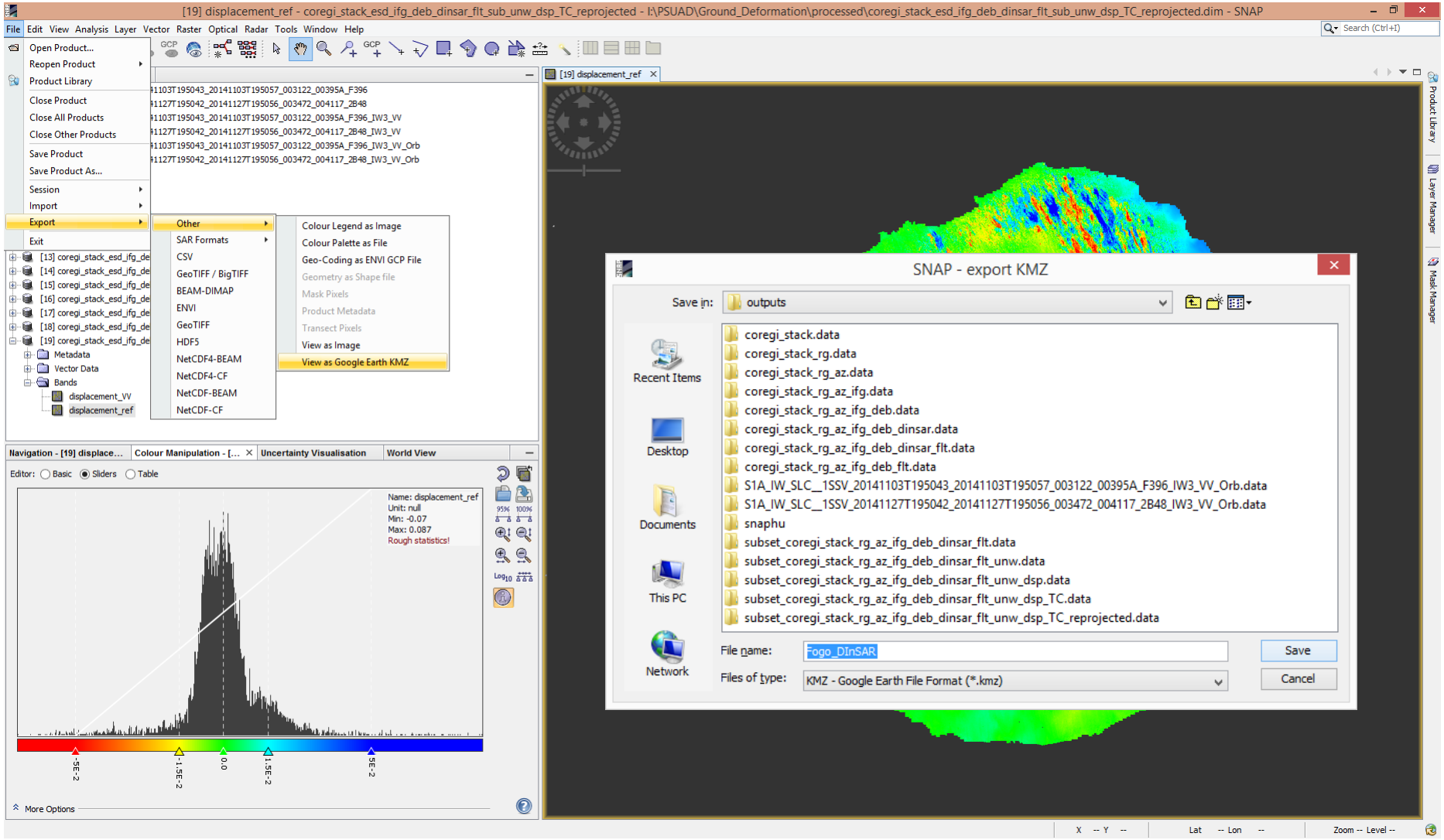
Data Reprojection Geographic Lat/Lon (WGS'84)

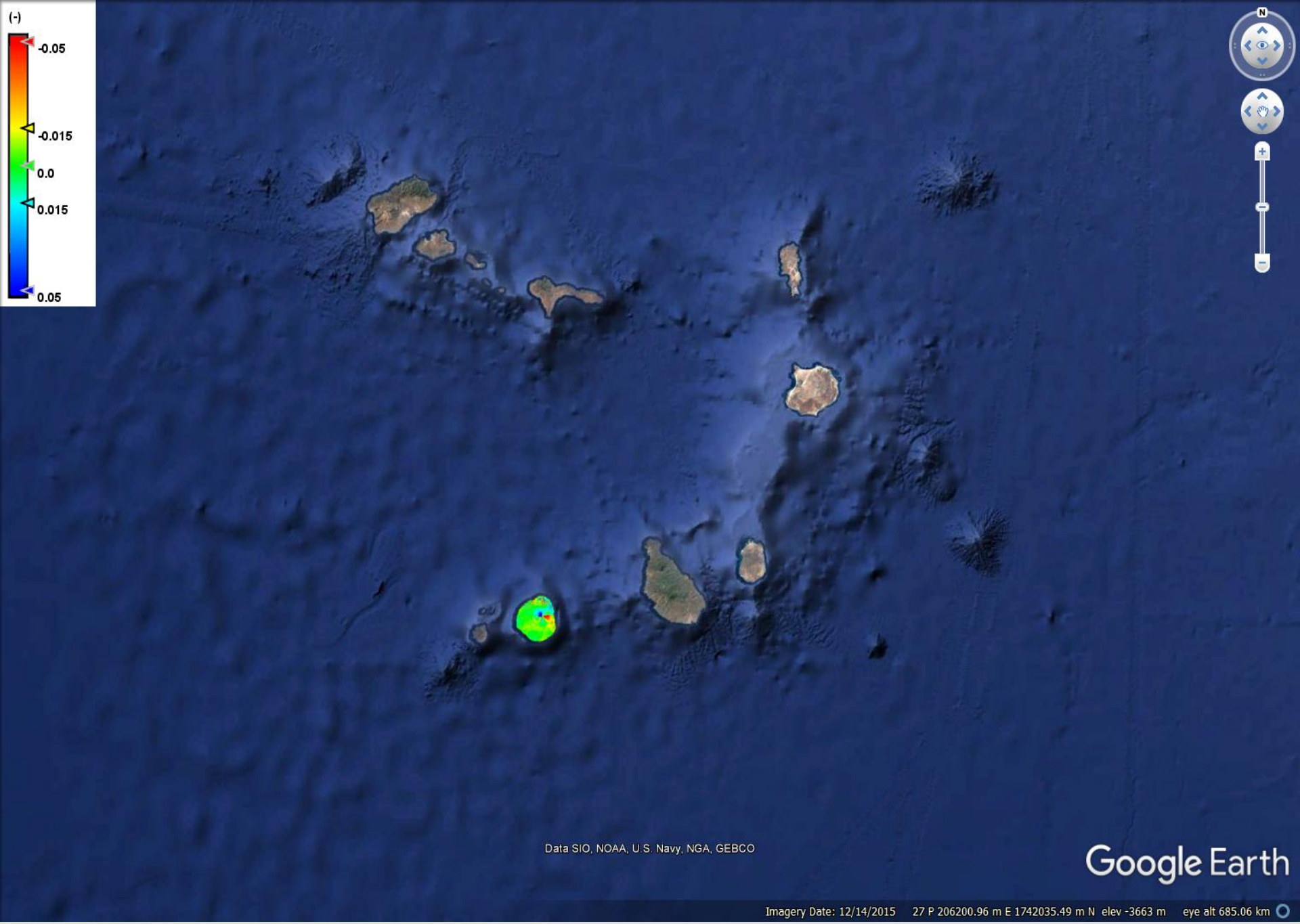


Inspection of Reprojected Products



Export to Google Earth (*.kmz file)

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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth
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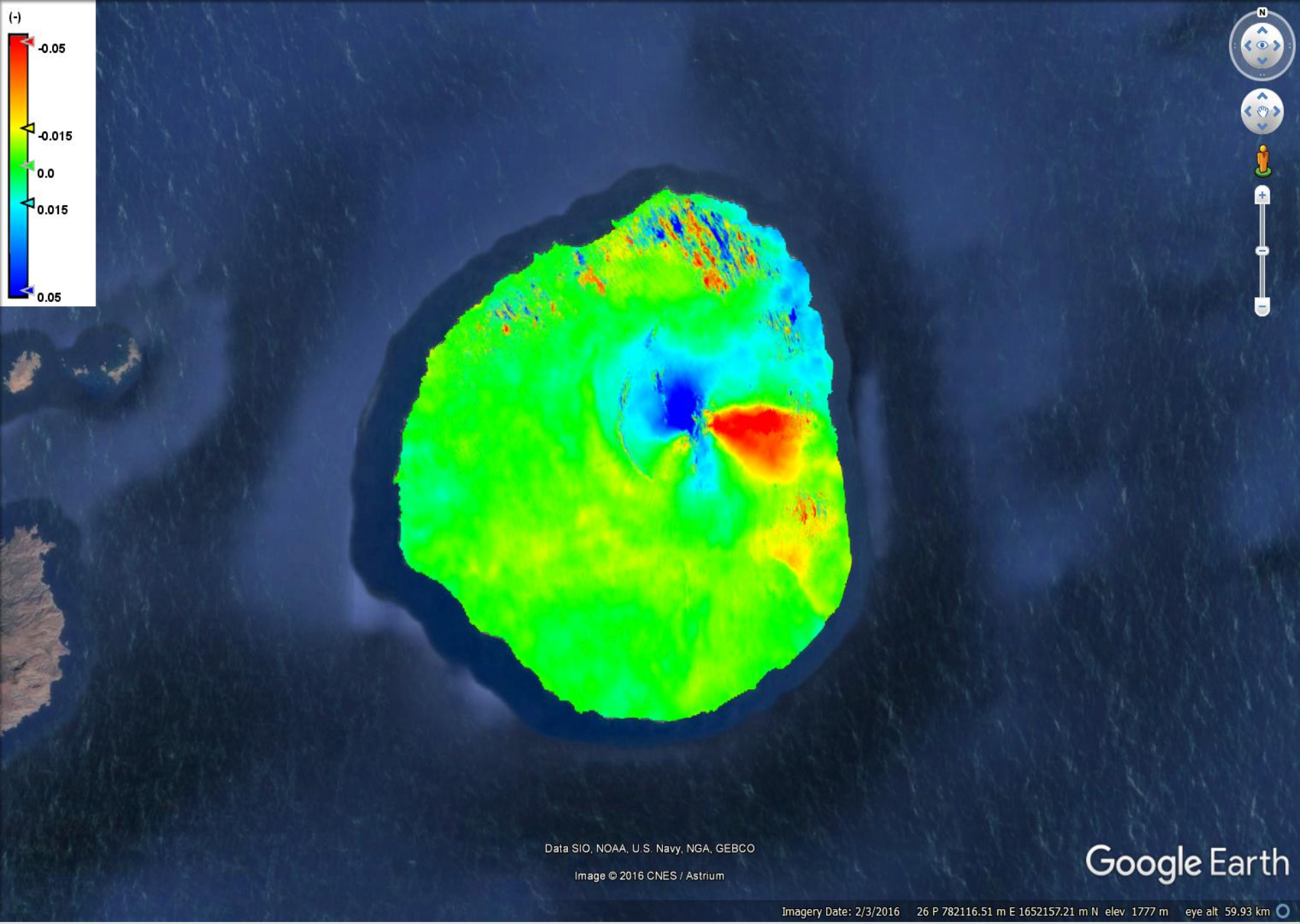
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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2016 CNES / Astrium
Google Earth
Imagery Date: 2/3/2016 26 P 782116.51 m E 1652157.21 m N elev 1777 m eye alt 59.93 km


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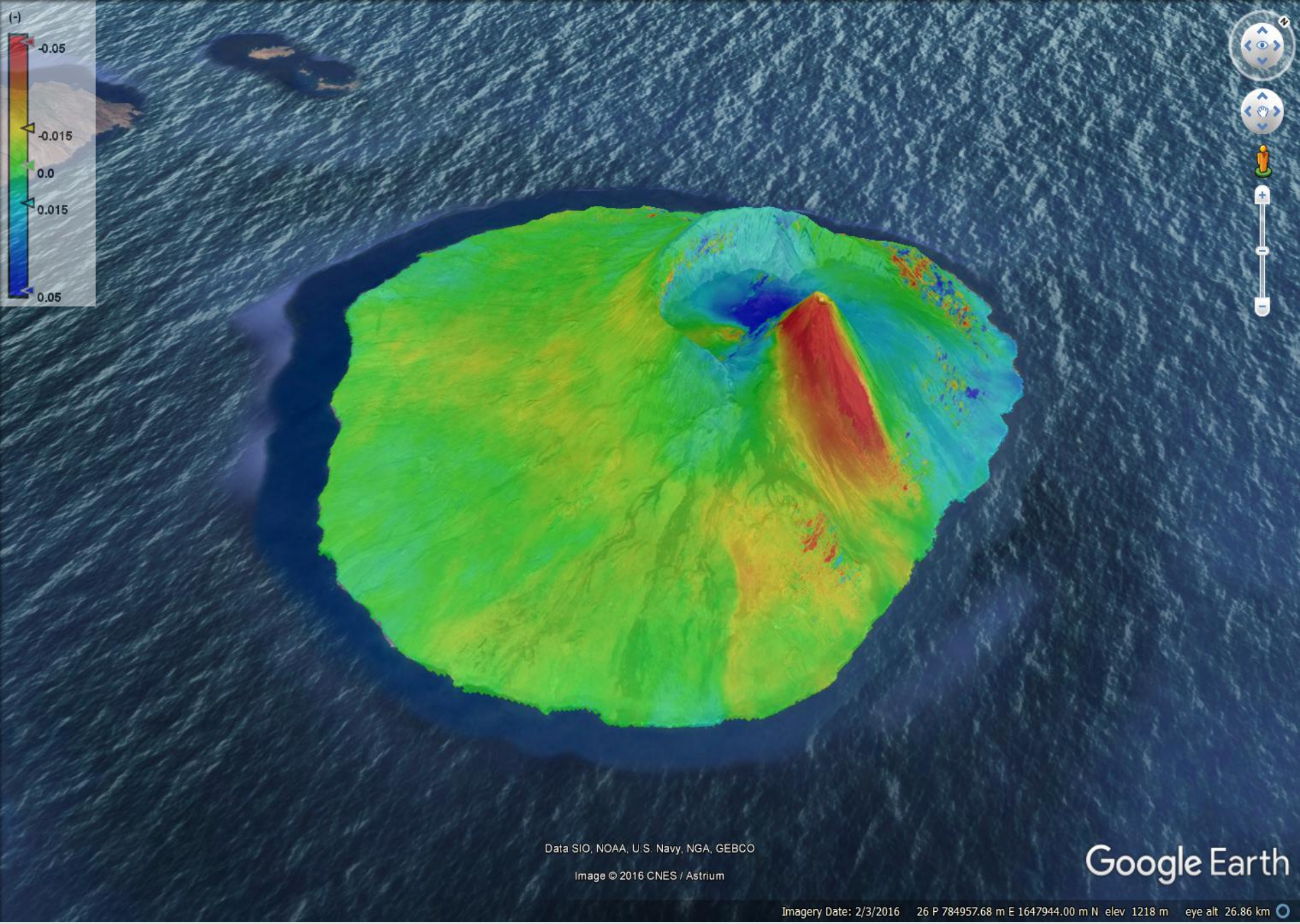
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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2016 CNES / Astrium
Google Earth
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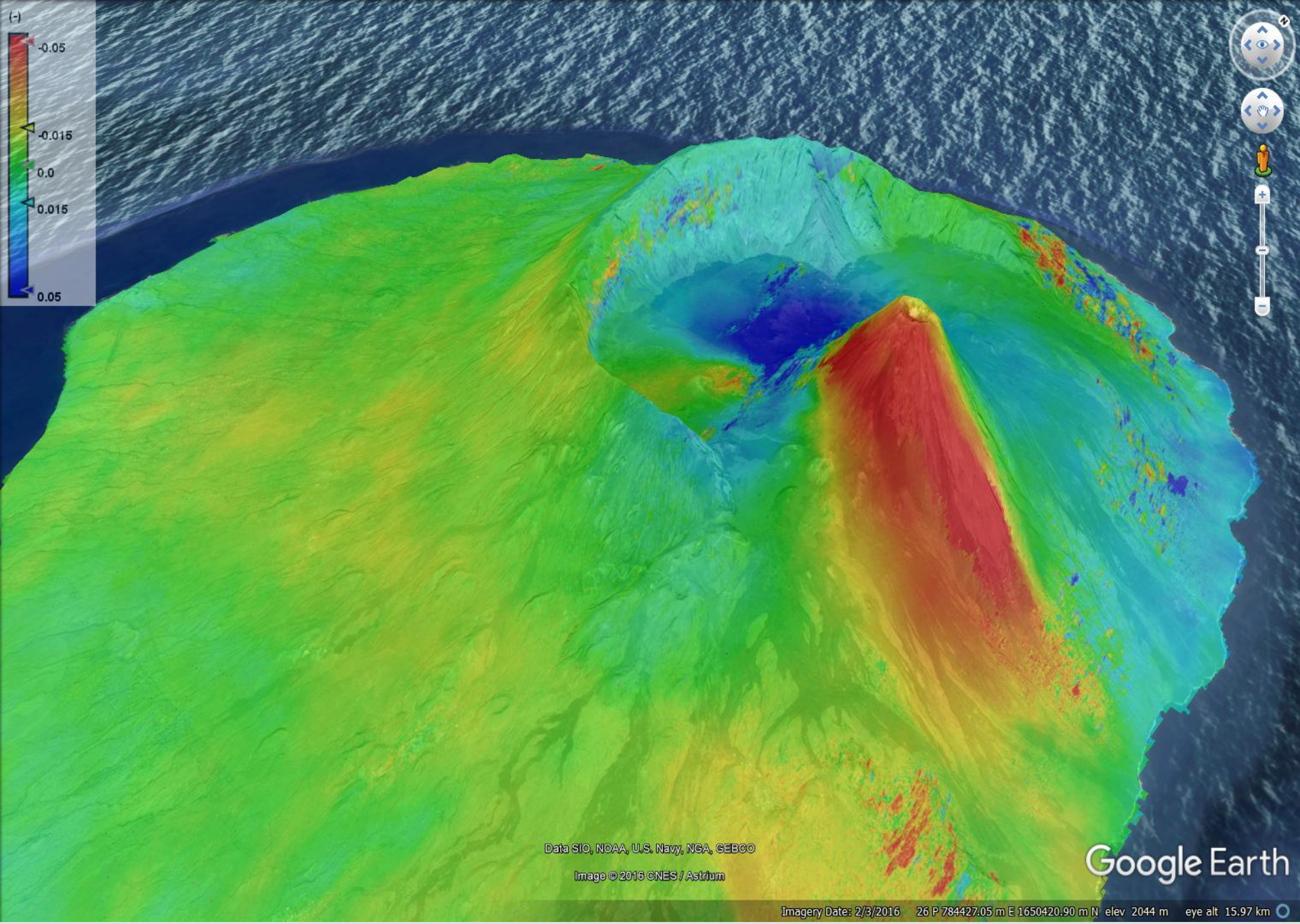
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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2016 CNES / Astrium
Google Earth
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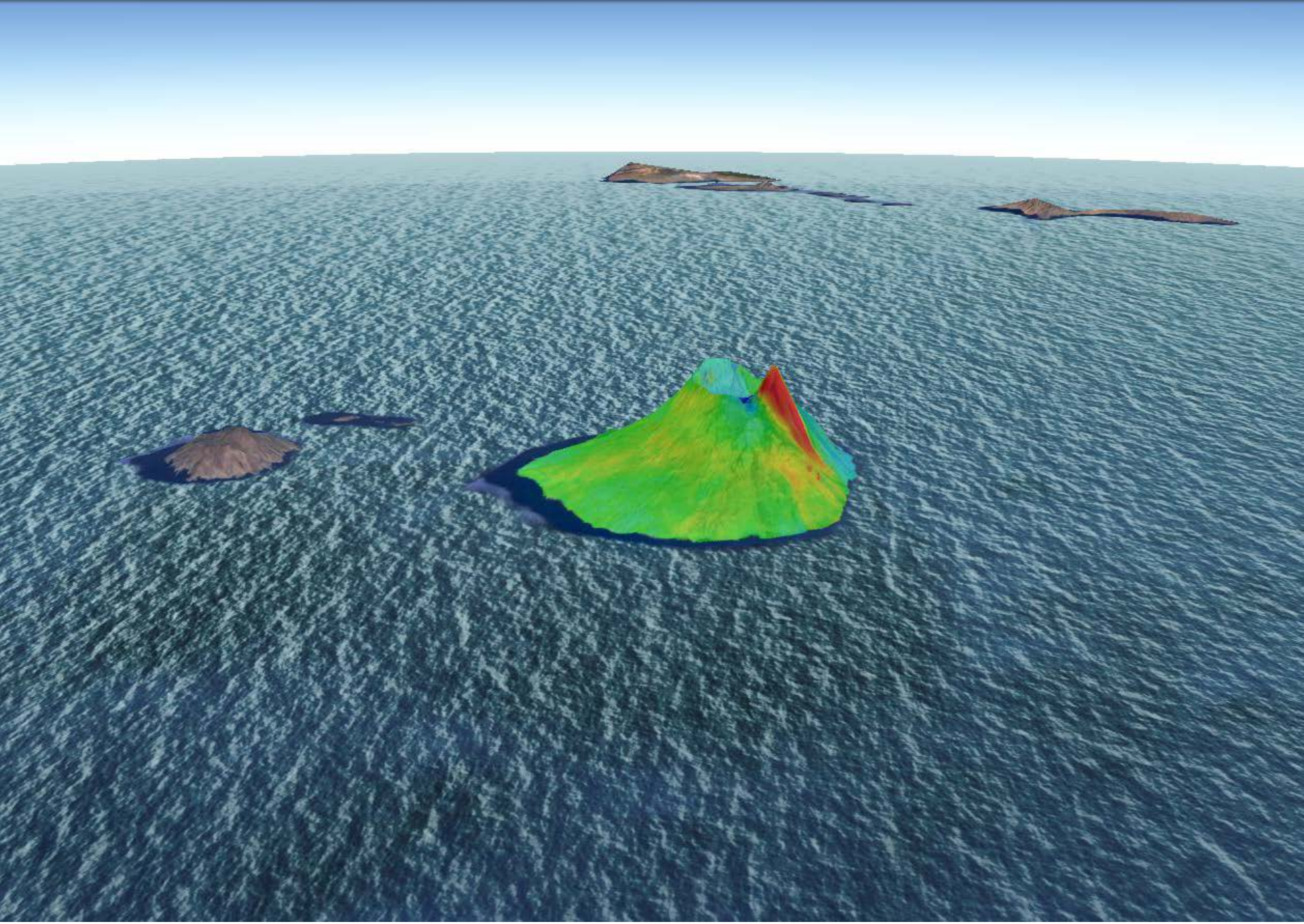

Lesson Learnt

- 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?

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