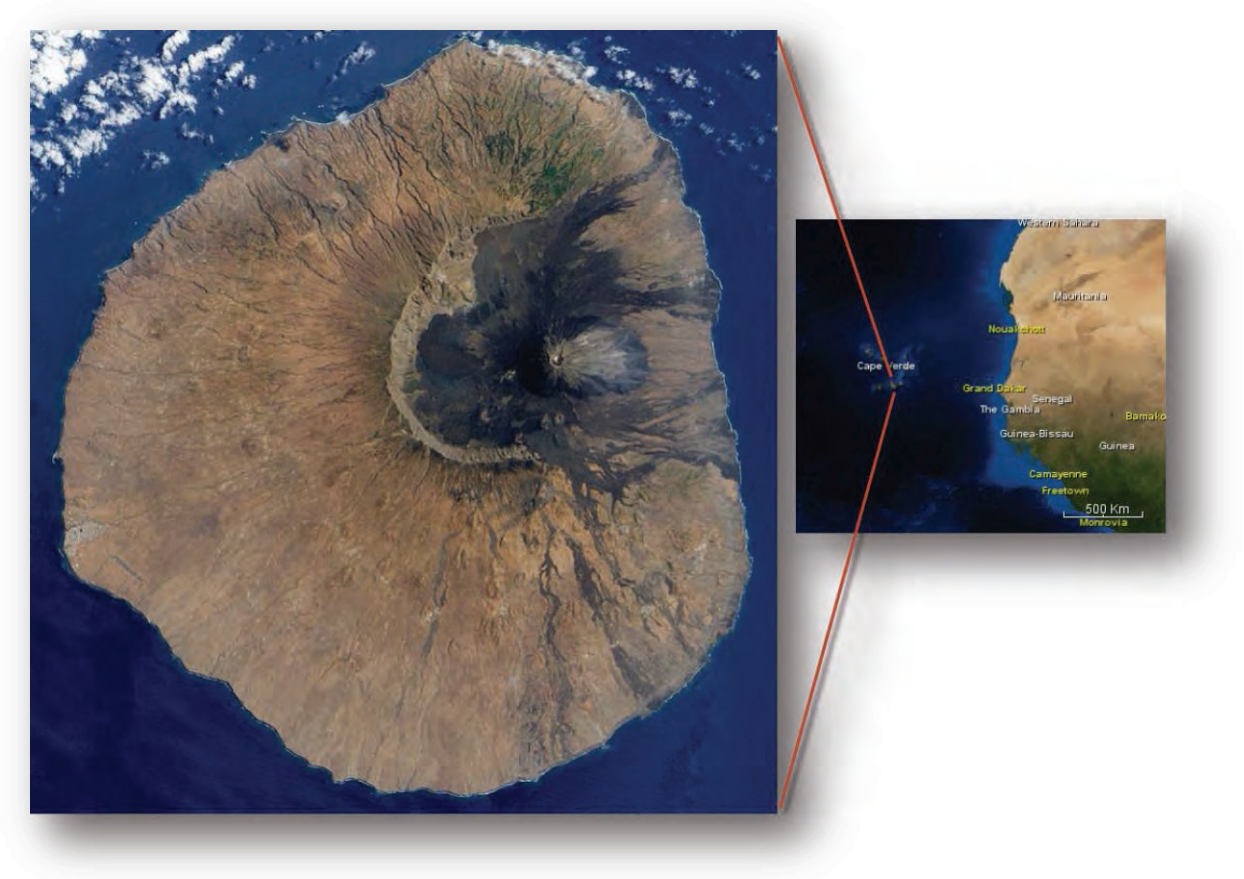
ARRAY SYSTEMS COMPUTING INC.

esa

Sentinel-1 Toolbox

TOPS Interferometry Tutorial

Issued May 2014



Pico de Fogo in Cape Verde off the coast of Africa

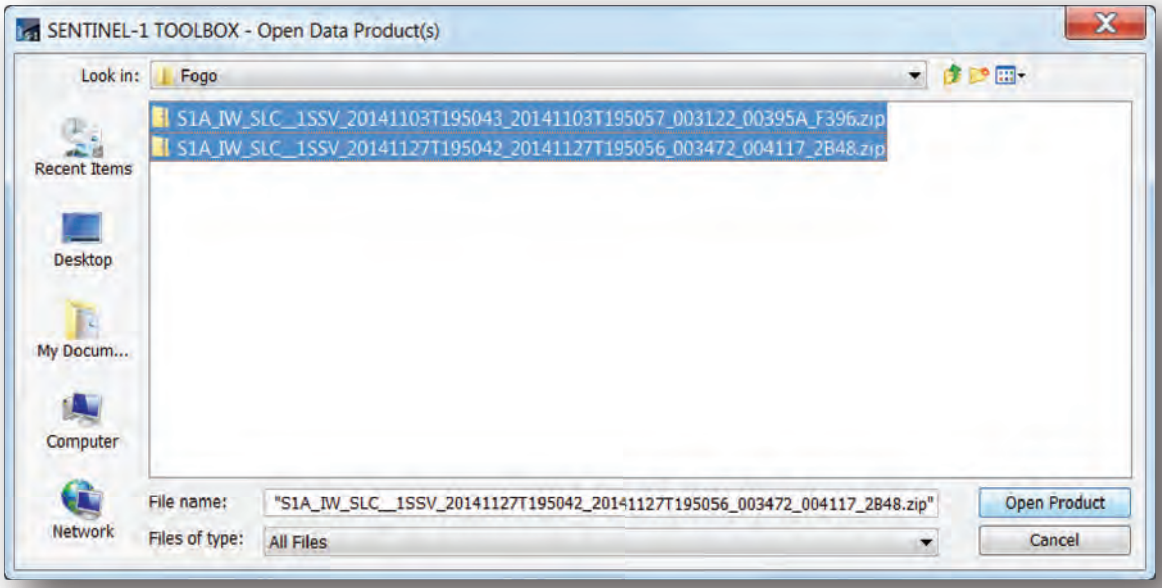
Opening a Pair of SLC Products

In order to perform interferometric processing, the input products should be two or more Single Look Complex (SLC) products over the same area acquired at different times.

Step 1 - Open the products: Use the **Open Product** button in the top toolbar and browse for the location of the **Sentinel-1 Interferometric Wide (IW) swath** products.

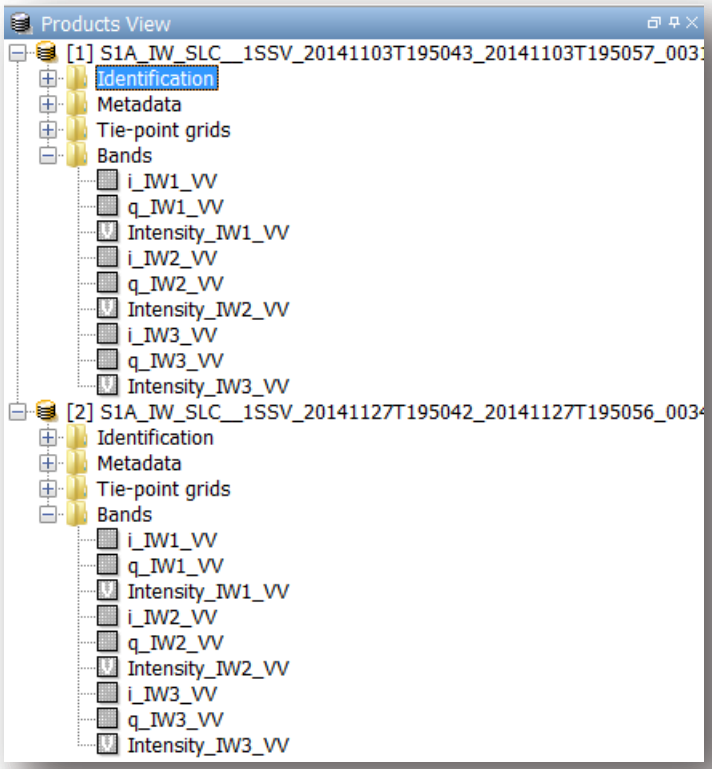
Select the **manifest.safe** file from each Sentinel-1 product folder and press **Open Product**. Press and hold the Ctrl button on the keyboard to select multiple products at a time.

If the product is zipped, you may also select the zip file.



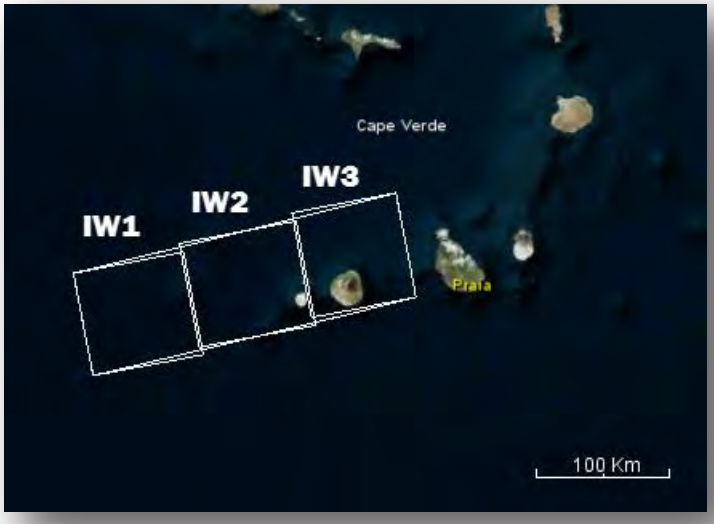
Opening a Product

Step 2 - View the product: In the **Products View** you will see the opened products. Within the product bands, you will find two bands containing the real (i) and imaginary (q) parts of the complex data. The i and q bands are the bands that are actually in the product. The virtual Intensity band is there to assist you in working with complex data.



Products View

In Sentinel-1 IW SLC products, you will find 3 subswaths IW1, IW2, IW3. Each subswath is for an adjacent acquisition by the TOPS mode. Fogo Island can be seen in IW3.



Footprint of Subswaths on World Map

Step 3 - View a band: To view the data, double-click on the **Intensity_IW3_VV** band. Zoom in using the mouse wheel and pan by clicking and dragging the left mouse button.

Intensity IW3 Band

Within a subswath, TOPS data is acquired in bursts. Each burst is separated by demarcation zones. Any 'data' within the demarcation zones can be considered invalid and should be zero-filled but may contain garbage values.

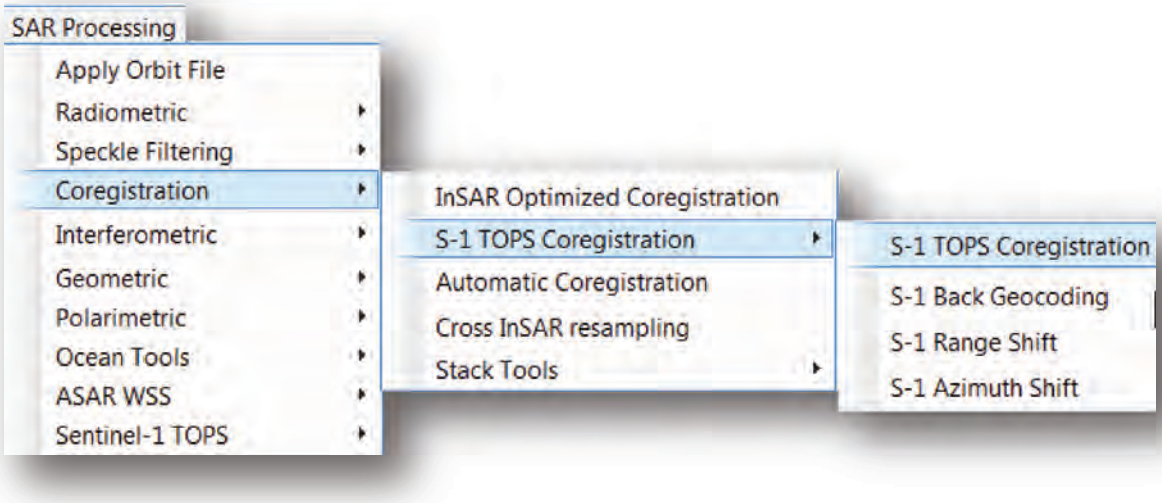
Coregistering the Data

For interferometric processing, two or more images must be coregistered into a stack. One image is selected as the master and the other images are the slaves. The pixels in slave images will be moved to align with the master image to sub-pixel accuracy.

Coregistration ensures that each ground target contributes to the same (range, azimuth) pixel in both the master and the slave image.

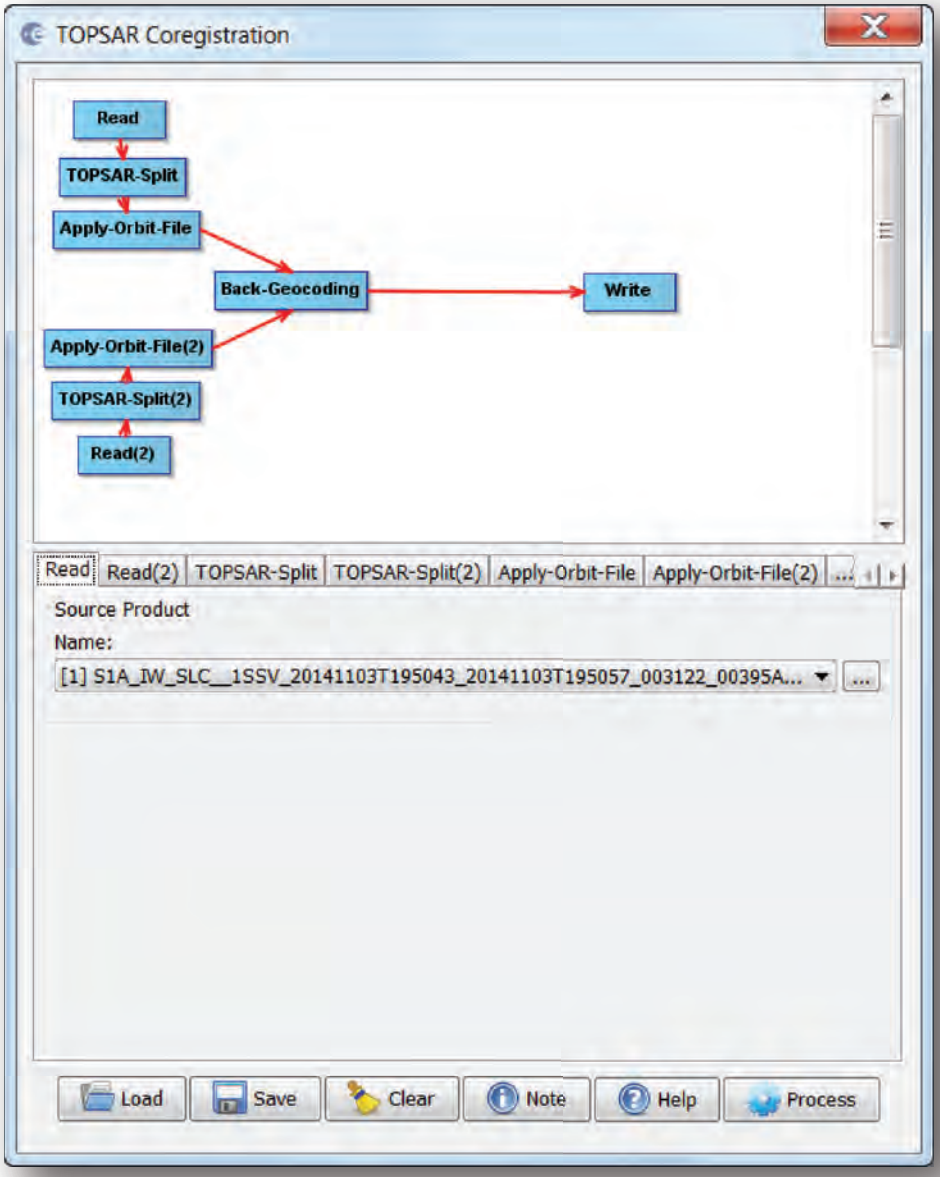
For TOPS InSAR, **S-1 TOPS Coregistration** should be used.

Step 4 - Coregister the images into a stack: Select **S-1 TOPS Coregistration** in the **SAR Processing** menu.



Select S-1 TOPS Coregistration

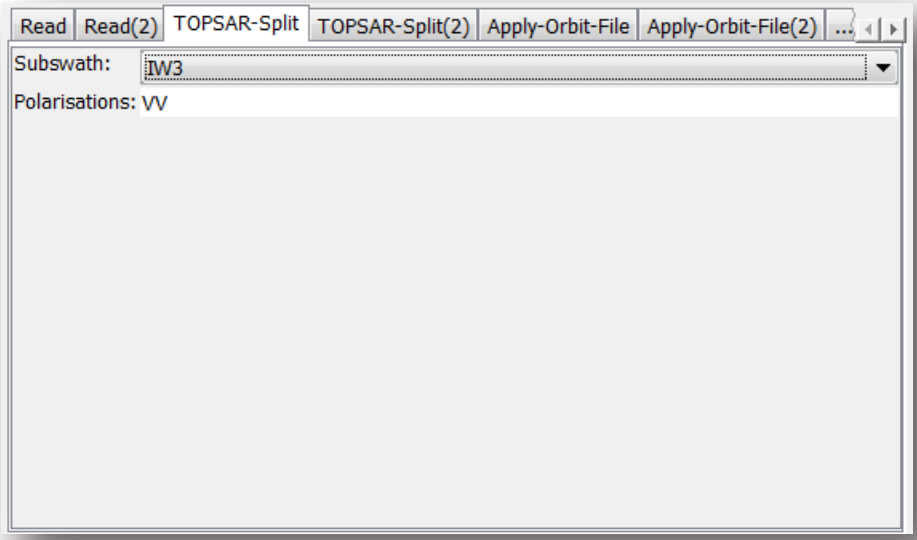
TOPS Coregistration consists of a graph that reads two products, select a single subswath with **TOPSAR-Split**, applies a precise orbit correction with **Apply-Orbit-File** and performs a DEM assisted **Back-Geocoding** coregistration.



S-1 TOPS Coregistration

In the first Read operator, select the first product [1]. This will be your **master** image. In Read(2) select the other product. This will be your **slave** image.

In the TOPSAR-Split tab, select the IW3 subswath for each of the products.



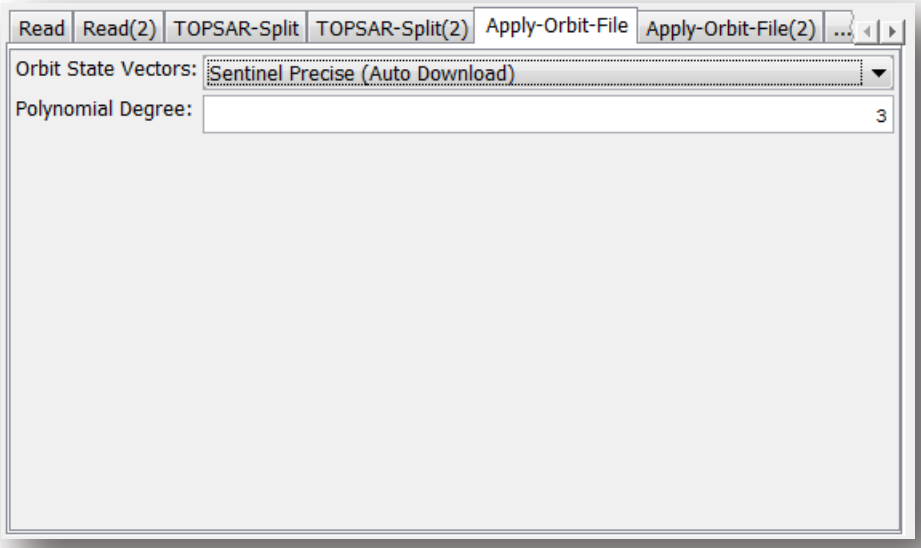
Select a Subswath and Polarisation

In the Apply-Orbit-File tab, select **Sentinel Precise Orbits**. Orbit auxiliary data contain information about the position of the satellite during the acquisition of SAR data.

The Precise Orbit Determination (POD) service for SENTINEL-1 provides Restituted orbit files and Precise Orbit Ephemerides (POE) orbit files. POE files cover approximately 28 hours and contain orbit state vectors at fixed time steps of 10 seconds intervals. Files are generated one file per day and are delivered within 20 days after data acquisition.

If Precise orbits are not yet available for your product, you may select the Restituted orbits which may not be as accurate as the Precise orbits but will be better than the predicted orbits available within the product.

Orbit files for Sentinel-1 are automatically downloaded by the Toolbox.

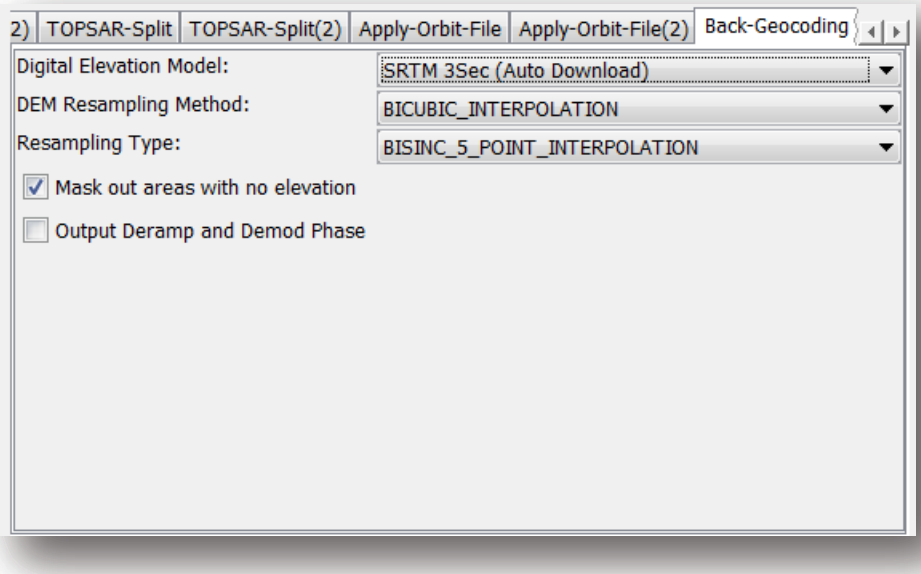


Select Sentinel Precise Orbits

In the Back-Geocoding tab, select the Digital Elevation Model (DEM) to use and the interpolation methods.

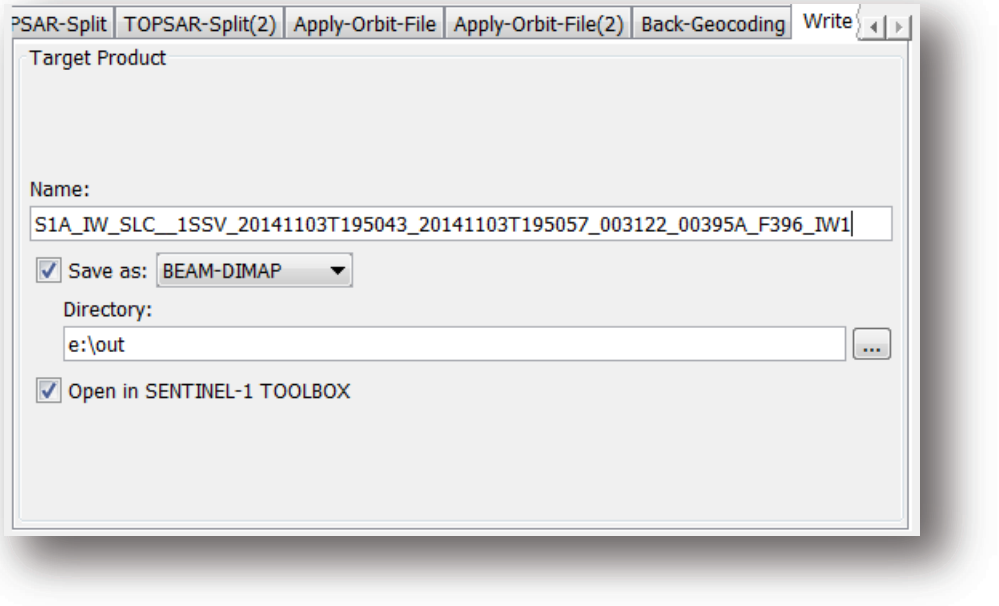
Areas outside the DEM or in the sea may be optionally masked out.

Select to output the Deramp and Demod phase if you require Enhanced Spectral Diversity to improve the coregistration.



Back-Geocoding Parameters

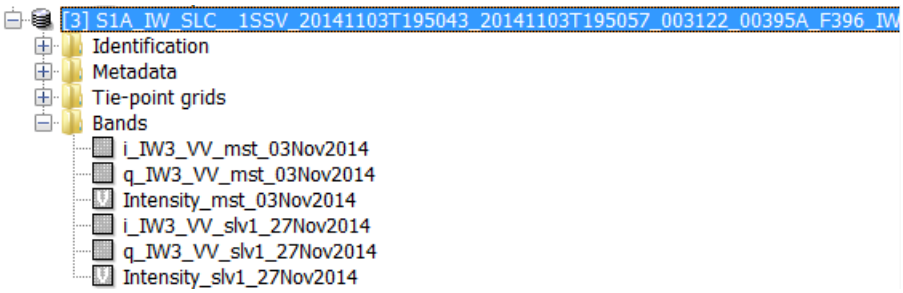
In the **Write** tab, specify the output folder and the target product name.



Specify the output name, format and folder

Press **Process** to begin processing the coregistration.

The resulting coregistered stack product will appear in the **Products View**.



Coregistered Stack Product

Interferogram Formation and Coherence Estimation

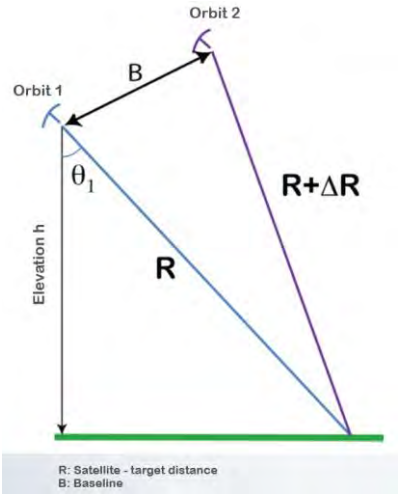
The interferogram is formed by cross multiplying the master image with the complex conjugate of the slave. The amplitude of both images is multiplied while the phase represents the phase difference between the two images.

The interferometric phase of each SAR image pixel would depend only on the difference in the travel paths from each of the two SARs to the considered resolution cell.

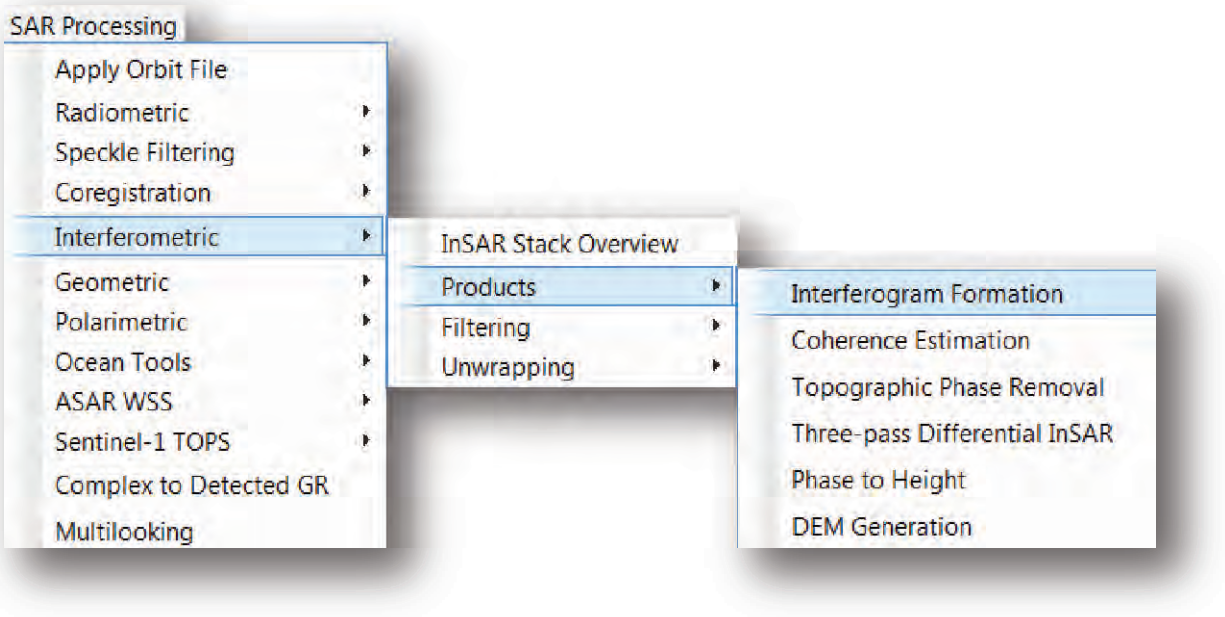
The interferometric phase variation $\Delta\phi$ is then proportional to ΔR divided by the transmitted wavelength λ.

$$\phi_1 = \frac{4\pi R}{\lambda}, \quad \phi_2 = \frac{4\pi(R+\Delta R)}{\lambda}$$

$$\Delta\phi = \phi_2 - \phi_1 = \frac{4\pi\Delta R}{\lambda}$$



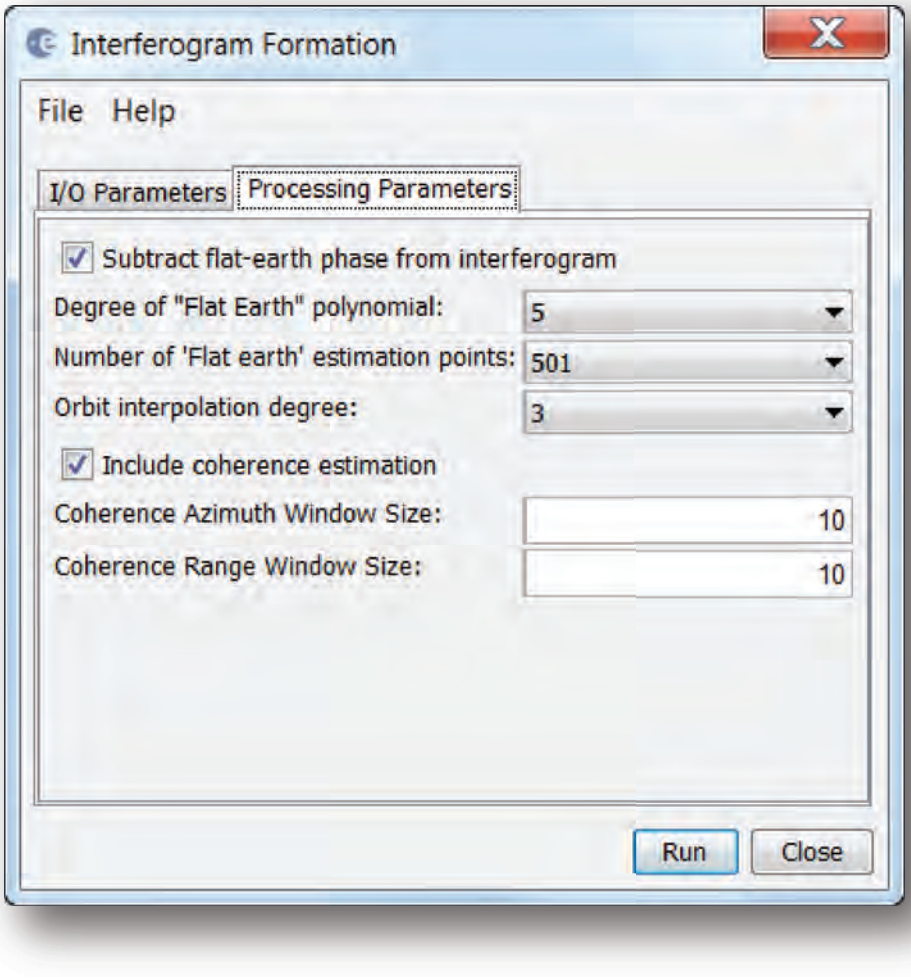
Step 5 - Form the Interferogram: Select the stack and select **Interferogram Formation** from the **InSAR Products** menu.



Select Interferogram Formation

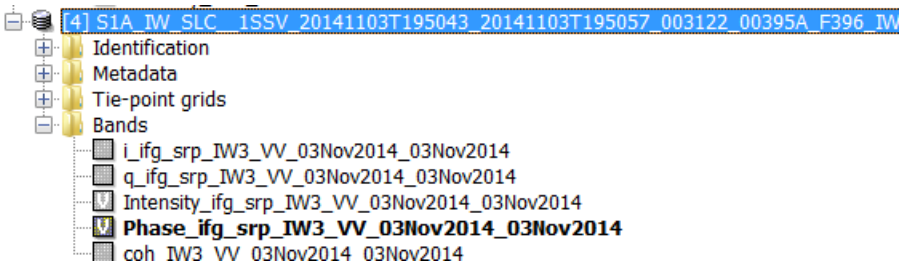
The phase difference can have contributions from five different sources:

- *Δϕflat* is called flat Earth phase which is the phase contribution due to the earth curvature.
- *Δϕelevation* is the topographic contribution to the interferometric phase.
- *Δϕdisplacement* is the surface deformation contribution to the interferometric phase.
- *Δϕatmosphere* is the atmospheric contribution to the interferometric phase. It is introduced due to the atmospheric humidity, temperature and pressure change between the two acquisitions.
- *Δϕnoise* is the phase noise introduced by temporal change of the scatterers, different look angle, and volume scattering.



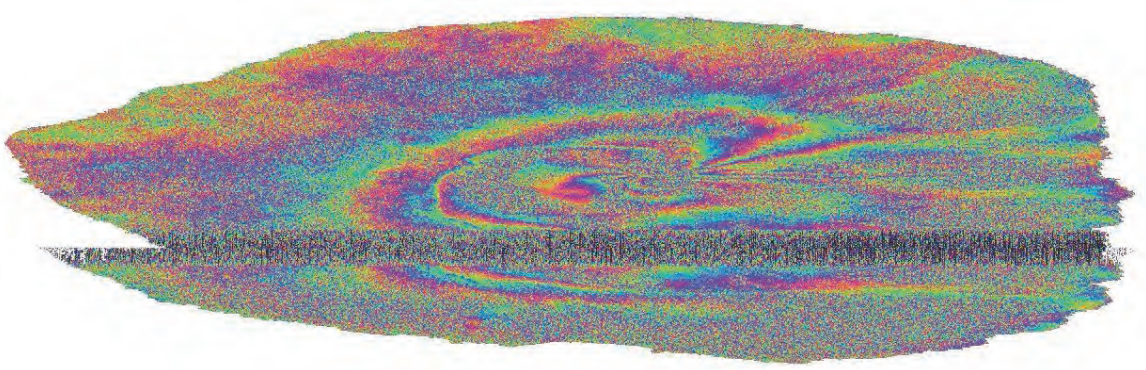
Interferogram Dialog

The interferogram product produced will contain a band for the interferometric phase.



Interferometric Phase Band

If you open the interferometric phase band, you will still see the demarcation zone between two bursts. This will be removed once TOPS Deburst is applied.



Interferometric Phase

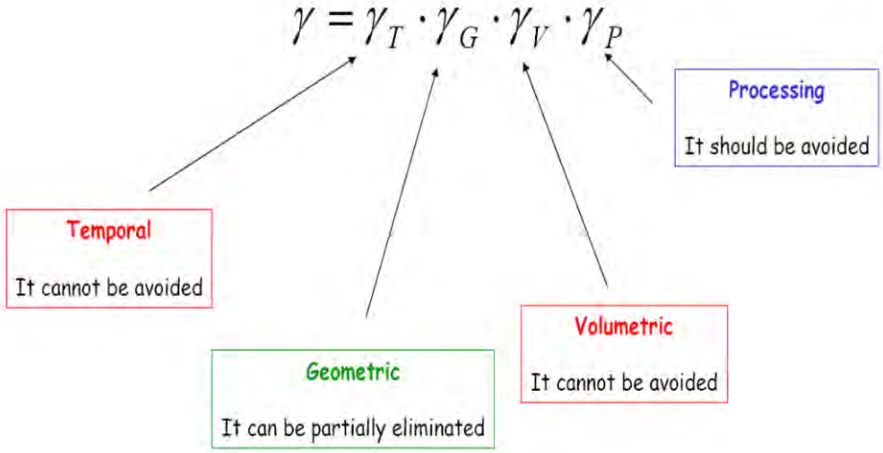
Interferometric fringes represent a full 2π cycle. Fringes appear on an interferogram as cycles of arbitrary colours, with each cycle representing half the sensor's wavelength. Relative ground movement between two points can be calculated by counting the fringes and multiplying by half of the wavelength. The closer the fringes are together, the greater the strain on the ground.

Flat terrain should produce a series of regularly spaced, parallel fringes. Any deviation from a parallel fringe pattern can be interpreted as topographic variation.

With the same operator, you may also generate the coherence estimation in the same processing step as the interferogram.

The coherence between master and slave images can show you if the images have strong similarities and are therefore good candidates for generating a DEM. Loss of coherence can produce poor interferometric results.

Loss of coherence could be caused by temporal (time between acquisitions), geometric (orbit errors), volumetric (vegetation) or processing.

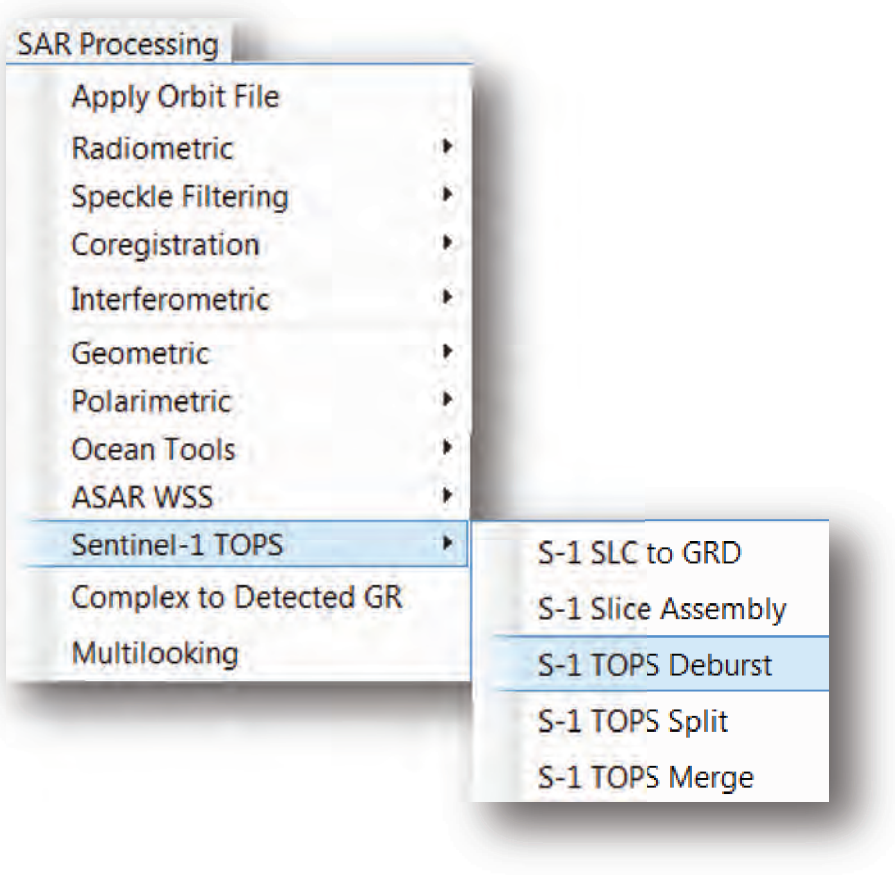


Coherence Contribution

The coherence band shows how similar each pixel is between the slave and master images in a scale from 0 to 1. Areas of high coherence will appear bright. Areas with poor coherence will be dark. In the image, vegetation is shown as having poor coherence and buildings have very high coherence.

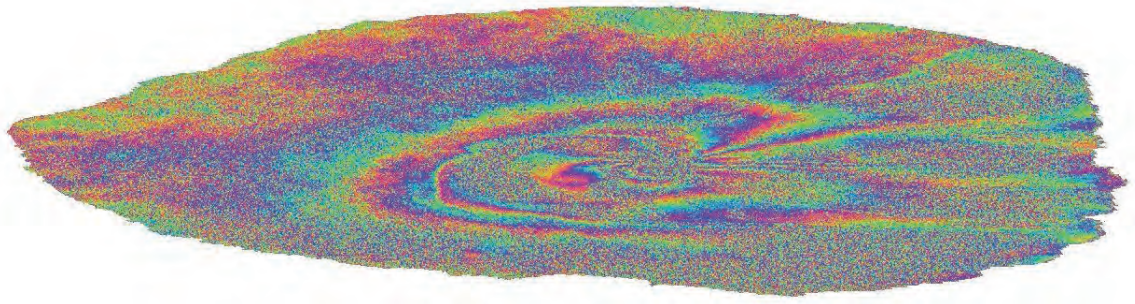
TOPS Deburst and TOPS Merge

To seamlessly join all burst data into a single image, apply the **TOPS Deburst** operator from the Sentinel-1 TOPS menu.



Select TOPS Deburst

Open the resulting deburst interferometric phase band and deburst coherence band.



Interferometric Phase

Coherence

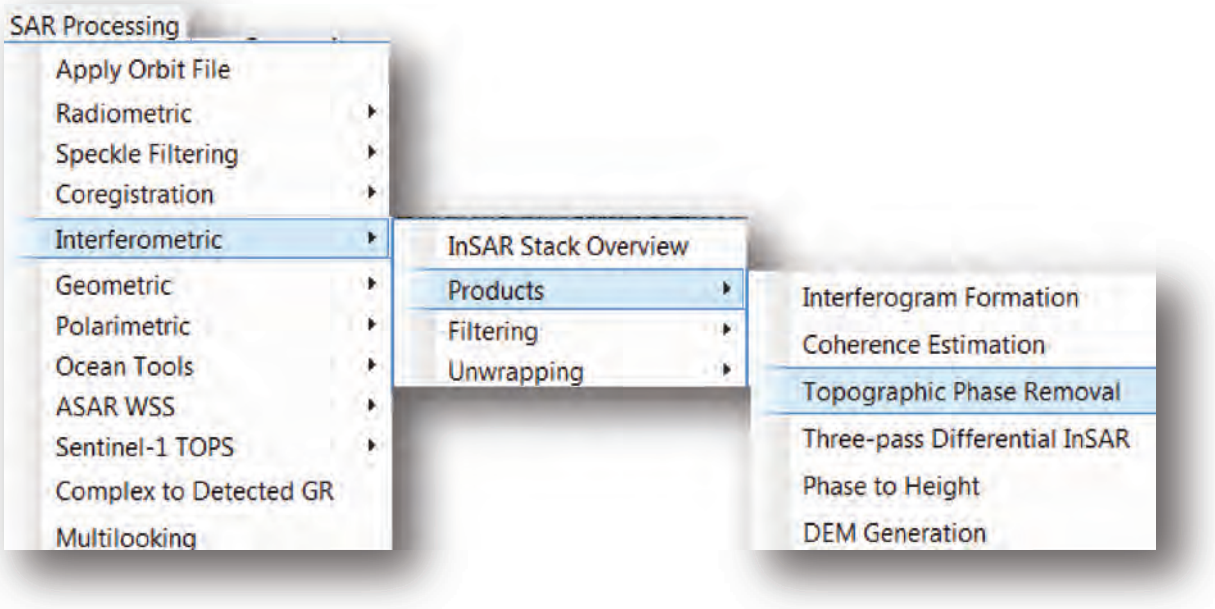
To process multiple swaths, repeat steps 4 & 5 selecting the other subswaths in the TOPS Split operator. To merge the results of the processing from all subswaths, use the **TOPS Merge** operator.

Note: In the September 2015 release of the Toolbox, it should be possible to process all subswaths all at once.

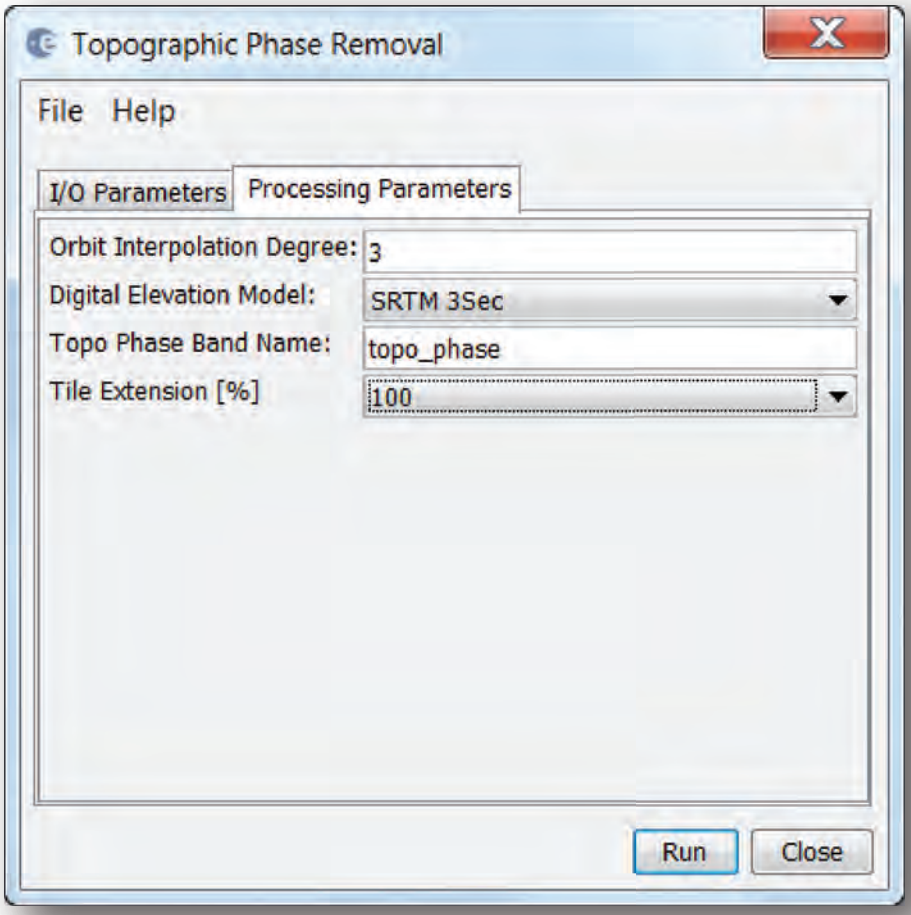
Topographic Phase Removal

The Interferogram can then be flattened by removing the topographic phase. The operator will simulate an interferogram based on a reference DEM and subtract it from the processed interferogram.

Step 6 - Remove Topographic Phase: Select the Interferogram product and go to the **InSAR Products** menu. Select **Topographic Phase Removal**.

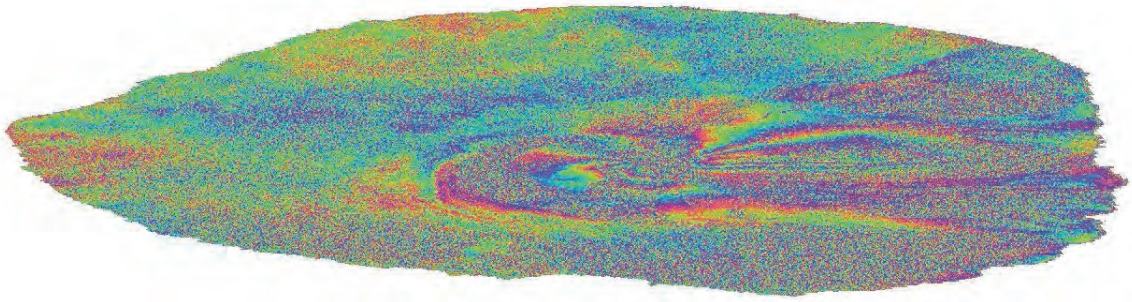


Select Topographic Phase Removal



Topographic Phase Removal Dialog

The resulting product will have an interferogram with topographic phase removed and a band for the topographic phase.



Topographic Phase Removed

Phase Filtering

Interferometric phase can be corrupted by noise from:

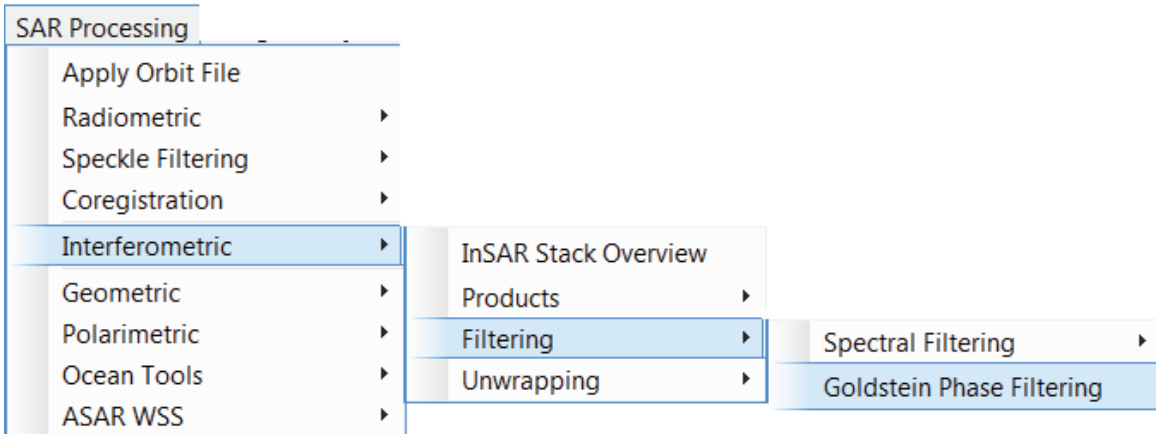
- Temporal decorrelation
- Geometric decorrelation
- Volume scattering

- Processing error

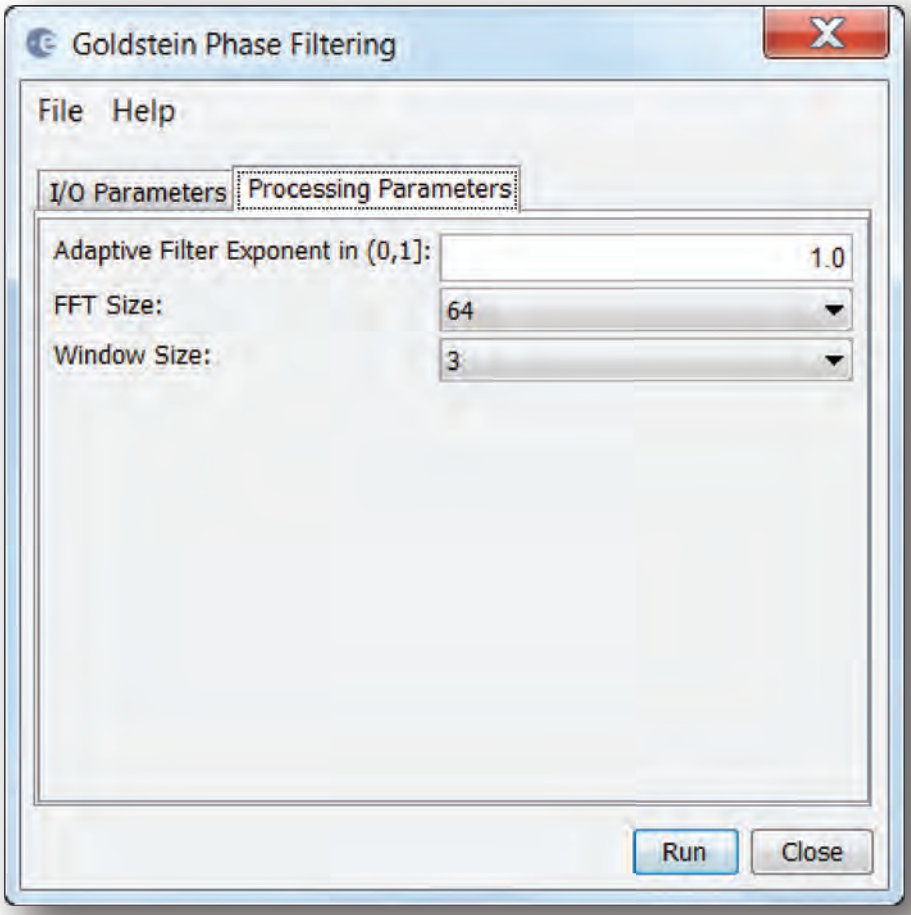
Where there is loss of coherence, the interference pattern is lost.

To be able to properly unwrap the phase, the signal-to-noise ratio needs to be increased by filtering the phase.

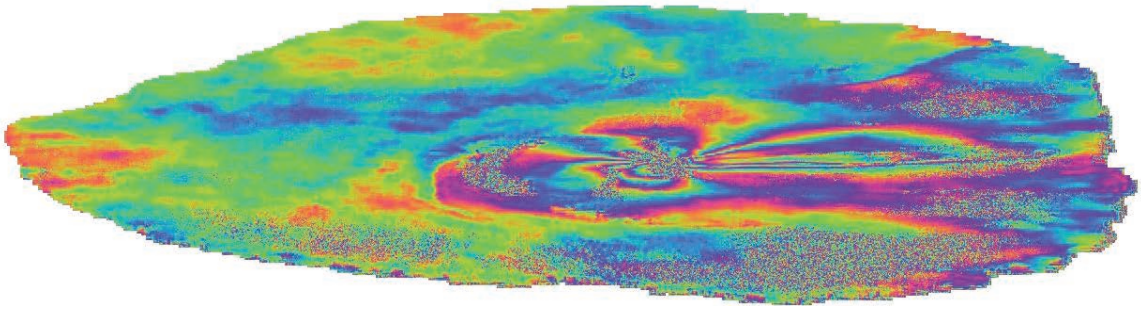
Step 7 - Phase Filtering: Select the Interferogram product and go to the **InSAR Tools** menu. Select **Goldstein Phase Filtering**.



Select Phase Filtering



Phase Filtering Dialog



Filtered Phase Band