Microwave Toolbox

Multi-Reference InSAR tutorial

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Multi-Reference InSAR Tutorial

The goal of this tutorial is to provide a workflow for the generation of multiple interferograms for a given coregistered stack of multiple complex SAR images using the Multi-Reference InSAR operator.

Interferometric synthetic aperture radar (InSAR) is a radar technique that exploits the phase difference between two complex SAR observations taken over the same region to reveal surface topography or surface motion. Here we assume that the readers already have some knowledge of the InSAR technique. Readers who are new to InSAR are referred to Sentinel-1 Toolbox TOPS Interferometry Tutorial (https://step.esa.int/docs/tutorials/S1TBX TOPSAR Interferometry with Sentinel-1 Tutorial_v2.pdf).

From the phase difference of two complex images, we can create an image known as an interferogram which can be used in generating digital elevation model or analyzing the ground movement. However, to generate an interferogram, the two images cannot be selected arbitrarily and some conditions must be met. When we are given more complex images over the same region, more interferograms can be produced, but forming the interferometric pairs is more difficult.

The Multi-Reference InSAR operator provides a visual tool that can help users select the image pairs interactively. In this operator, the users can specify the ranges for some pair selection parameters such as Doppler centroid difference, spatial baseline difference and temporal baseline difference. Based on the user's input, the operator creates a Reference-Secondary plot in which all possible pairs (known as reference and secondary product pairs) are connected with a line. The users can modify the plot by adjusting the ranges of the pair selection parameters. Once the selection is done, the operator can then compute the interferograms for the user selected image pairs.

Download the Data

For this tutorial, we use Sentinel-1 TOPS SLC product. The data can be downloaded from the Copernicus Data Open Spaces (https://dataspace.copernicus.eu/) or from the Alaska Satellite Facility Vertex portal (https://search.asf.alaska.edu/#/). Login is required and registration is free.

Search for the following four product IDs and download them:

S1A_IW_SLC__1SDV_20161112T004003_20161112T004030_013902_016605_5C70
S1A_IW_SLC__1SSV_20161124T004007_20161124T004031_014077_016B4D_686A
S1A_IW_SLC__1SDV_20161206T004002_20161206T004029_014252_0170CD_AE2F
S1A_IW_SLC__1SSV_20161218T004006_20161218T004031_014427_017650_F25C

As some of the required steps are computationally intensive, it is good to store the data at a location which offers good reading and writing speed. If your computer has an internal SSD (https://en.wikipedia.org/wiki/Solid-state_drive), processing should be done there to ensure best performance. Network drives or external storage devices are not recommended. Also, paths which include special characters should be avoided.

Location of the Data

The data used for this tutorial are over Mexico City. Figure 1 shows the location and extent of the Sentinel-1 data (red rectangle).

Figure 1 Location and extent of the data

Prepare the Data

The Sentinel-1 Interferometric Wide (IW) product has three sub-swaths, i.e. IW1, IW2 and IW3. Since Mexico City is located in the IW1 sub-swath, we will split the IW product to extract data for IW1 sub-swath. We also need to correct the orbit of the product.

We run the following graph for each of the four products:

Figure 2 Graph for data preparation

For the TOPSAR-Split operator, we select IW1 sub-swath and VV polarization. The Sentinel-1 TOP SLC product generally has 9 bursts in each sub-swath. If the area of interest is covered by only a few bursts, for example by burst 1 to 4, then you should select burst 1 to 4. Here we select burst 1 to 2 to save some computations (Figure 3).

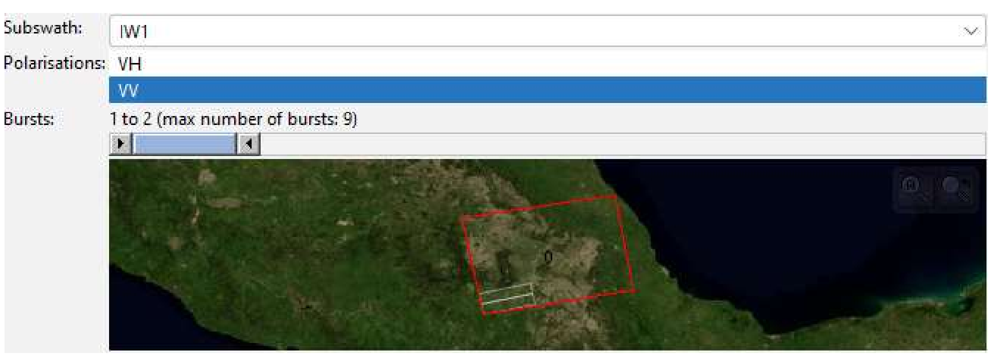

Figure 3 TOPS-Split operator UI

For Apply-Orbit-File operator, we use the default parameters.

Now we get the following split products ready for the interferogram generation:

S1A_IW_SLC__1SDV_20161112T004003_20161112T004030_013902_016605_5C70_Orb.data
S1A_IW_SLC__1SSV_20161124T004007_20161124T004031_014077_016B4D_686A_Orb.data
S1A_IW_SLC__1SDV_20161206T004002_20161206T004029_014252_0170CD_AE2F_Orb.data
S1A_IW_SLC__1SSV_20161218T004006_20161218T004031_014427_017650_F25C_Orb.data

Open the split products

Open the four split products in SNAP (Figure 4).

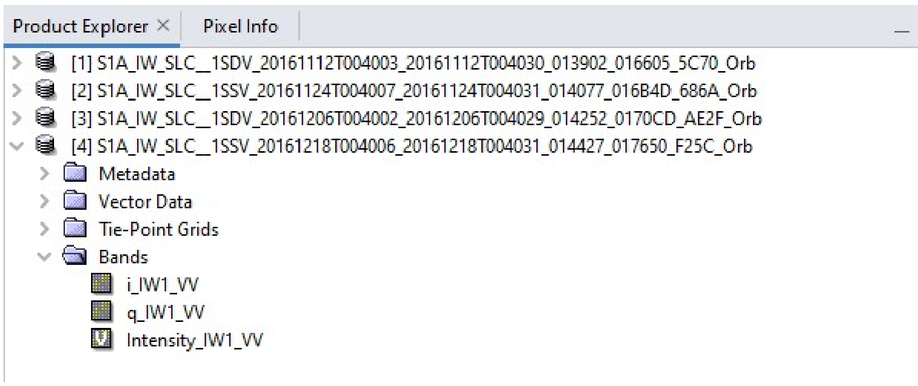

Figure 4 The split IW products

Coregistration using S-1 Back Geocoding

The S-1 Back Geocoding operator coregisters two or more split Sentinel-1 IW products with the first product being the reference product and the rest as the secondary products. As the result of the coregistration, the images in the secondary products are aligned with the image in the reference product.

Open Radar > Coregistration > S-1 TOPS Coregistration > S-1 Back Geocoding operator (Figure 5).

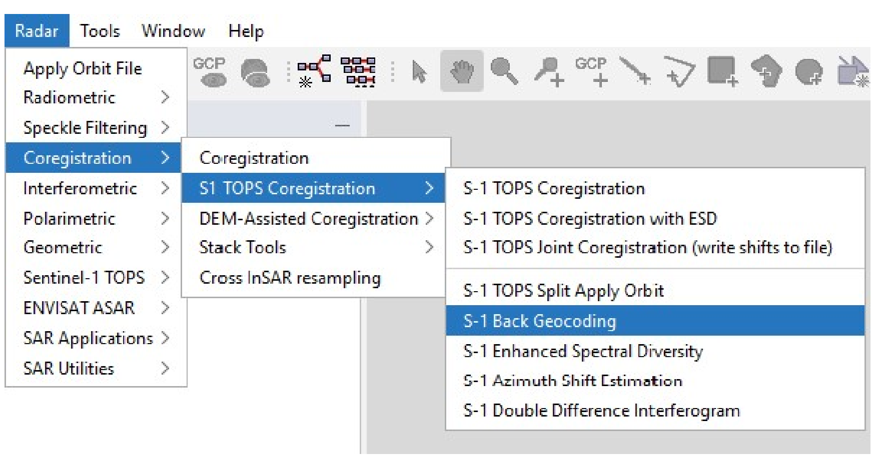

Figure 5 S-1 Back Geocoding in SNAP menu

Select the split IW products as input in the ProductSet-Reader tab (Figure 6).

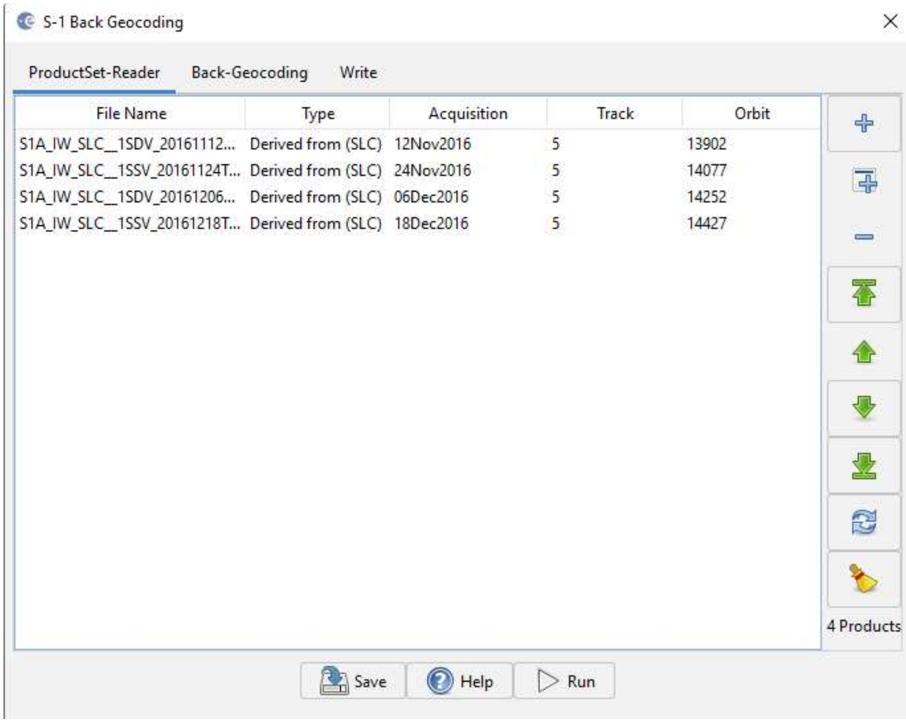

Figure 6 Split IW products in ProductSet-Reader

Select Copernicus 30m Global DEM as the Digital Elevation Model and click on Run button (Figure 7).

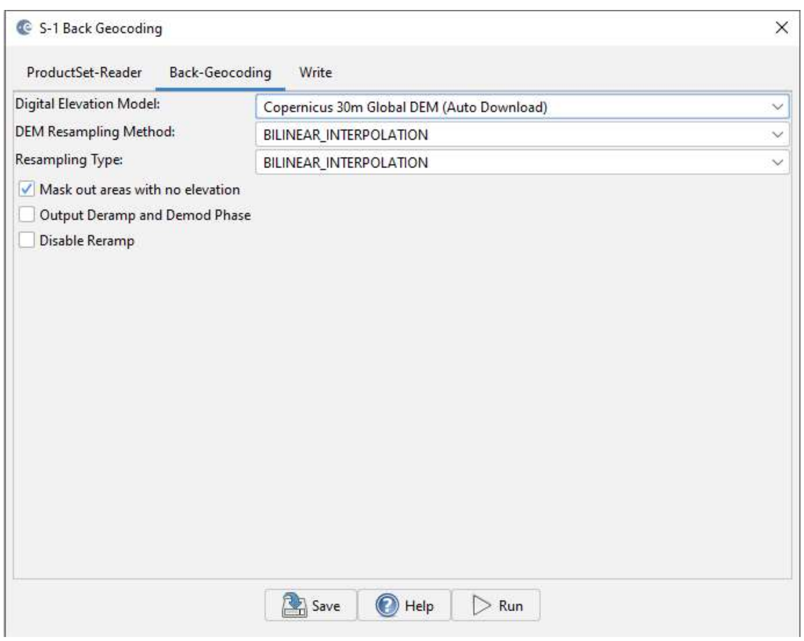

Figure 7 S-1 Back Geocoding UI

The S-1 Back Geocoding operator will generate a stack product with 12 bands (Figure 8) with the first 3 bands from the reference product and the rest from the 3 secondary products. Up to now, the images of the secondary products have been coregistered with the image in the reference product.

Figure 8 Stack product generated by the S-1 Back Geocoding operator

Add elevation band

Right click on the stack product in SNAP and select Add Elevation Band in the popup menu (Figure 9).

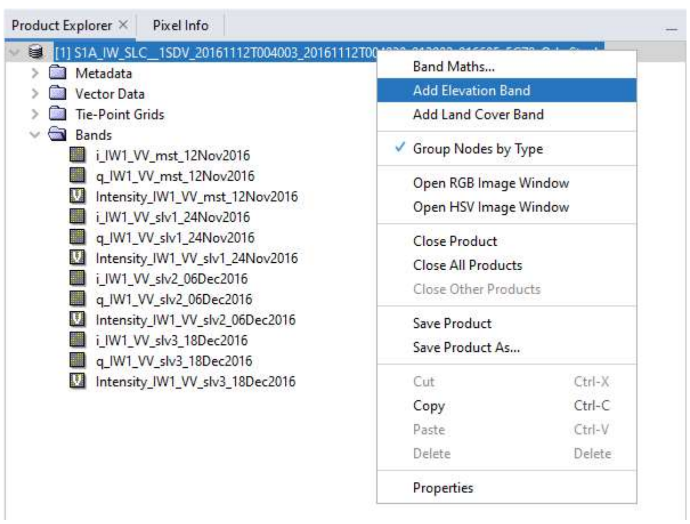

Figure 9 Add Elevation Band in the popup menu

Then select Copernicus 30m Global DEM in the Add Elevation Band window (Figure 10).

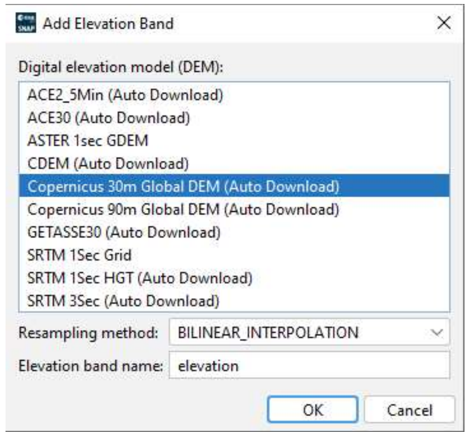

Figure 10 Add Elevation Band window

A new band named “elevation” will be added to the stack product.

Run Multi-Reference InSAR operator

Open Radar > Interferometric > Product > Multi-Reference InSAR operator (Figure 11).

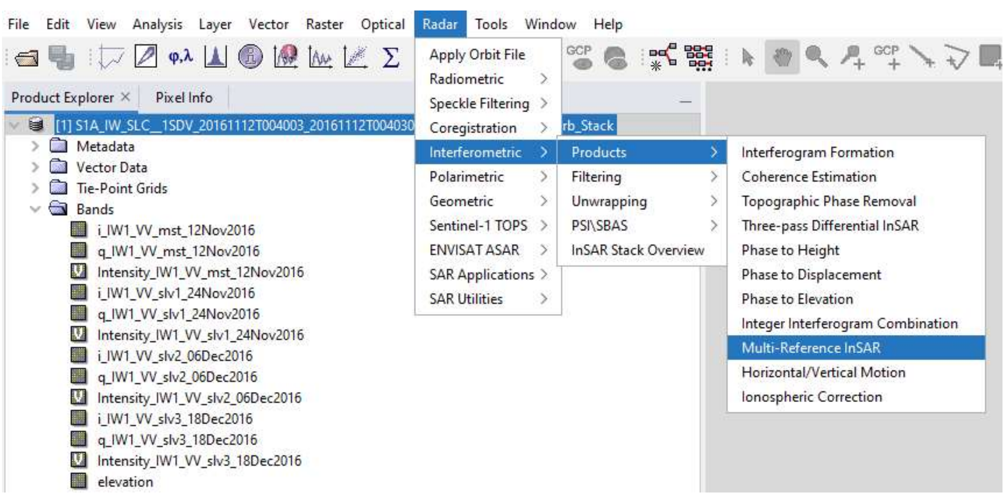

Figure 11 Multi-Reference InSAR operator in Radar menu

In the Multi-Reference InSAR operator UI, select the stack product as the Source Product (Figure 12).

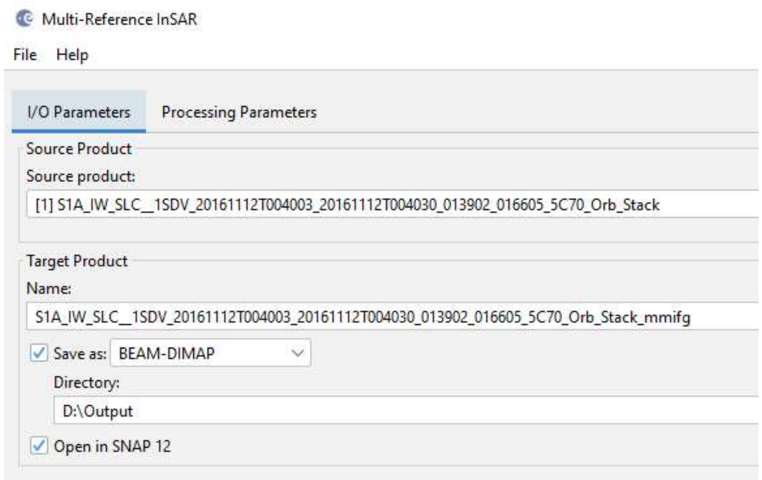

Figure 12 Multi-Reference InSAR operator UI

The Processing Parameters tab in the operator UI consists of two parts. The upper part contains parameters for the interferogram generation and parameters for the additional output band selection (Figure 13). Details of the parameters are given below:

- *Orbit interpolation degree*: Degree for polynomial interpolation of orbit.
- *Coherence range window size*: Number of pixels for coherence estimation.
- *Coherence azimuth window size*: Number of lines for coherence estimation.
- *Include latitude and longitude*: If True, the corresponding bands will be created.
- *Include wavenumber*: If True, the corresponding band will be created.
- *Include incidence angle*: If True, the corresponding band will be created.

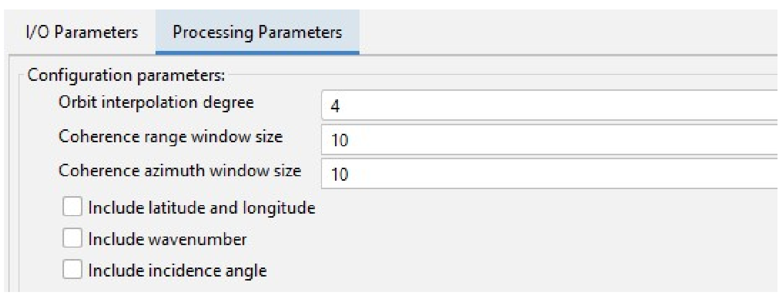

Figure 13 Upper part of the Processing Parameters tab

The lower part of the Processing Parameters tab includes three pair-selection parameters and a Reference-Secondary Plot. Details of the pair-selection parameters are as the follows:

- *Max doppler centroid diff*: The maximum allowed absolute Doppler centroid difference between image pairs (unit: Hz).
- *Max spatial baseline diff*: The maximum allowed absolute spatial baseline difference between images pairs (unit: meters).
- *Max temporal baseline diff*: The maximum allowed absolute temporal baseline difference between images pairs (unit: days).

The vertical axis of the Reference-Secondary plot is the spatial baseline of the product with respect to the reference product. The horizontal axis is the acquisition time of the product with respect to the reference product. In this plot, every product is represented by a blue dot. For example, the reference product is represented by the blue dot at the upper-left corner of the plot. The positions for other products can be found based on their acquisition times. For example, the second product in our product list was acquired on Nov. 24, 2016, i.e. 12 days after the reference product acquisition time which is Nov. 12, 2016. Then we know that the blue dot at 12 on the Time axis represent this product.

If two blue dots are connected by a line, that means the two corresponding products can form an interferometric pair, i.e. an interferogram can be generated from the two products. The product with the earlier acquisition time is defined as the reference product while the other product is the secondary product. If we have multiple lines in the plot, then we have multiple reference-secondary pairs, and hence multiple interferograms. That is where the Multi-Reference InSAR name comes from.

With the current settings for the pair-selection parameters, we can see that product 1 (the reference product) and product 2 form a pair. Similarly product 2 and 3 form a pair, product 2 and 4 also form a pair, and product 3 and 4 form a pair. Users can adjust the three pair-selection parameters on the left and the plot on the right will be updated accordingly.

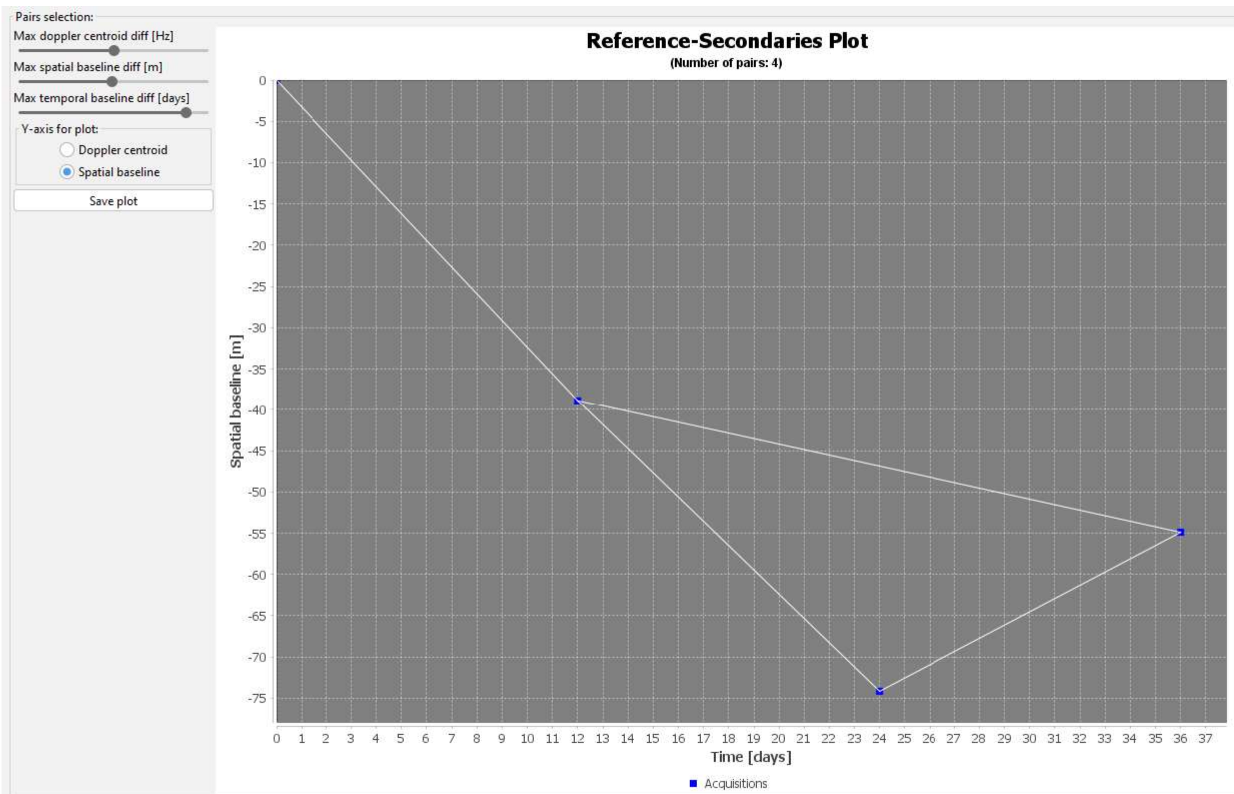

Figure 14 Lower part of the Processing Parameters tab

Once the users are happy with the pair selection result, they can click on the Run button to start the processing. With the plot above, a total of four interferograms will be produced with each interferogram corresponds to one pair of products.

Figure 15 shows the output product of the Multi-Reference InSAR operator. The four “Phase_ifg_” bands in the product are the four interferograms generated based on the Reference-Secondary plot. The flat earth phase has been removed during the interferogram generation.

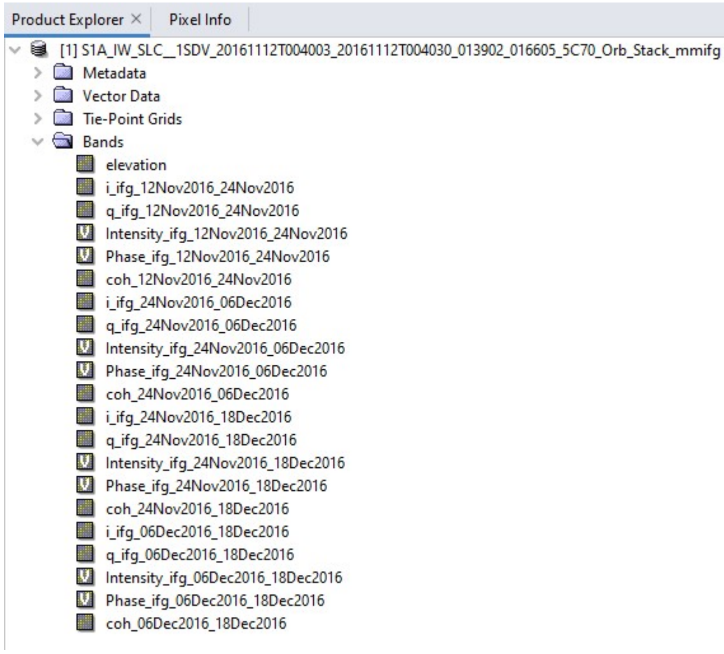

Figure 15 Output product of the Multi-Reference InSAR operator

Figure 16 shows the four interferograms and Figure 17 shows the corresponding interferometric coherences.

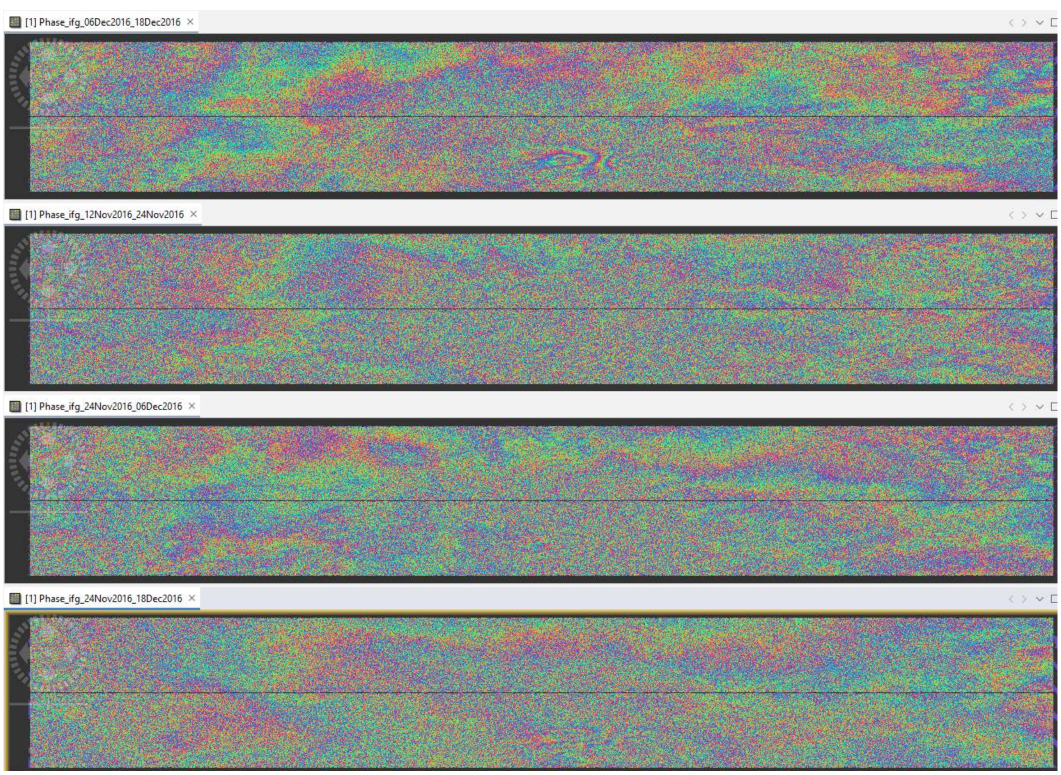

Figure 16: Interferograms generated by the Multi-Reference InSAR operator

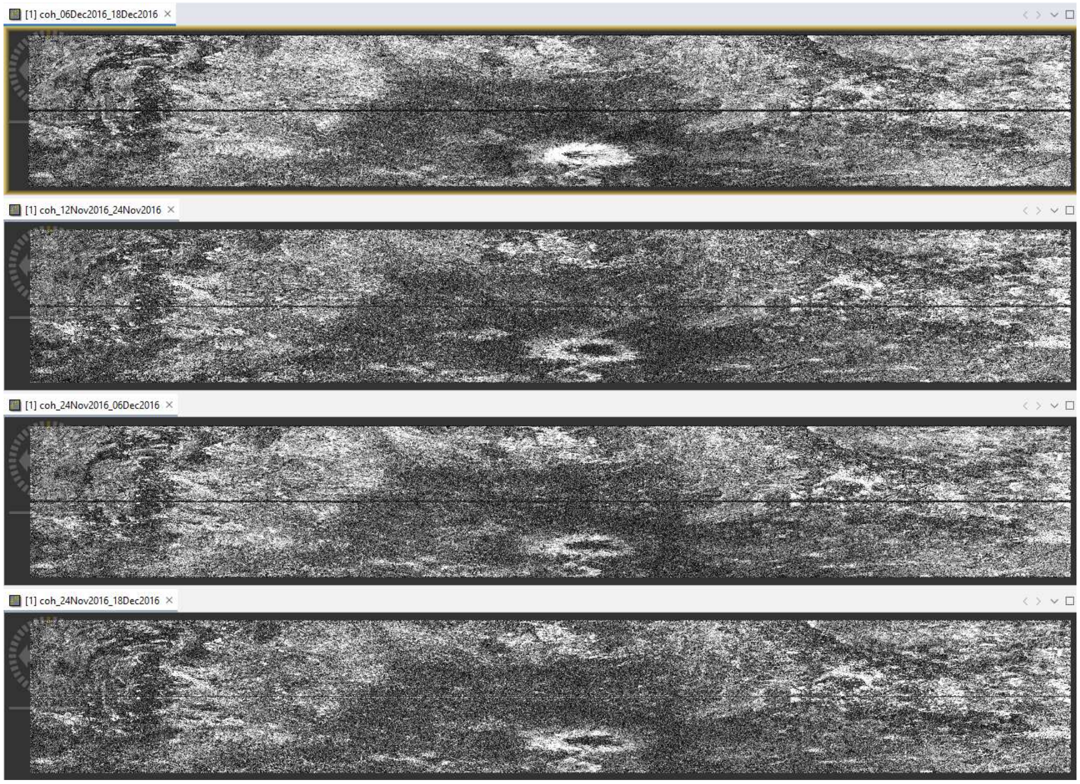

Figure 17 Coherences generated by the Multi-Reference InSAR operator

Suggestions for further processing

This tutorial shows how to derive multiple interferograms for a given stack of multiple complex images using the Multi-Reference InSAR operator. The interferograms produced by this operator are not ready for analyses and further processing is needed. Depending on the user's applications, the processing steps needed could be different. Below are some common steps in the interferogram processing:

- *TOPS Deburst*: Remove the seam lines between the bursts using the S-1 TOPS Deburst operator.
- *Phase Filtering*: Remove the noise in the interferogram using the Goldstein Phase Filtering operator.
- *Phase Unwrapping*: Perform phase unwrapping using snaphu which is an independent software and should be installed separately.

For more information about these processing steps, users are referred to the "Sentinel-1 Toolbox TOPS Interferometry Tutorial" mentioned at the beginning of this tutorial.