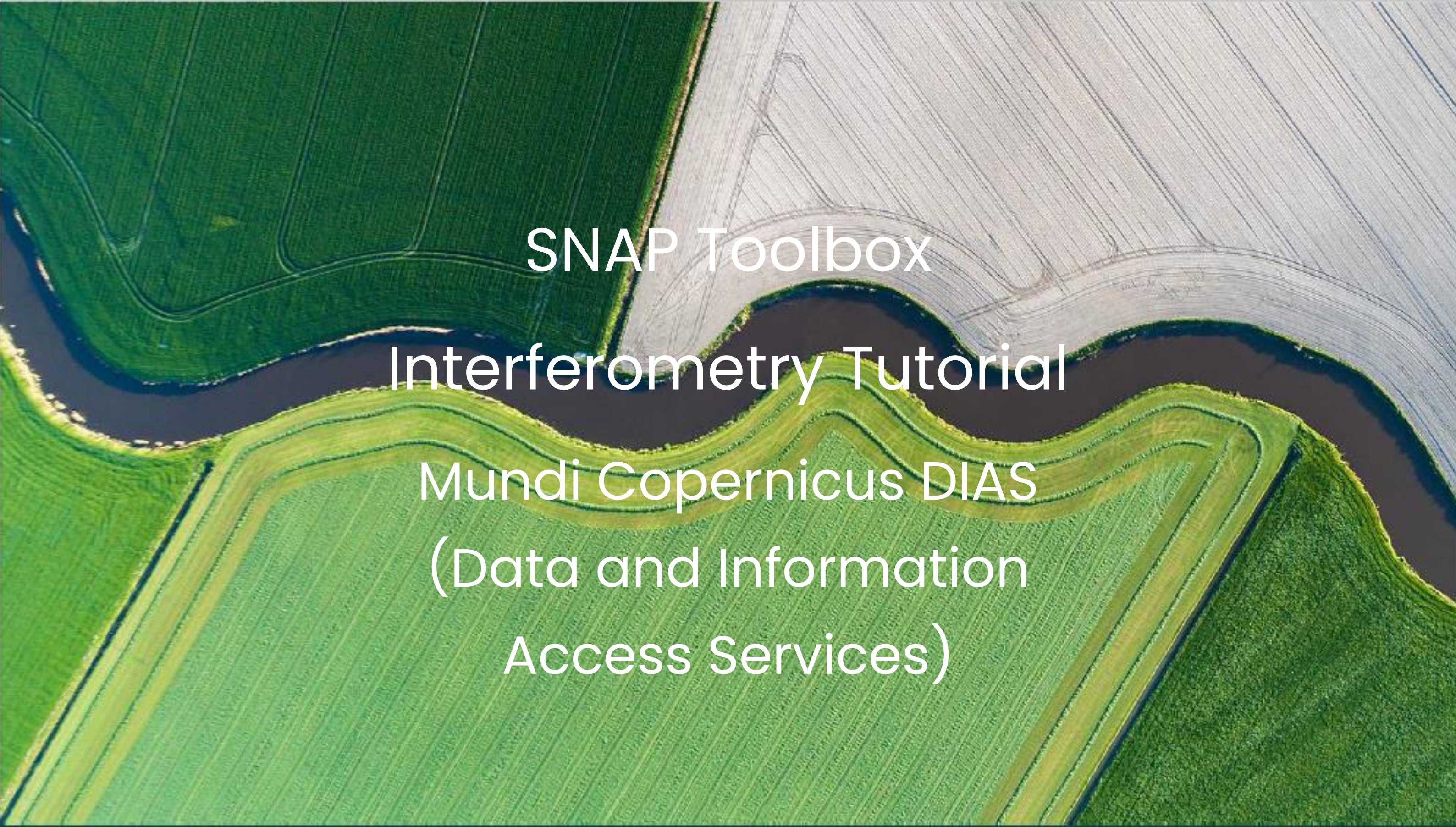

SNAP Toolbox

Interferometry Tutorial

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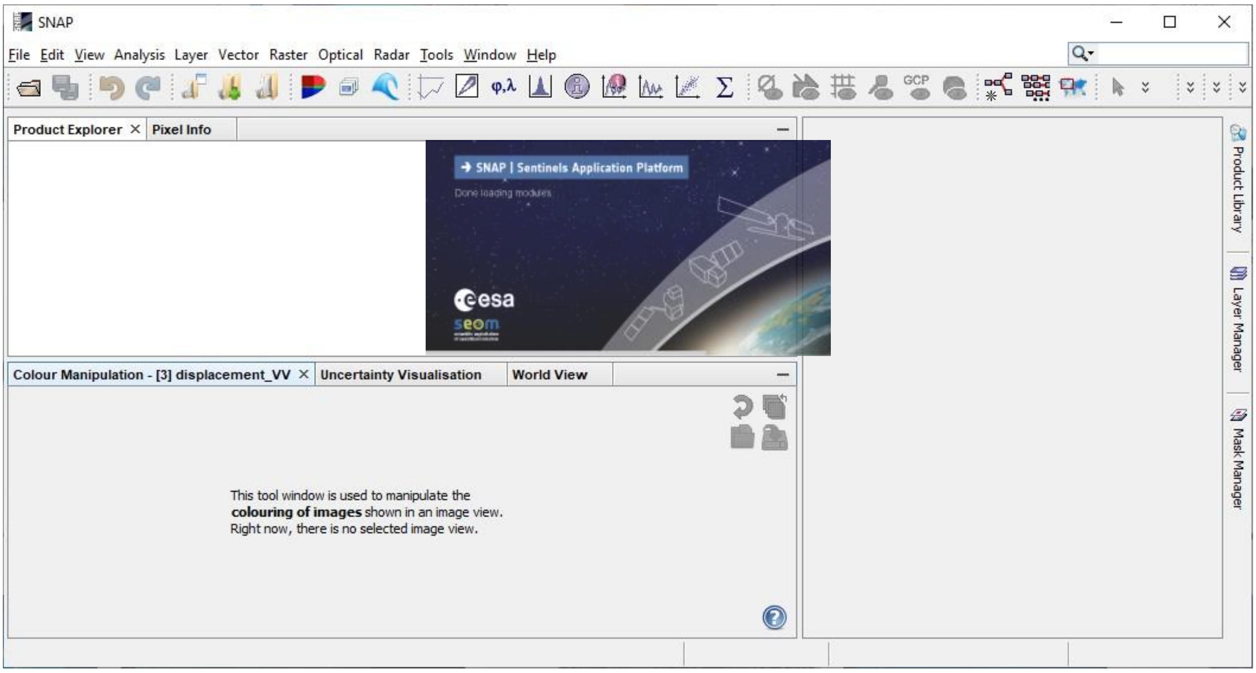
2.1 Introduction

The SentiNel Application Platform (SNAP) is built on prior open source toolbox development (such as BEAM, NEST and ORFEO) and presents a strong evolution, in particular, by sharing a common architecture and by introducing innovative functionalities and new processing capabilities. SNAP is being developed, under GNU GPL open source license, in a coordinated joint venture by several industrial partners and scientists. The SNAP architecture has been designed to ensure highest performance when dealing with very large imagery and consists of several toolboxes that process data from the Copernicus Sentinels satellite series, including SAR (Synthetic Aperture Radar) and optical satellites. Among them, S1TBX (Sentinel-1 ToolBoX) which is mainly used to process Sentinel-1A/BSAR images and interferometric techniques. it provides a flowchart processing method such as Graph Builder, and has several practical features such as automatic downloading of DEM (Digital Elevation Model), InSAR (Interferometric SAR) and DInSAR (Differential InSAR) techniques which work correctly and are widely used recently around the world thanks to the latest updates to the toolbox.

2.2 Feature Highlights

- Common architecture for all Toolboxes
- Very **fast image display and navigation** even of giga-pixel images
- Graph Processing Framework (GPF): for creating user-defined processing chains
- Advanced **layer management** allows adding and manipulation of new overlays such as images of other bands, images from WMS servers or ESRI shapefiles
- Rich **region-of-interest** definitions for **statistics** and various **plots**
- Easy **bitmask** definition and overlay
- Flexible **band arithmetic** using arbitrary mathematical expressions
- Accurate **reprojection** and **ortho-rectification** to common map projections
- Geo-coding and rectification using **ground control points**
- Automatic SRTM DEM download and tile selection
- Product library for scanning and cataloguing large archives efficiently
- Multithreading and Multi-core processor support
- Integrated WorldWind visualisation



3. Interferometry Tutorial

What is Interferometry?

Interferometric synthetic aperture radar (InSAR) exploits the phase difference between two complex radar SAR observations taken from slightly different sensor positions and extracts information about the earth's surface.
A SAR signal contains amplitude and phase information. The amplitude is the strength of the radar response and the phase is the fraction of one complete sine wave cycle (a single SAR wavelength). The phase of the SAR image is determined primarily by the distance between the satellite antenna and the ground targets. By combining the phase of these two images after coregistration, an interferogram can be generated whose phase is highly correlated to the terrain topography. In the case of differential interferometry (DInSAR), this topographic phase contribution is removed using a digital elevation model (DEM). The remaining variation in the interferogram can be attributed to surface changes which occurred between the two image acquisition dates, as well as unwanted atmospheric effects

3.1 Goal

The goal of this tutorial is to provide novice and experienced remote sensing users with step-by-step instructions on interferometric processing with Sentinel-1 Interferometric Wide Swath products.

3.2 Skills aquired at the end of the training

- Interferometry
- Building interferograms from SLC images
- Map deformation

3.3 Training kit

- **Mundi SNAP Docker Image**

The docker version made available on Mundi, has been built by Mundi development team and can be found [here](). Note that, you will have to log with your mundi credentials to access the mundi shared docker repository.
To use the SNAP docker image on your virtual machine (VM) , docker must be installed in all Mundi VM templates and the following commands must be executed replacing `<variable>` according to your needs:

- Log yourself to the docker repository with your mundi website credentials :

```
sudo docker login -u <Mundi website user email> -p <Mundi website user password>
https://publicreg.mundiwebservices.com/
```

- Upload the desired docker images on your VM :

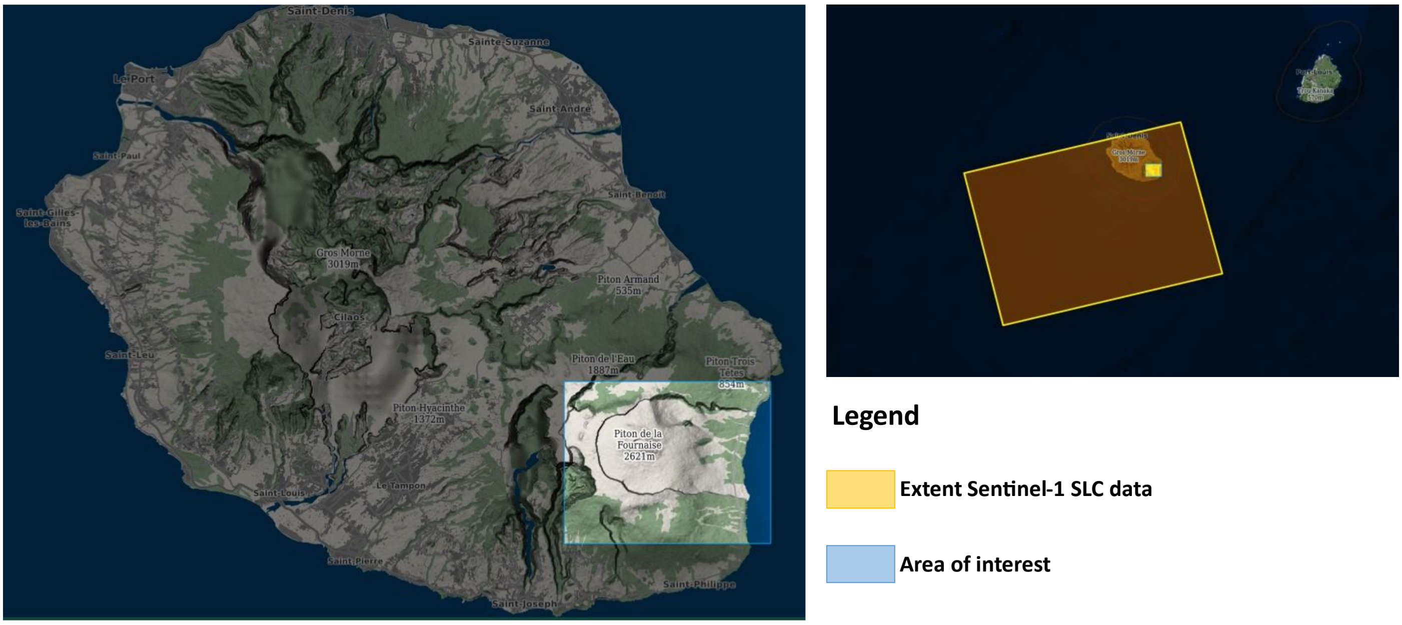
```
sudo docker pull publicreg.mundiwebservices.com/esa-snap:<version>
```

- Launch your docker in order to use orfeo-toolbox :

```
sudo docker run -it -v $(pwd):/data publicreg.mundiwebservices.com/esa-
snap:<version> bash
```

- **Dataset**

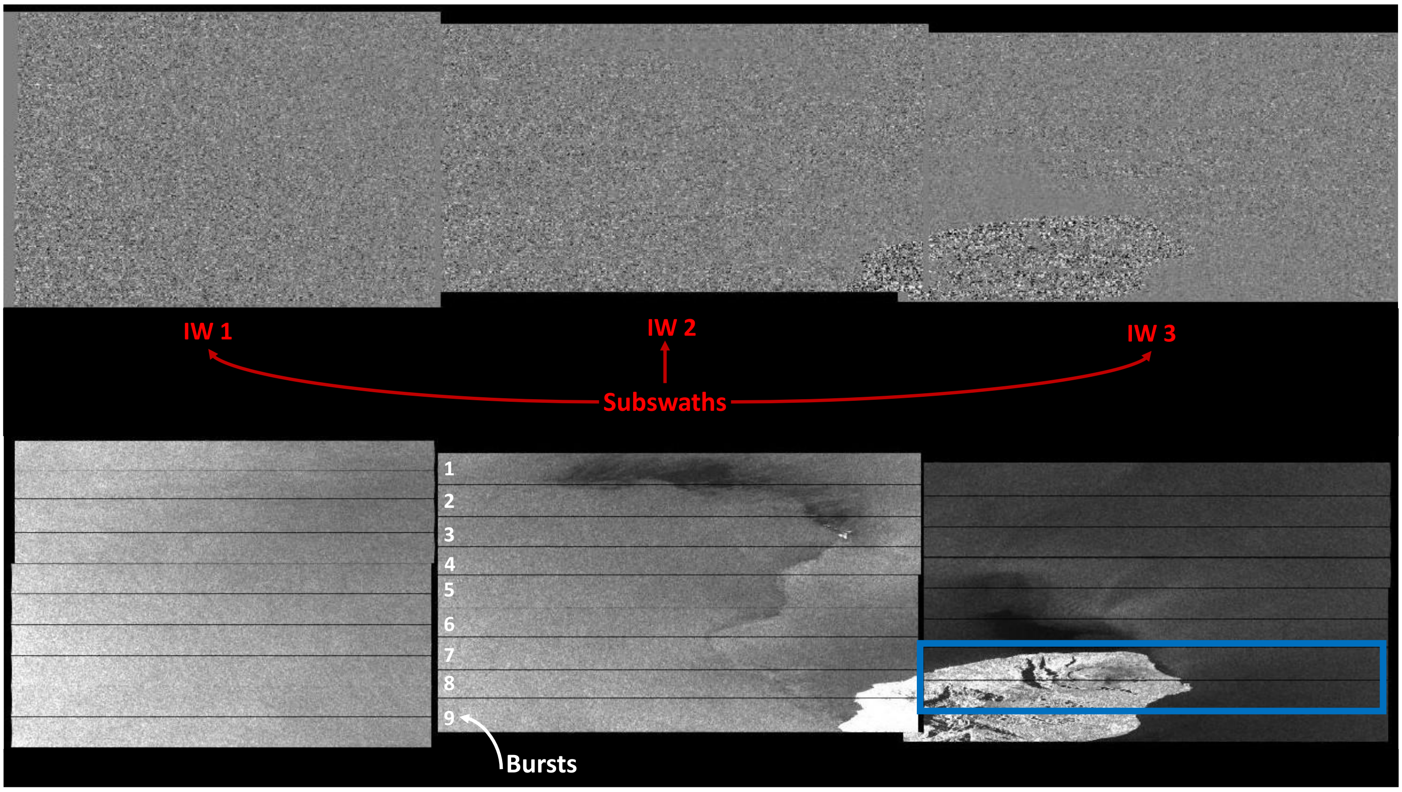
The data used in this tutorial includes images from Sentinel-1 SLC IW over the eastern side of Réunion island (a French department) in the Indian Ocean at different time. The figure below shows the extent and location of the Sentinel 1 -1 SLC IW data (yellow), and the area of interest over the shield volcano Peak of the Furnace (blue)



- **Sentinel-1 SLC IW :** Single Look Complex (SLC) Interferometric Wide (IW) Swath products consist of focused SAR data geo-referenced using orbit and attitude data from the satellite and provided in zero-Doppler slant-range geometry. Mundi Web Services provides the complete collection, with fresh free data ONLINE from January 2018 with global coverage, and from January 2017 for Europe. A rolling policy of 12 months for World and 24 months for Europe is currently applied.
  The data used in this tutorial can be downloaded from the Mundi Web Services Geodata UI here (login required, registration is free)

  Search for the two product IDs and download them:
  S1A_IW_SLC__1SDV_20191212T145256_20191212T145324_030316_0377B2_B7C8
  S1A_IW_SLC__1SDV_20200305T145254_20200305T145322_031541_03A23C_8627

  The IW SLC products downloaded contains one image per sub-swath, per polarization channel, for a total of three images. Each sub-swath image consists of a series of bursts, where each burst was processed as a separate SLC image. The individually focused complex burst images are included, in azimuth-time order, into a single sub-swath image, with black-fill demarcation in between.
  The figure below shows the Sub-swaths (red) and bursts (white) of S1 IW products as well as the subset used in this tutorial (bleu)



- **System Requirements**

  Creating an interferogram using Sentinel-1 Toolbox is a very computer resource-intensive process and some steps can take a very long time to complete. Here are some hints to help speed things up and keep the program from freezing.

  - Requires at least 16 GB memory RAM
  - A Solid State Drive (SSD), as opposed to Hard Disk Drive, will speed up processing
  - Close other applications
  - Do not use the computer while a product is being processed
  - Remove the previous product once a new product has been generated

3.4 Steps for DInSAR Processing

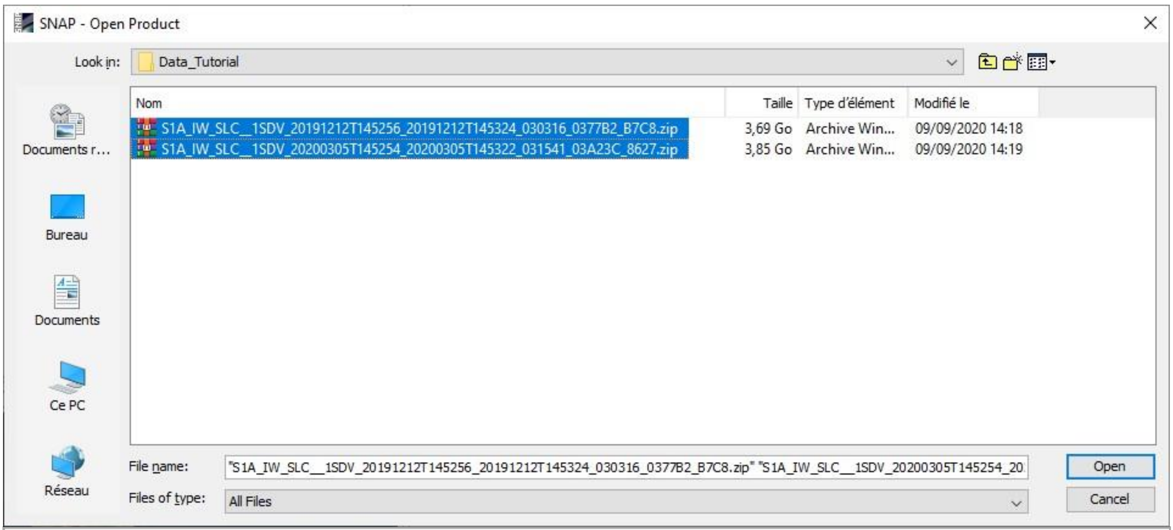
3.4.1 Data Manipulation:

In order to perform interferometric processing, the input products should be two or more SLC products over the same area acquired at different times, such as the sample images provided in this tutorial.

Important: Sentinel-1 Toolbox works from the zip file format, so SLC files must remain zipped.

- **Open the Products**

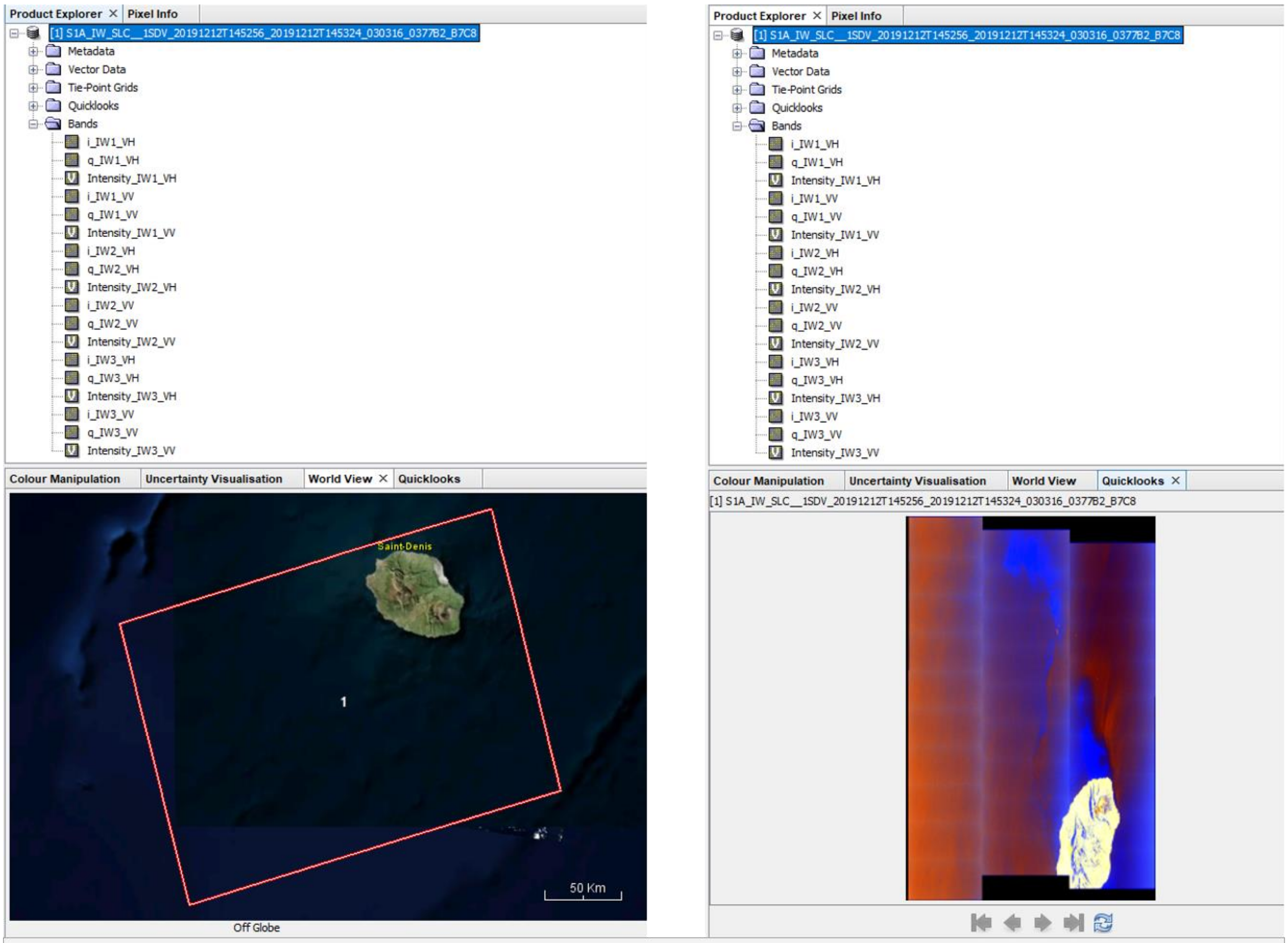
  - Use the  **Open Product** button in the top toolbar and browse to the location of the zipped Sentinel-1 Interferometric Wide (IW) SLC products.
  - Select the two *.zip* SLC files. Click **Open** to load the files into Sentinel-1 Toolbox.



Open Product Dialog in SNAP Toolbox

- **Locate the Products**

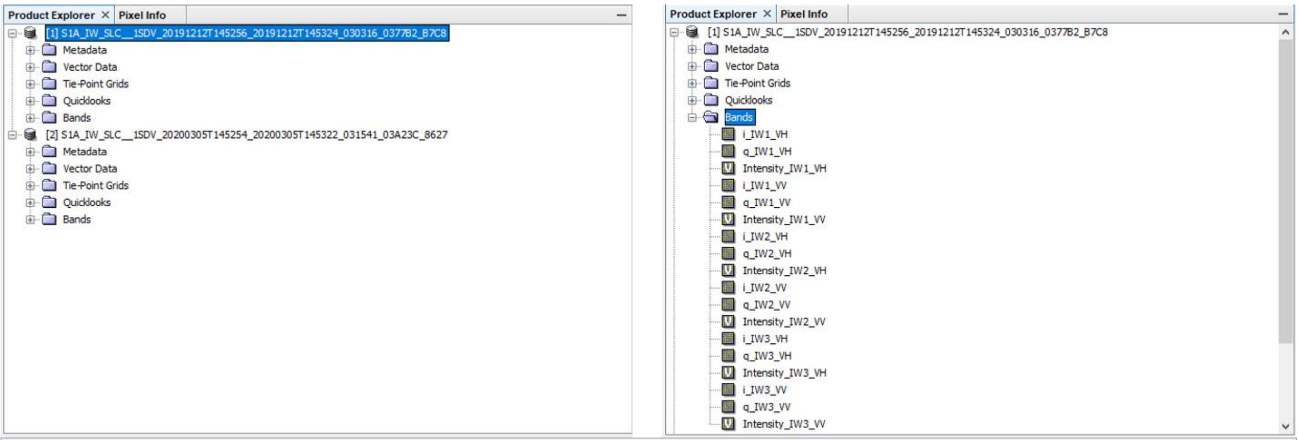
In order to identify the location of your study area within the product, you can use the *World View* or *World Map* (to see its full extent on a base map) or open the *Quicklook* for a preview of the dataset in an RGB color representation.
Note: If you miss any items in your user interface you can activate them in the menu under *View* and *Tool Windows*.



Product Explorer and World View/Quicklooks

- **Explore the products**

  In the *Product Explorer* window, you will see the products listed.
  - Double-click on each product to expand the view.
  - Double-click **Bands** to expand that folder for each product.



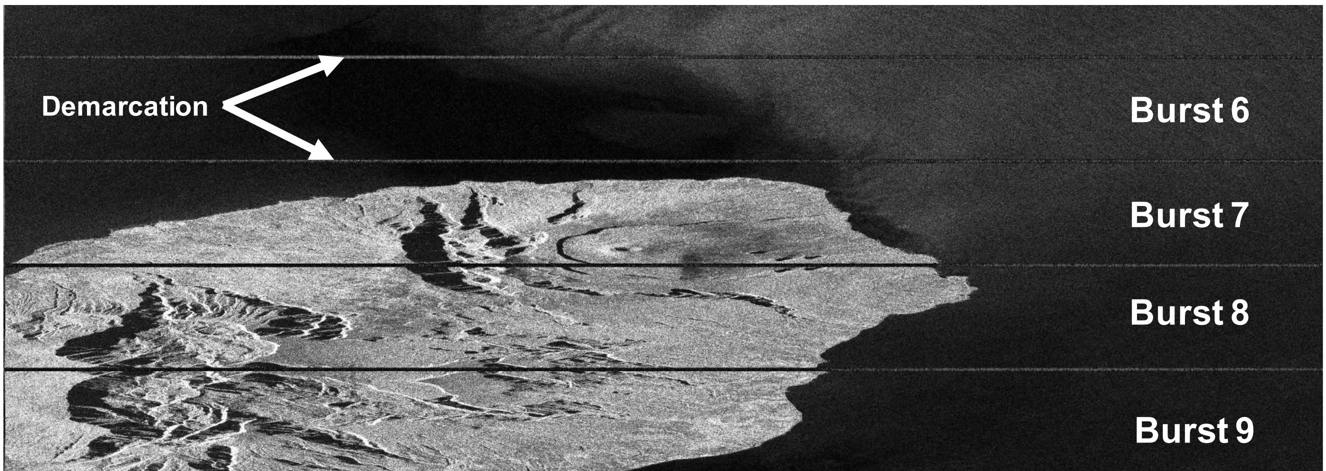
Product Explorer Tab within the SNAP Toolbox user interface

In the *Bands* folder, you will find 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, while the V(irtual) Intensity band is there to assist you in working with and visualizing the complex data.
In Sentinel-1 IW SLC products, you will find three sub-swaths labeled IW1, IW2, and IW3. Each sub-swath is for an adjacent acquisition by the TOPS mode.

Note: To more easily follow the recipe, ensure that the _B7C8 SLC (earlier acquisition data) is listed as the first product and the _8627 SLC (later acquisition data) is listed as the second product in the Product Explorer window.

- **View the products**

To view the data, double-click on the **Intensity_IW1_VV** band of one of the two images. Zoom in on the image and pan by using the tools in the *Navigation* window displayed below the *Product Explorer* window. Within a sub-swath, TOPS data are acquired in bursts. Each burst is separated by a demarcation zone. Any "data" within these demarcation zones can be considered invalid and should be zero-filled but may also contain garbage values.



Intensity image of IW3 sub-swath with bursts and demarcation areas identified.

3.4.2 Data Processing

- **Coregistration**

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.

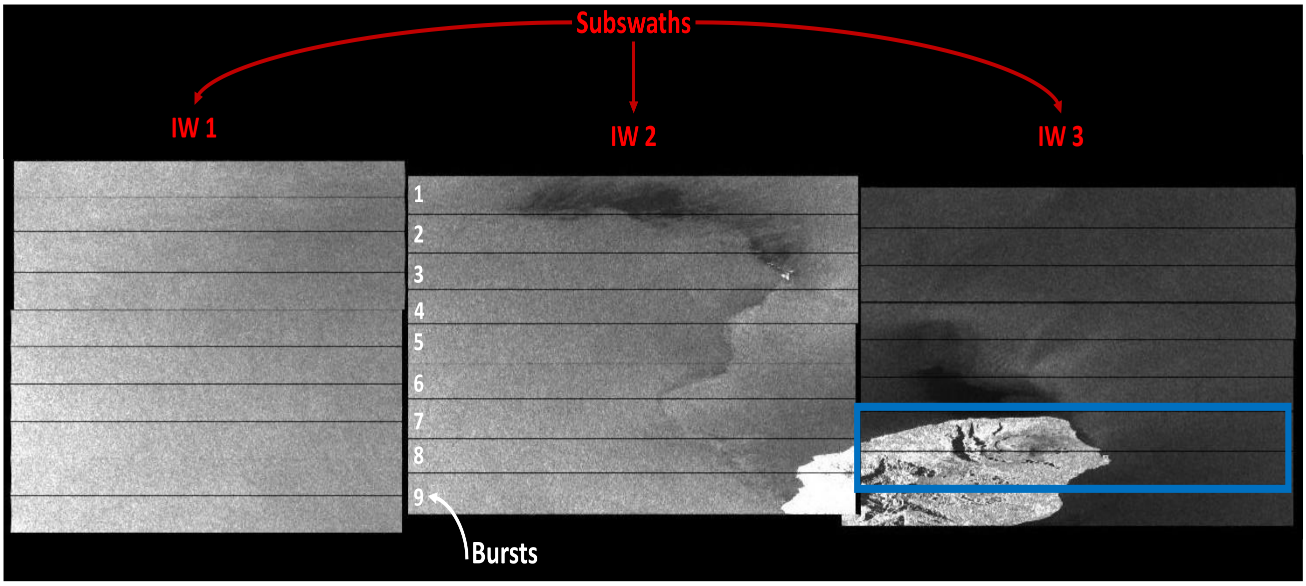
S-1 TOPS Coregistration consists of a series of steps, which occur automatically once processing starts:

1. Reading the two data products
2. Selecting a sub-swath and bursts with TOPSAR-Split
3. Applying precision orbit correction with Apply-Orbit-File
4. Conducting a DEM-assisted Back-Geocoding Coregistration
5. increasing the quality of the coregistration by applying the *S-1 Enhanced Spectal Diversity* (ESD) operator

SNAP offers to combine all these steps within the *S-1 TOPS Coregistration with ESD* operator, but this processing chain consumes a lot of memory. In this tutorial, the single steps to correctly coregister the products are performed individually and successively.

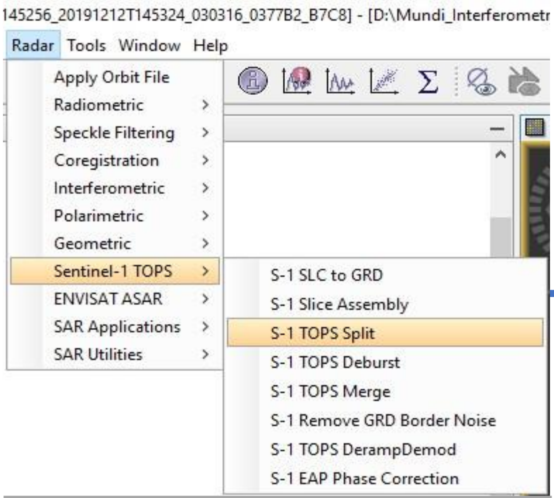
- **TOPS Split**

S-1 TOPS Split is applied to the data to select only those bursts which are required for the analysis. They are marked in blue in the figure below

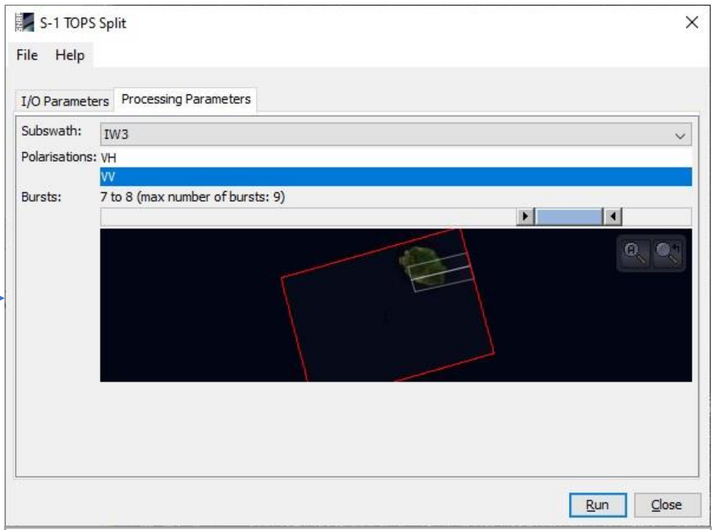


To reduce the loaded data to the area of interest

- From the *Radar* menu, select *Sentinel-1 TOPS > S-1 TOPS Split*
- In the *TOPS-Split tabs*, select the **IW3** sub-swath, **VV** polarization and bursts from **7 to 8** for each of the products and confirm with **Run**



Navigate to S-1 TOPS Split



Select Sub-Swath **IW3, VV** polarization and Bursts **7 to 8**

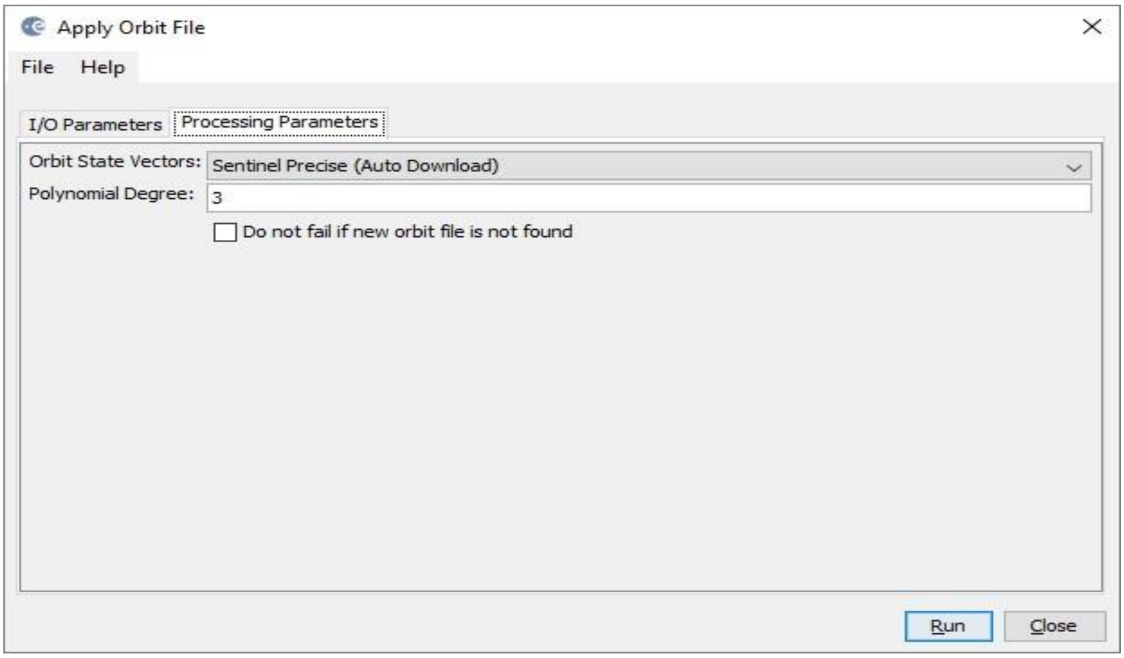
- **Applying Orbit Information**

Orbit auxiliary data contain information about the position of the satellite during the acquisition of SAR data. Orbit data are automatically downloaded by Sentinel-1 Toolbox and no manual search is required by the user.

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-second intervals. Files are generated one file per day and are delivered within 20 days after data acquisition.

To execute the operator for both split products as generated in the previous step

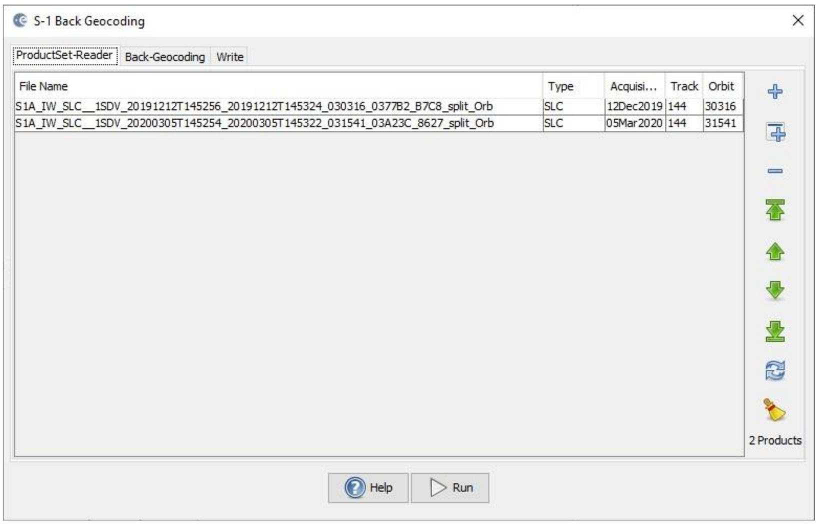
- From the *Radar* menu, select *Apply Orbit File*
- In the *Apply Orbit File* tabs, select *Sentinel Precise (Auto Download) for Orbit State Vectors* and 3 for *Polynomial Degree*

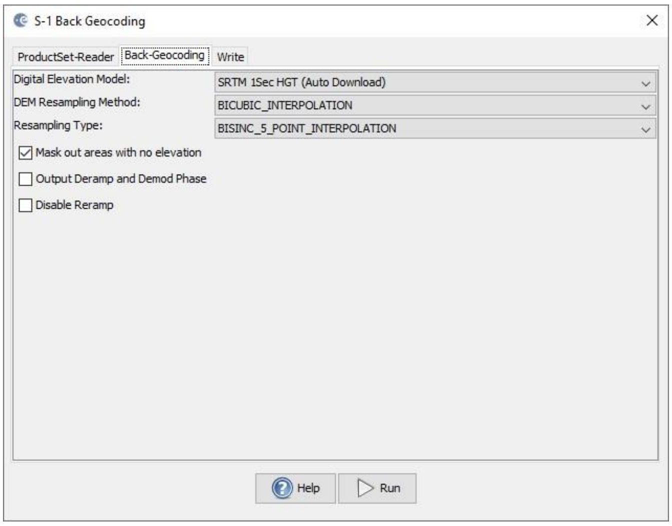


- **Back Geocoding and Enhanced Spectral Diversity**

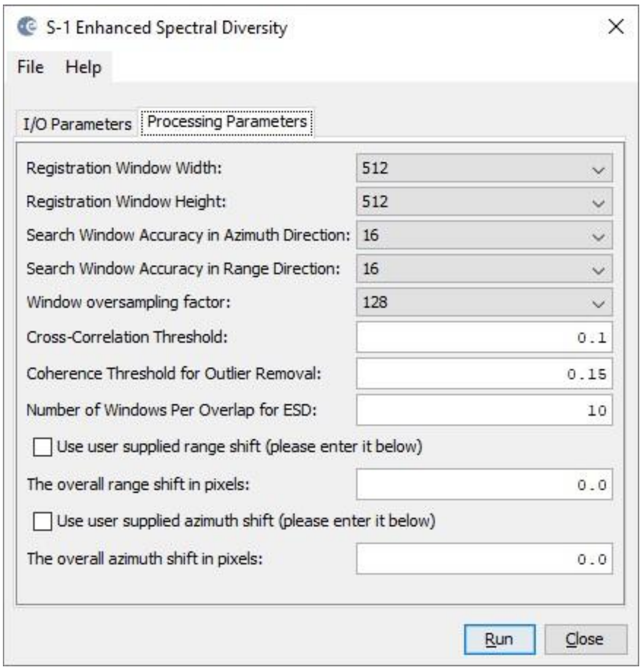
The S-1 Back Geocoding operator coregisters the two split products based on the orbit information added in the previous step and information from a digital elevation model (DEM) which is downloaded by SNAP.

- From the *Radar* menu, select *Coregestration > S-1 TOPS Coregestration > S-1 Back Geocoding*
- In the *ProductSet-Reader* tab, add the products of the two dates (ending with "_split_Orb") to the file list
- In the *Back-Geocoding* tab, select *SRTM 1Sec HGT (AutoDownload)* for *Digital elevation model*, BICUBIC_INTERPOLATION for *DEM Resampling Method* and BISINC_5_POINT_INTERPOLATION for *Resampling Type.* Areas that are not covered by the DEM or are located in the ocean may optionally be masked out.
- In the *Write* tab, set the Directory path to your working directory.
- Click **Run** to begin coregistering the data. The resulting coregistered stack product will appear in the *Product Explorer* window with the suffix *Orb_Stack.*

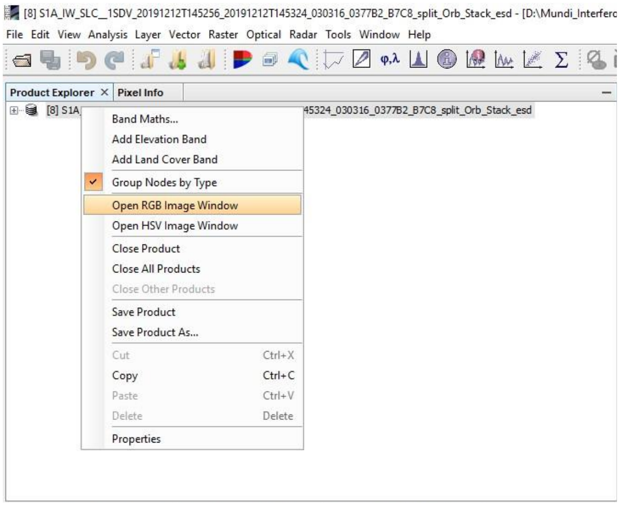


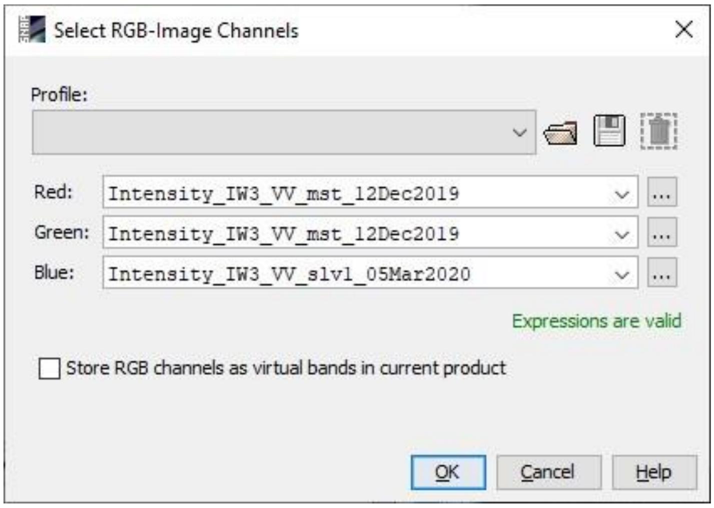


- To increase the quality of the coregistration you apply the *S-1 Enhanced Spectal Diversity* (ESD) operator (under *Radar > Coregistration > Sentinel-1 TOPS Coregistration*) on the stack generated by the Back Geocoding. It applies range and azimuth shift corrections to the slave image.

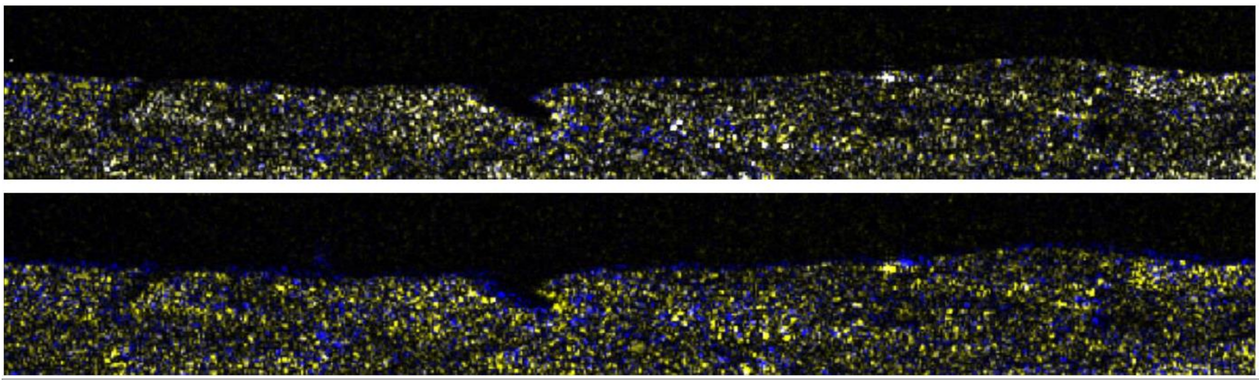


After the coregistration is completed, it is advisable to visually check the quality of the stack. This can be done by an RGB representation of the master and slave product which shows if the images are correctly aligned. Select the master for red and green and the slave for blue





Zoom in to an area with distinct surfaces, for example the border between land and water. The RGB image should be clear and sharp and not be dominated by one of the images (yellow [red+green] for the master or blue for the slave image). The only exception are changes in landcover or scattering mechanisms which occurred in the time between the first and the second image acquisition



Successful (top) vs failed (bottom coregistration in an RGB

- **Interferogram Formation and Coherence Estimation**

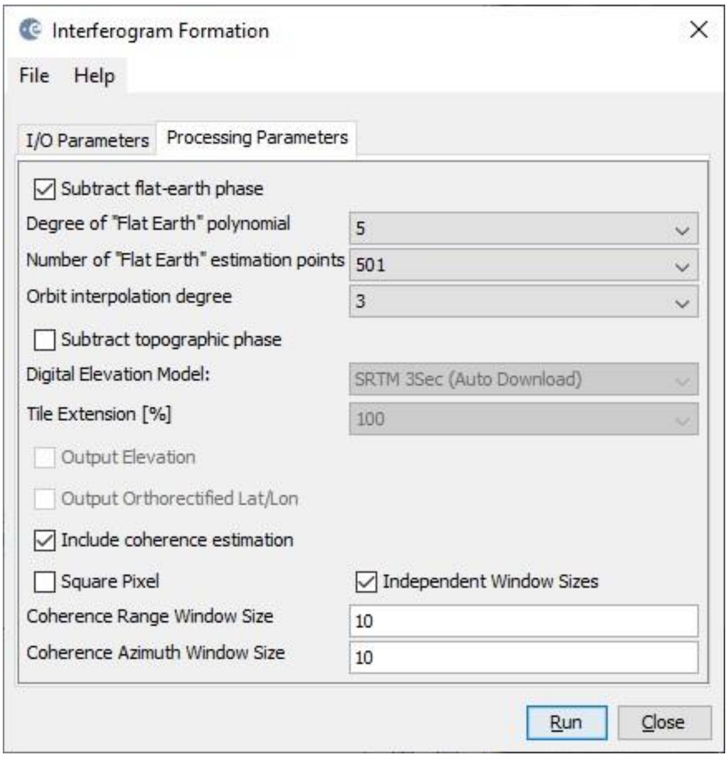
The interferogram is formed by cross-multiplying the master image with the complex conjugate of the “slave.” The amplitude of both images is multiplied while their respective phases are differenced to form the interferogram.

The phase difference map, i.e., interferometric phase at each SAR image pixel, depends only on the difference in the travel paths from the SAR sensor to the considered resolution cell during the acquisition of each image.

To form the Interferogram

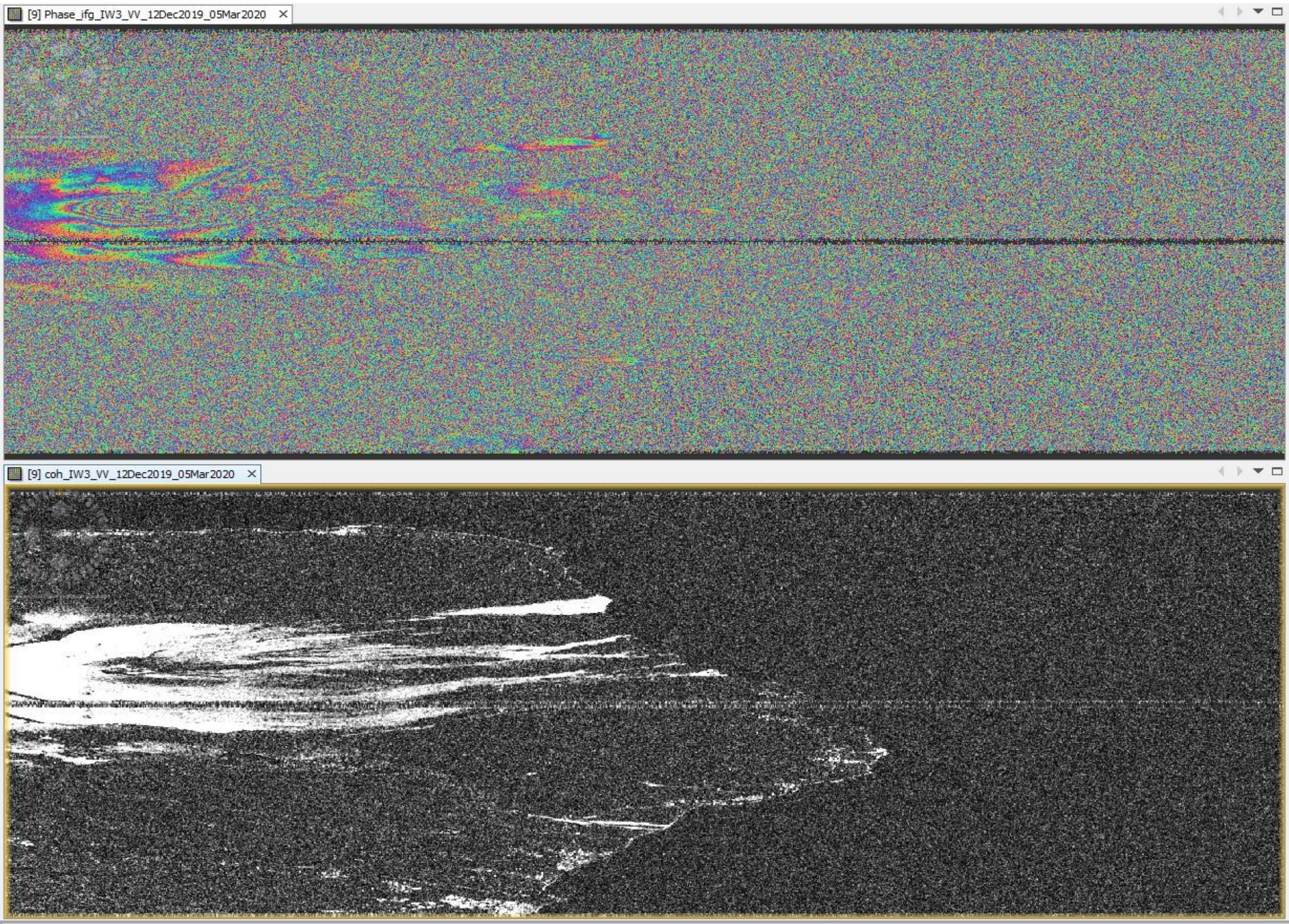
- From the *Radar* menu, select *Interferometric > Products > Interferogram Formation*

Through the interferometric processing flow, we will try to eliminate other sources of error and be left with only the contributor of interest, which is typically the surface deformation related to an event.



The flat-earth phase removal is done automatically during the Interferogram Formation step. The flat-earth phase is the phase present in the interferometric signal due to the curvature of the reference surface. The flat-earth phase is estimated using the orbital and metadata information and subtracted from the complex interferogram.

The resulting product appended with "…Orb_Stack_esd_ifg" will contain the interferogram (Phase_ifg_IW…) and the coherence (coh_IW_…) as separate bands. Double click them to check for their quality. When zoomed in, you may still see the demarcation zones between bursts in this initial interferogram. This will be removed once TOPS Deburst is applied.

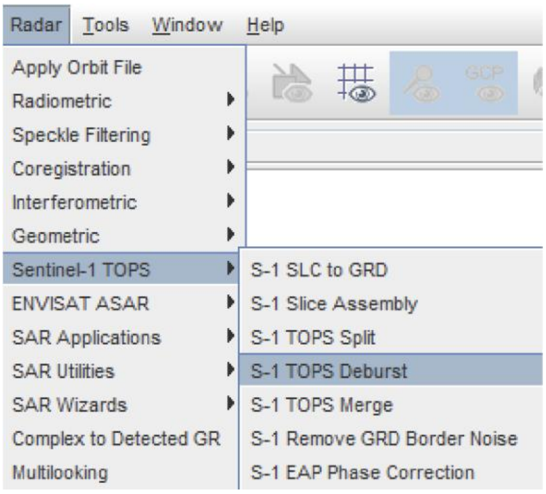


Interferogram (top) and coherance (bottom)

As flat-earth phase removal removal was applied, the interferogram should now only contain variations from displacement, atmosphere, topographic and noise. It is displayed in a rainbow color scale ranging from -π to +π. The patterns, also called “fringes” represent a full 2π cycle and appear in an interferogram as cycles of arbitrary colors, with each cycle representing half the sensor’s wavelength. Relative ground movement between two points is later derived by counting the fringes and multiplying by half of the wavelength. The closer the fringes are together, the greater the strain on the ground.

- **TOPS Deburst**

To seamlessly join all bursts in a swath into a single image, we apply the TOPS Deburst operator from the Sentinel-1 TOPS menu.



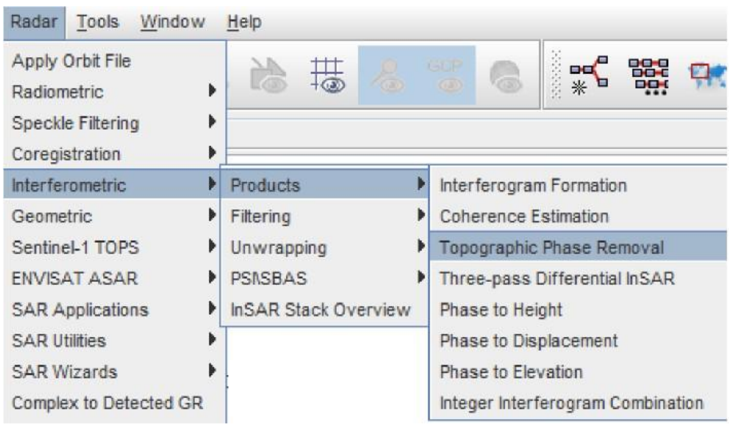
- Navigate to the *Radar* menu, select *Sentinel-1 TOPS > S-1 TOPS Deburst* option
- Keep the default values, ensuring that product (tagged.._Orb_Stack_esd_ifg) is selected as the Source and output Directory path is correct
- Click Run

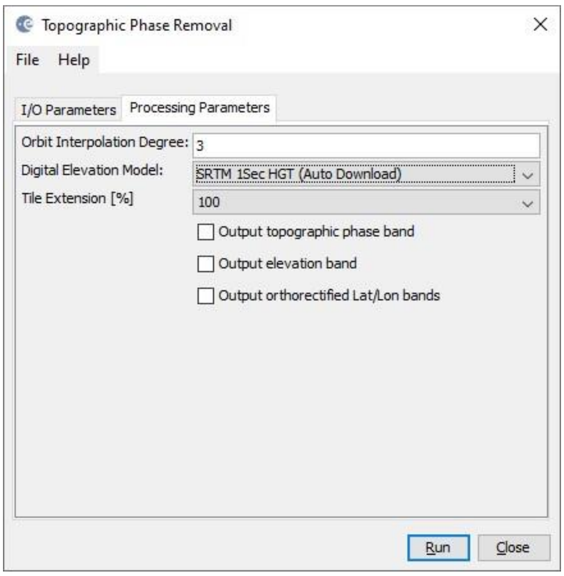
The resulting product will be appended with Orb_Stack_esd_ifg_deb

- **Topographic Phase Removal**

To emphasize phase signatures related to deformation, topographic phase contributions are typically removed using a known DEM. In Sentinel-1 Toolbox, the Topographic Phase Removal operator will simulate an interferogram based on a reference DEM and subtract it from the processed interferogram.

- Navigate to the *Radar* menu, select *Interferometric > Products > Topographic Phase Removal* option
- In the *Topographic Phase Removal* tab, select *SRTM 1Sec HGT (AutoDownload)* for *Digital elevation model* and click Run

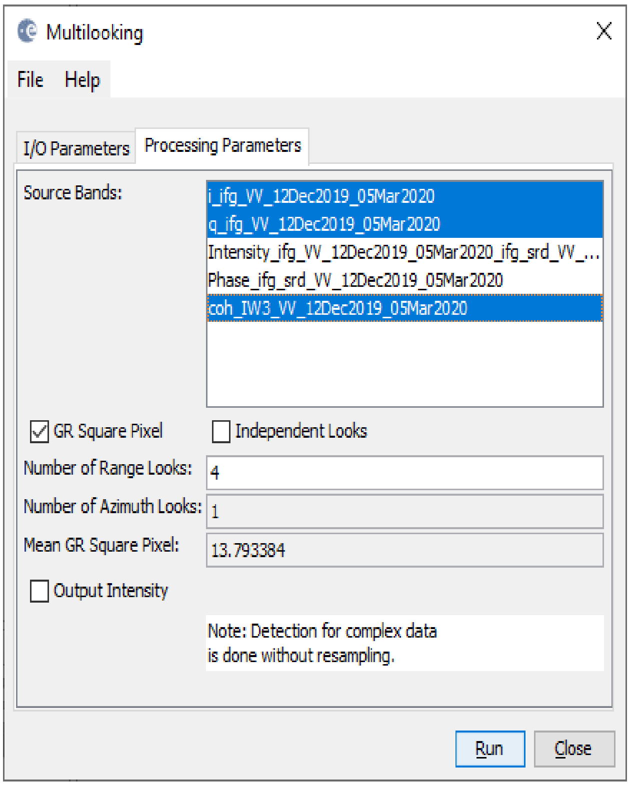




- **Multi-looking**

The first step to improve phase fidelity is called multi-looking. Navigate to the *Radar* dropdown menu.

- Select the *SAR Utilities > Multilooking* option, ensure that the source is set to product with (tagged _dinsar) and the output Directory is correct
- Click on the *Processing Parameters* tab.



Note: The coherence band (starting with coh_) will be essential if your intention is to unwrap the interferogram or create a deformation map. Coherence is used to verify the legitimacy of the derived phase data; typically, data with coherence values less than 0.3 are thrown out.

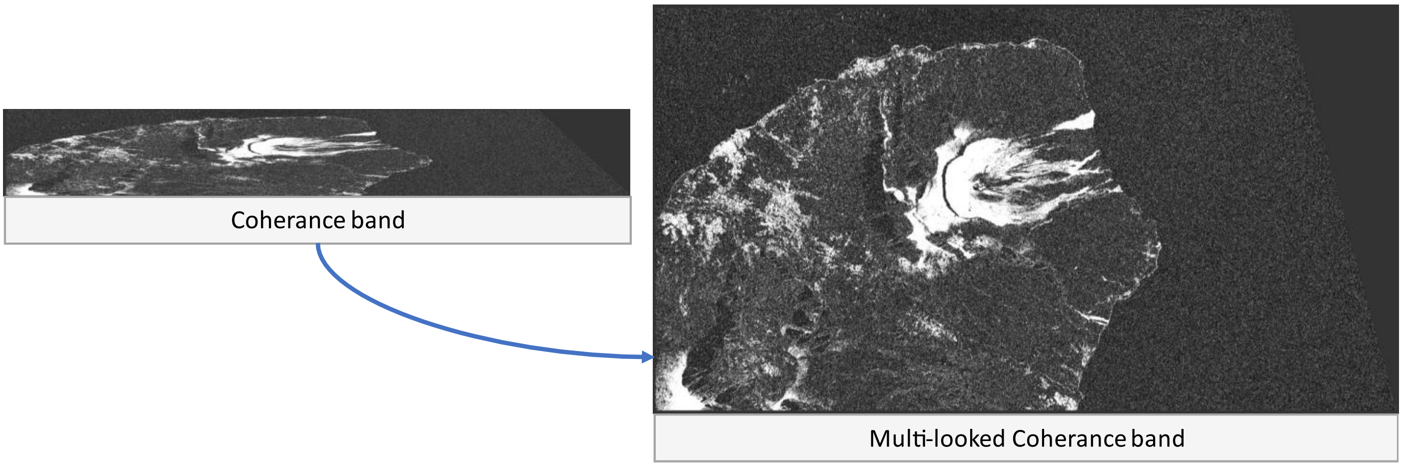
- Use the Ctrl button to select the i, q, and coh bands from the list as the Source Bands to be multi-looked.

Because the phase band is virtual, it is only a temporary visualization of the interferogram. After multi-looking is performed, this band will disappear, but it will be restored in the following Goldstein Phase Filtering step.

- In the *Number of Range Looks* field, enter **4**

In essence, multi-looking performs a spatial average of a number of neighboring pixels (in our case, 4×1 pixels) to suppress noise and proportion the image correctly. This process comes at the expense of spatial resolution.

- Click Run. The resulting product name is appended with *..Stack_esd_ifg_deb_dinsar_ML*

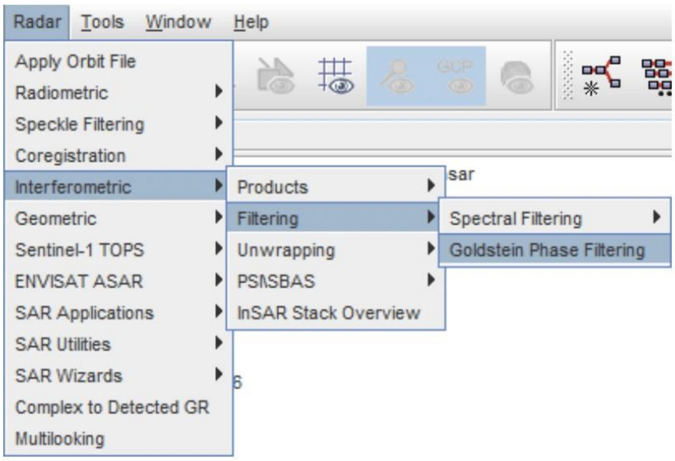


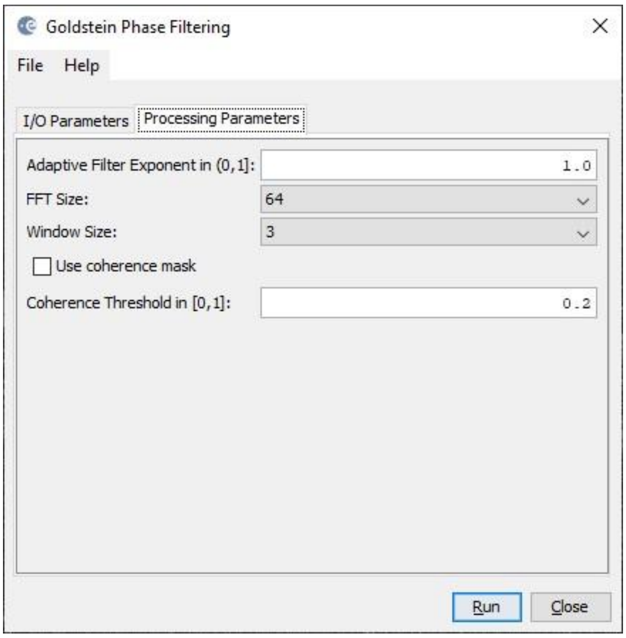
- **Phase Filtering**

Interferometric phase can be corrupted by noise from temporal and geometric decorrelation, volume scattering, and other processing errors. To be able to properly analyze the phase signatures in the interferogram, the signal-to-noise ratio will be increased by applying phase filtering techniques such as the Goldstein filter which uses a Fast Fourier Transformation (FFT) to enhance the signal-to-noise ratio of the image.

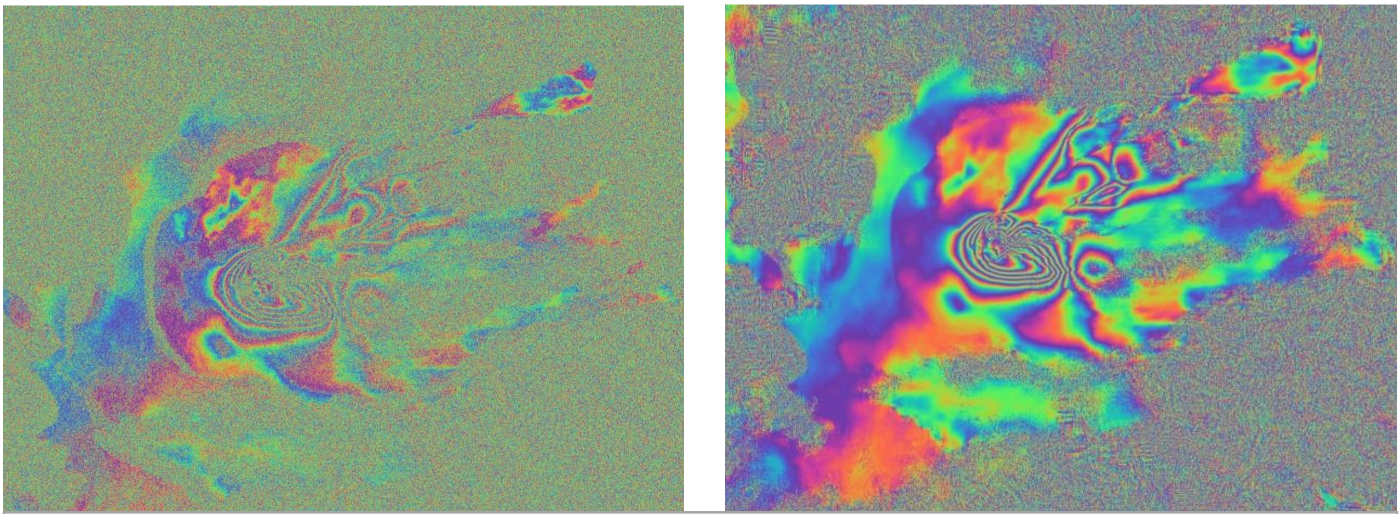
To apply the Goldstein Phase Filtering

- Navigate to *Radar > Interferometric > Filtering*
- Select *Goldstein Phase Filtering*
- Keep the default values and click *Run*





The resulting product name is appended with *Orb_Stack_esd_ifg_deb_dinsar_ML_flt*.



Interferogram before (left) and after (right) Goldstein Phase Filtering

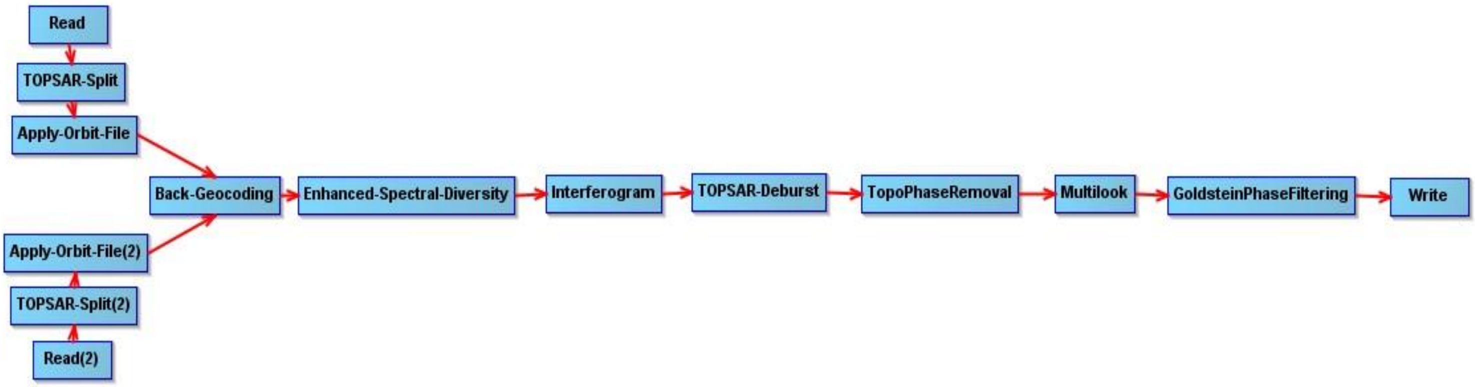
After phase filtering, the interferometric phase is significantly improved, and the dense earthquake deformation-related ring pattern is now clearly visible. This interferogram is now ready to be unwrapped.

- **Summary (Automatic *DInSAR processing using Graph Builder)***

SNAP offers to combine all the steps describe above within the Graph Builder, but this processing chain consumes a lot of memory. We recommend using the step by step method.

Build and Apply *DInSAR Processing Chain*

- Graphical User Interface path: Tools > Graph Builder
- Build a graph so that it looks like the following:



- Input 1: S1A_IW_SLC__1SDV_20191212T145256_20191212T145324_030316_0377B2_B7C8 (Read)
- Input 2: S1A_IW_SLC__1SDV_20200305T145254_20200305T145322_031541_03A23C_8627(Read2)
- Output: S1A_IW_SLC__1SDV_20191212T145256_20191212T145324_030316_0377B2_B7C8_split_Orb_Stack_esd_ifg_deb_dinsar_ML_flt (Write)
- Processing parameters:
  - Add operators by order as defined above in the manual step-by-step processing
  - Specify processing parameters accordingly
  - Save processing graph (*.xml file)
  - Run the processing graph

- **Phase Unwrapping**

Phase unwrapping is the most complicated stage of interferometric data processing. In this recipe, we will use SNAPHU, which is a two-dimensional phase unwrapping algorithm developed by Chen and Zebker. Once the interferogram is unwrapped, height values can be derived from the product for use in further processing, such as generating deformation maps or DEMs.

The interferometric phase is ambiguous and only known within 2π. In order to be able to relate the interferometric phase to the topographic height, the phase must first be unwrapped. The altitude of ambiguity is defined as the altitude difference that generates an interferometric phase change of 2π after interferogram flattening.

Phase unwrapping solves this ambiguity by integrating phase difference between neighboring pixels. After deleting any integer number of altitudes of ambiguity (equivalent to an integer number of 2π phase cycles), the phase variation between two points on the flattened interferogram provides a measurement of the actual altitude variation.

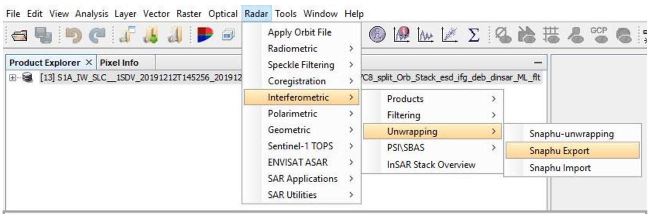
Unwrapping in SNAP follows three distinct steps:

- **Export** of the wrapped phase (and definition of the parameters)
- **Unwrapping** of the phase (performed outside SNAP by snaphu)
- **Import** of the unwrapped phase back into SNAP

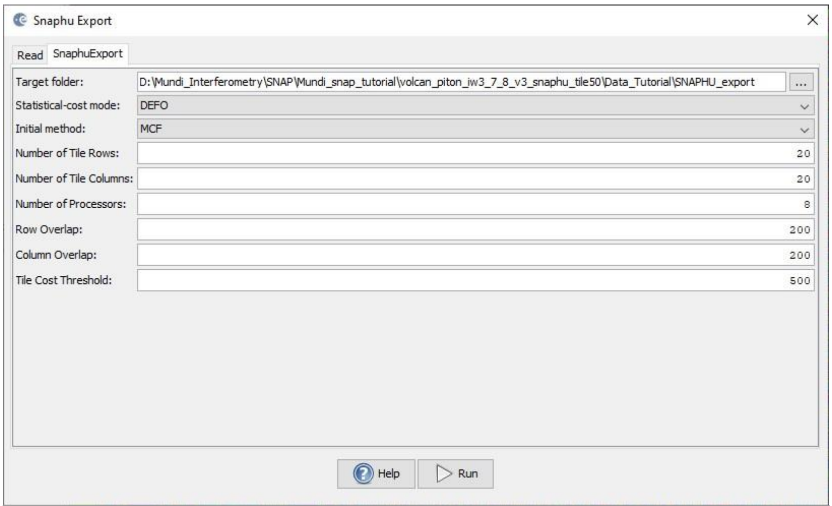
- **Export to SNAPHU**

- Select the product from the *Product Explorer* tab
- Navigate to: *Radar > Interferometric > Unwrapping > Snaphu Export*
- In the *Snaphu Export* tab, select your working directory as the target folder. If the selection of the directory does not work, simply copy and paste the path of your working directory into the text field.
    - We recommend creating a separate folder for this step.
- Select DEFO for deformation mapping in Statistical-cost mode and MCF as initial method
- To speed up the unwrapping process, you may increase the number of processors (this depends on the CPU you have)
- Click Run to create SNAPHU export folder

Note: You can neglect the eventual error message (Error: [NodeId: SnaphuExport Please add a target folder]. It will go away once you switch tabs or hit **Run**, as long as you have entered a valid target folder.



Navigation to SNAPHU export



Snaphu Export Dialog Box

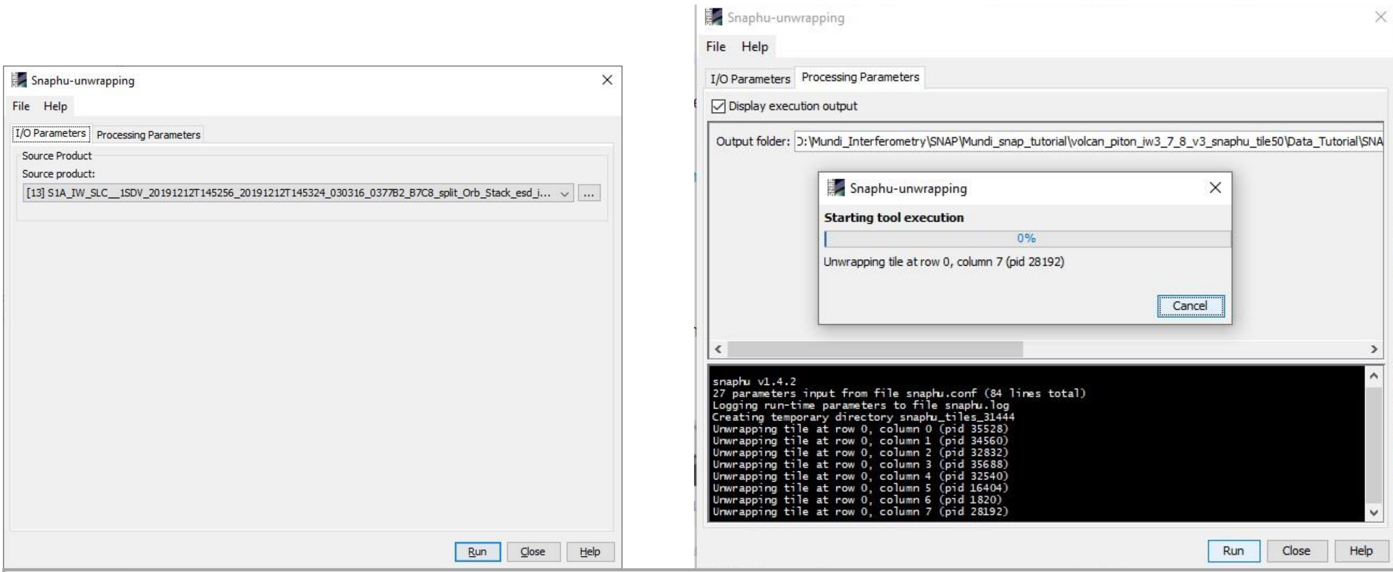
A directory is created in your working directory with the same name as the product you selected as an input (here: S1A_IW_SLC__1SDV_20191212T145256_20191212T145324_030316_0377B2_B7C8_split_Orb_Stack_esd_ifg_deb_dinsar_ML_flt). Inside this folder, you will find:

- the **coherence**: image (*.img) and metadata (*.hdr)
- the **wrapped phase**: image (*.img) and metadata (*.hdr)
- the **unwrapped phase**: only the metadata (*.hdr), because the image (*.img) is first to be created by snaphu in the next step.
- a **configuration file** (snaphu.conf) containing the parameters defined in the export operator

- **Unwrapping with SNAPHU**

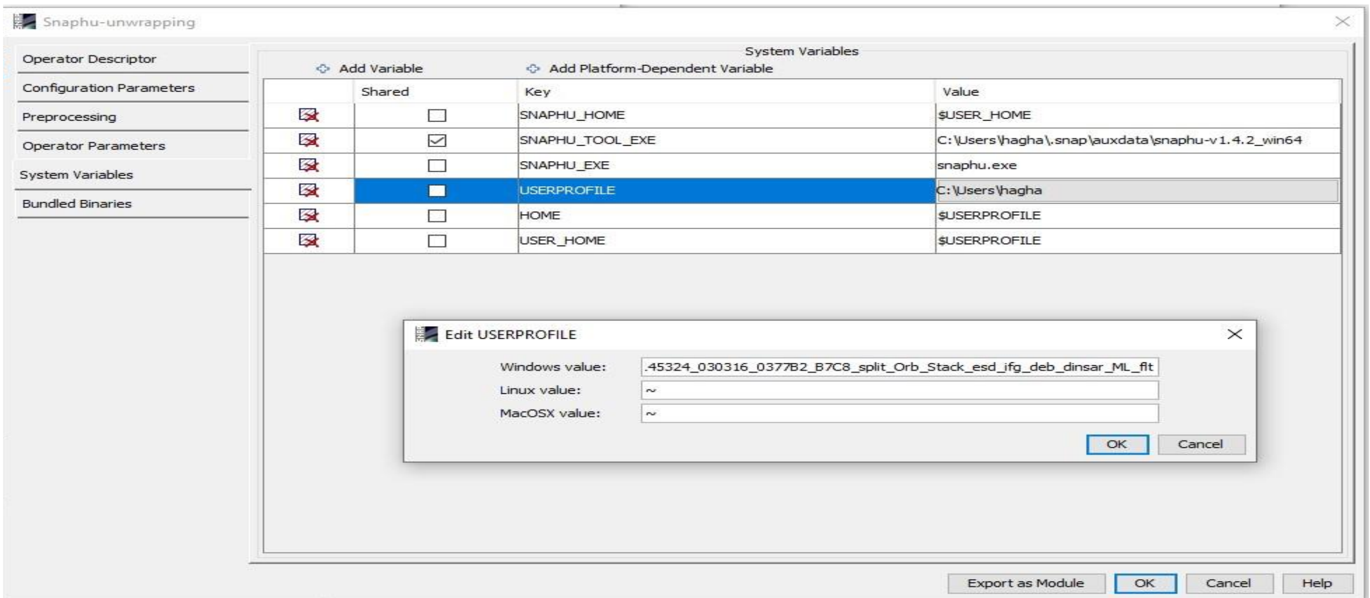
Once the product is exported correctly, the unwrapping can be started from within SNAP, by calling the *Snaphu-unwrapping* operator (under *Radar > Interferometric > Unwrapping*).

- As an input product, select the product (S1A_IW_SLC__1SDV_20191212T145256_20191212T145324_030316_0377B2_B7C8_split_Orb_Stack_esd_ifg_deb_dinsar_ML_flt) from the *Product Explorer* tab
- For the output folder in the *Processing Parameters* tab you can activate **Display execution output** and select the folder which was created during the export (here: S1A_IW_SLC__1SDV_20191212T145256_20191212T145324_030316_0377B2_B7C8_split_Orb_Stack_esd_ifg_deb_dinsar_ML_flt)
- To start the unwrapping, click **Run**. SNAP then sends the command stored in snaphu.conf to the snaphu.exe which creates the raster image belonging to the unwrapped phase metadata.



Unwrapping with the snaphu plugin

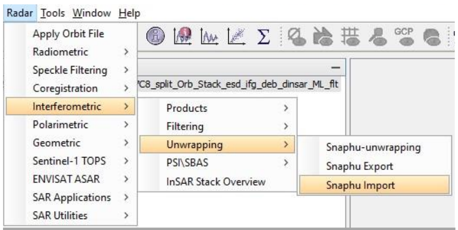
Note: If the tool is not executed by clicking Run, go to *Manage External Tools* in the *Tools* menu. Select “Snaphu-unwrapping” and click **Edit the selected operator** to open the configuration and enter the export directory in the variable **USERPROFILE** under the *System Variables* tab. Confirm with **OK** and start the *Snaphu-unwrapping* operator again.



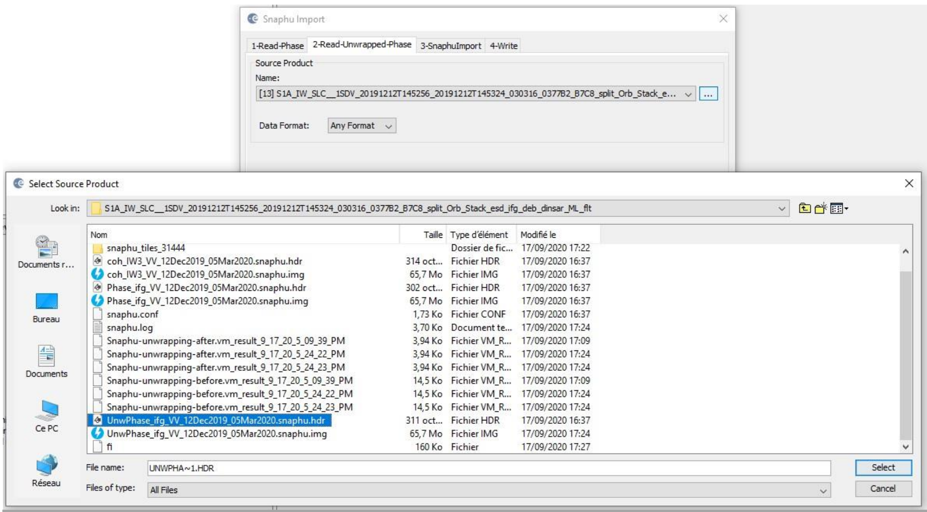
System variables of the snaphu plugin

- **SNAPHU Import**

- Navigate to *Radar > Interferometric > Unwrapping > Snaphu Import*
- In the *Snaphu Import* window:
    - In the *Read Phase* tab, select the interferogram product (S1A_IW_SLC__1SDV_20191212T145256_20191212T145324_030316_0377B2_B7C8_split_Orb_Stack_esd_ifg_deb_dinsar_ML_flt)
    - In the *Read Unwrapped Phase* tab, select the icon ... to open a file menu and navigate to your Snaphu export folder then select the UnwPhase_XXX.hdr file
    - Leave the option "Do NOT save Wrapped interferogram in the target product" unchecked, because it is required in the later step
    - In the *Write* tab, to store the imported unwrapped band in a separate product (recommended), add '_unw' to the output name (here: S1A_IW_SLC__1SDV_20191212T145256_20191212T145324_030316_0377B2_B7C8_split_Orb_Stack_esd_ifg_deb_dinsar_ML_flt**_unw**) and Run

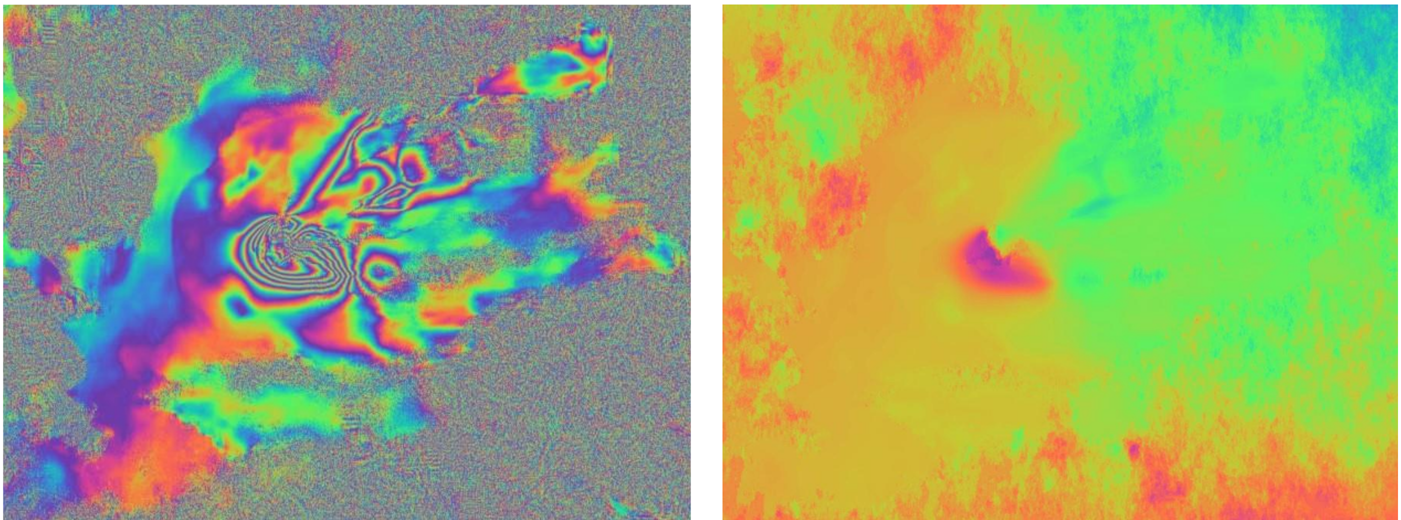


Navigation to Snaphu Import



The Snaphu Import tab

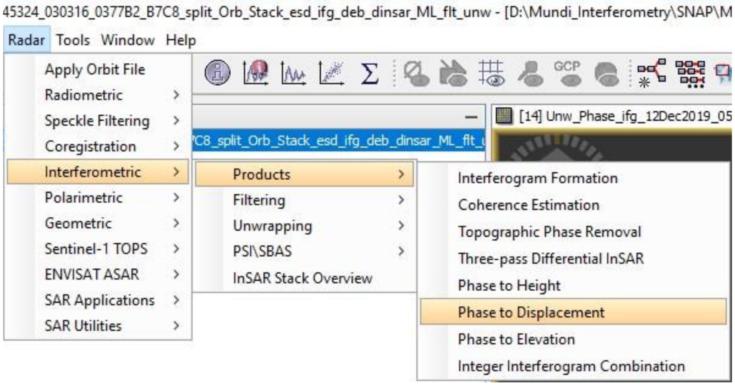
A new product is added to the Product Explorer which contains the wrapped interferogram (Phase_ifg_IW...), the coherence (coh_IW_...) and the unwrapped phase generated with snaphu (here: Unw_Phase_ifg_08Dec2019_20Dec2019)

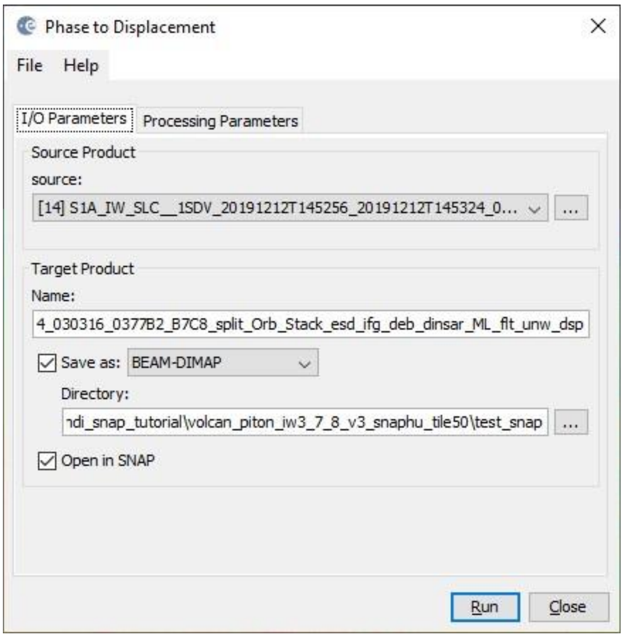


Phase before (left) and after (right) unwrapping

- **Phase to Displacement**

The unwrapped phase is now a continuous raster but not yet a metric measure. To convert the radian units into absolute displacements, the *Phase to Displacement* operator (under *Radar > Interferometric > Products*) is applied to the unwrapped product.

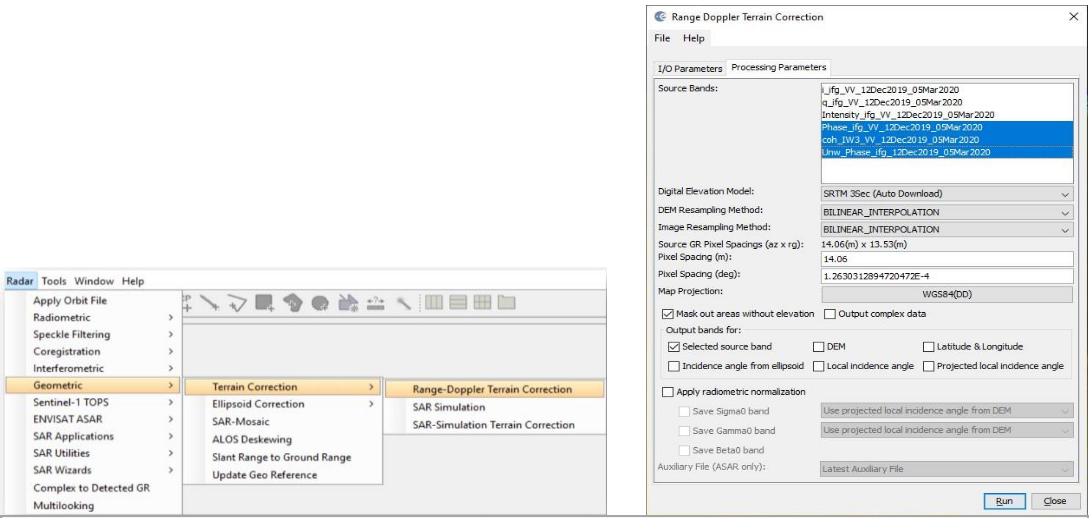




- **Terrain Correction (Geocoding)**

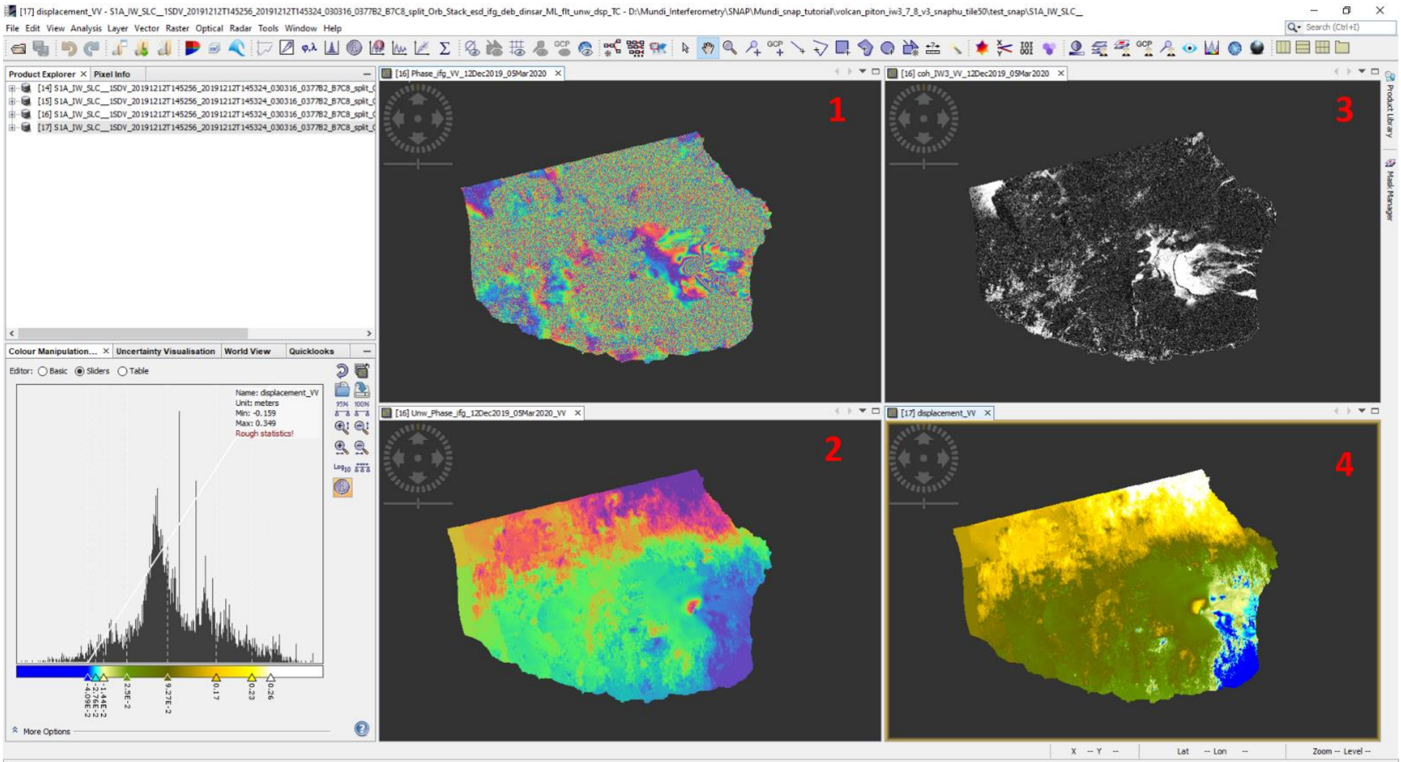
Terrain Correction will geocode the image by correcting SAR geometric distortions using a digital elevation model (DEM) and producing a map projected product.

- Navigate to *Radar > Geometric > Terrain Correction > Range-Doppler Terrain Correction*
- In the *Range-Doppler Terrain Correction* window, select the Unwrapped Phase product as an input in the first time and then repeat the same operation for the displacement product
- In the *Processing Parameters* tab:
  - Select the option to **Mask out areas without elevation**
  - Change **pixel spacing**, if desired
  - If no **Source Band** is selected, all bands of the input product are geometrically corrected
  - Click **Run** to geocode your data



Range Doppler Terrain Correction

The resulting product name is appended with **_TC.**

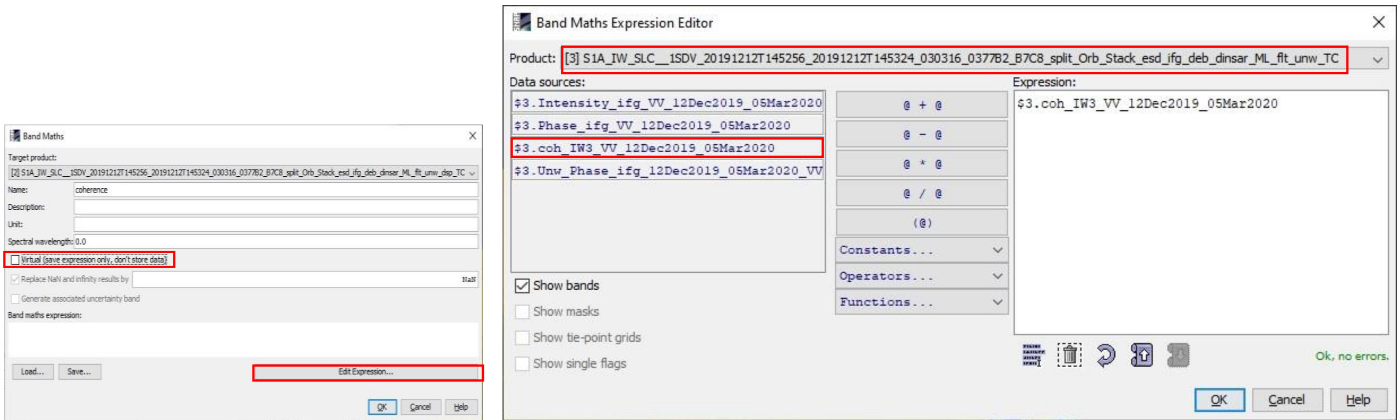


1 : Geocoded Phase **2 :** Geocoded Unwrapped phase **3 :** Geocoded Coherence **4 :** Geocoded Displacement

- **Mask out low coherence pixels**

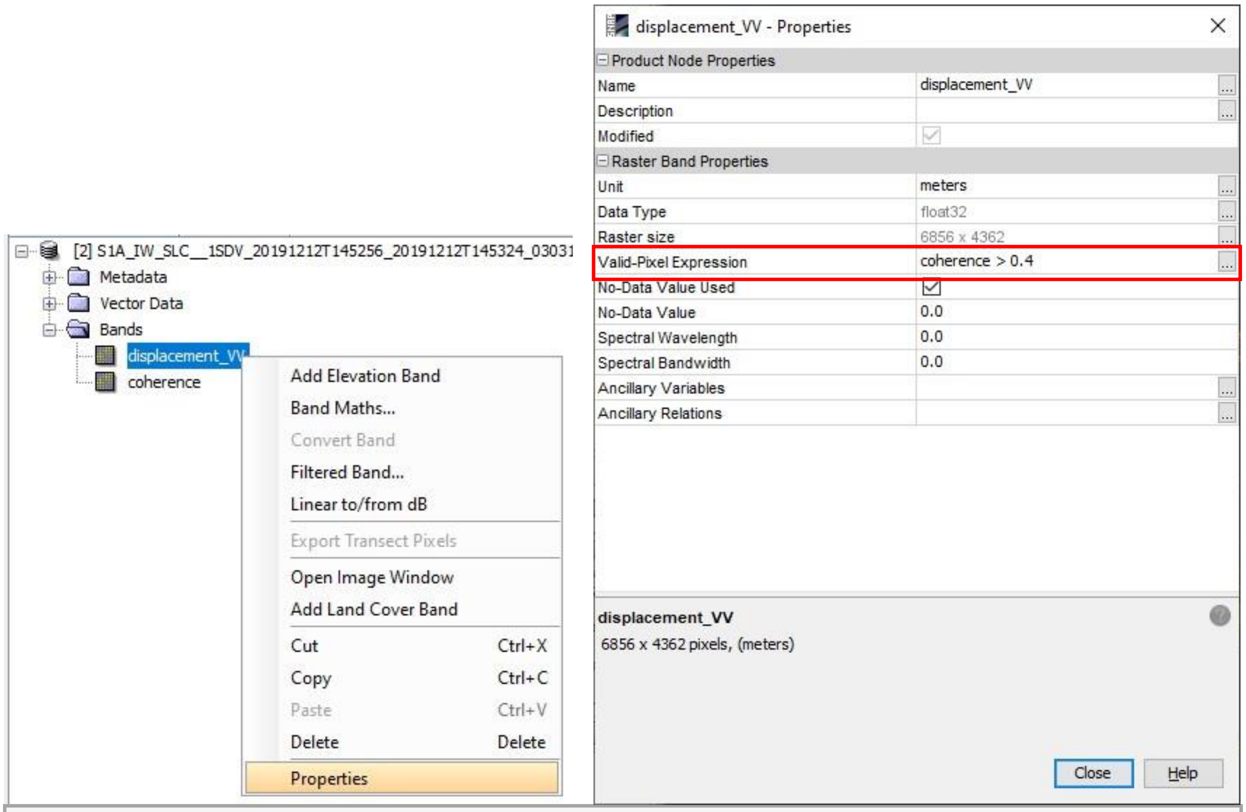
Sometimes it is good to mask out image parts with low coherence to prevent misinterpretation of patterns which resulted from phase decorrelation. This is why the coherence is transferred into the displacement product as follow:

- Add the coherence via the *Band Maths* operator (right-click on the displacement product and select **Band Maths**).
- Call the new raster which is to be generated coherence and uncheck the "Virtual" option
- Open the *Band Maths Expression Editor* by clicking **Edit Expression**. You can now switch between products which have the same dimensions (rows and columns) in the Band Maths Expression Editor and double-clicking the coherence band of a previous product to add it to the expression window. Confirm with **OK** (twice) to apply the calculation.
- The coherence band is now part of the displacement product

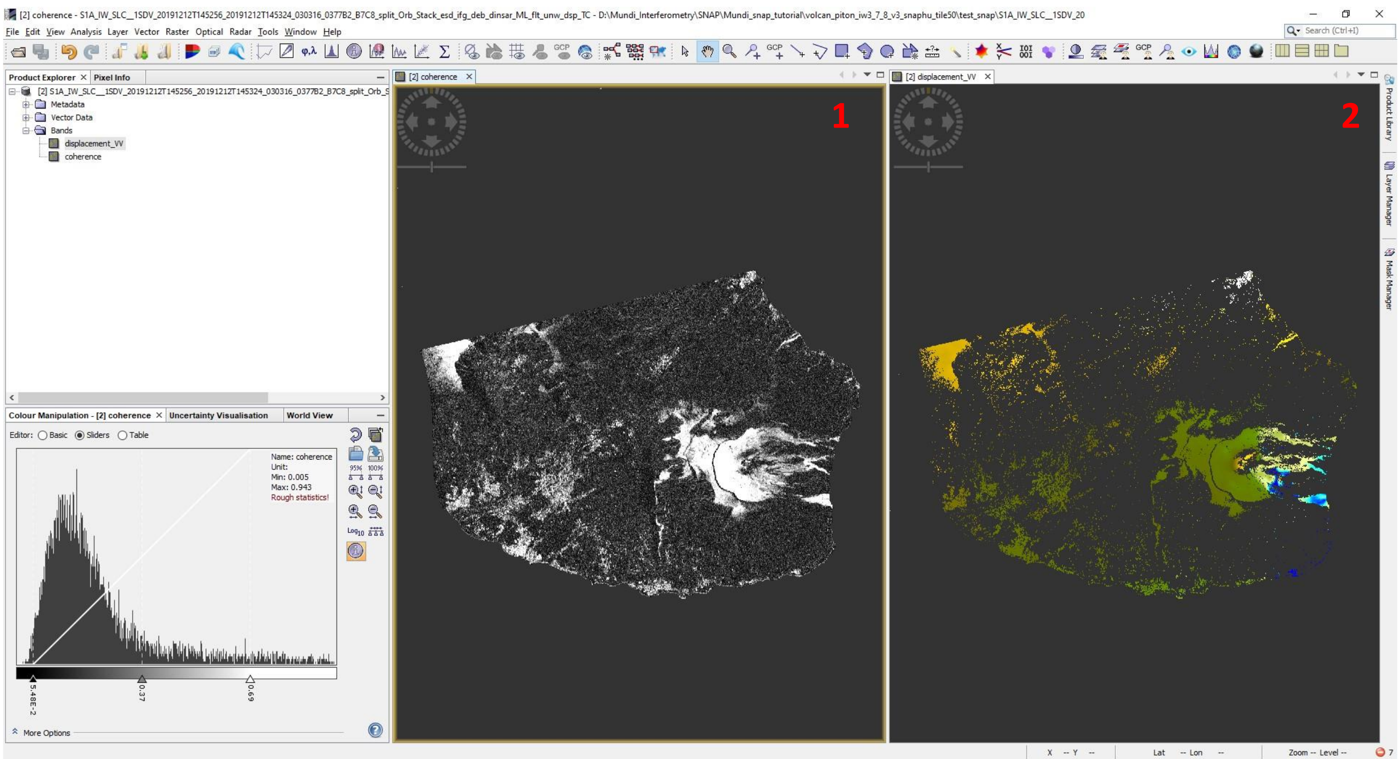


Transfer of bands between products

To mask out image parts with low coherence, right-click on the geocoded displacement band and select **Properties**.
In the *Valid-Pixel Expression*, enter the term `coherence > 0.6`
All pixels with a coherence value below 0.6 are now made transparent in SNAP.

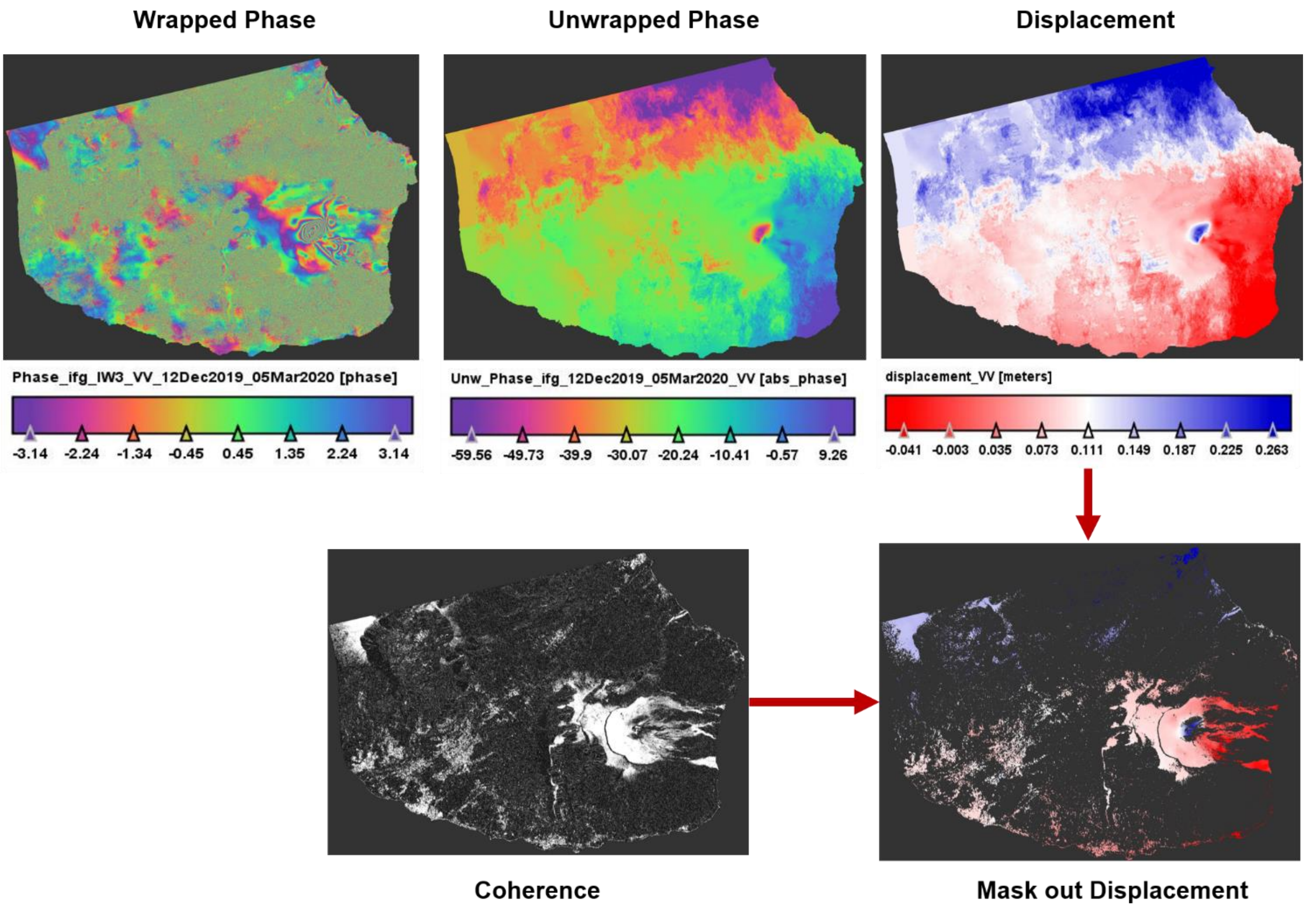


Masking out areas of low coherence

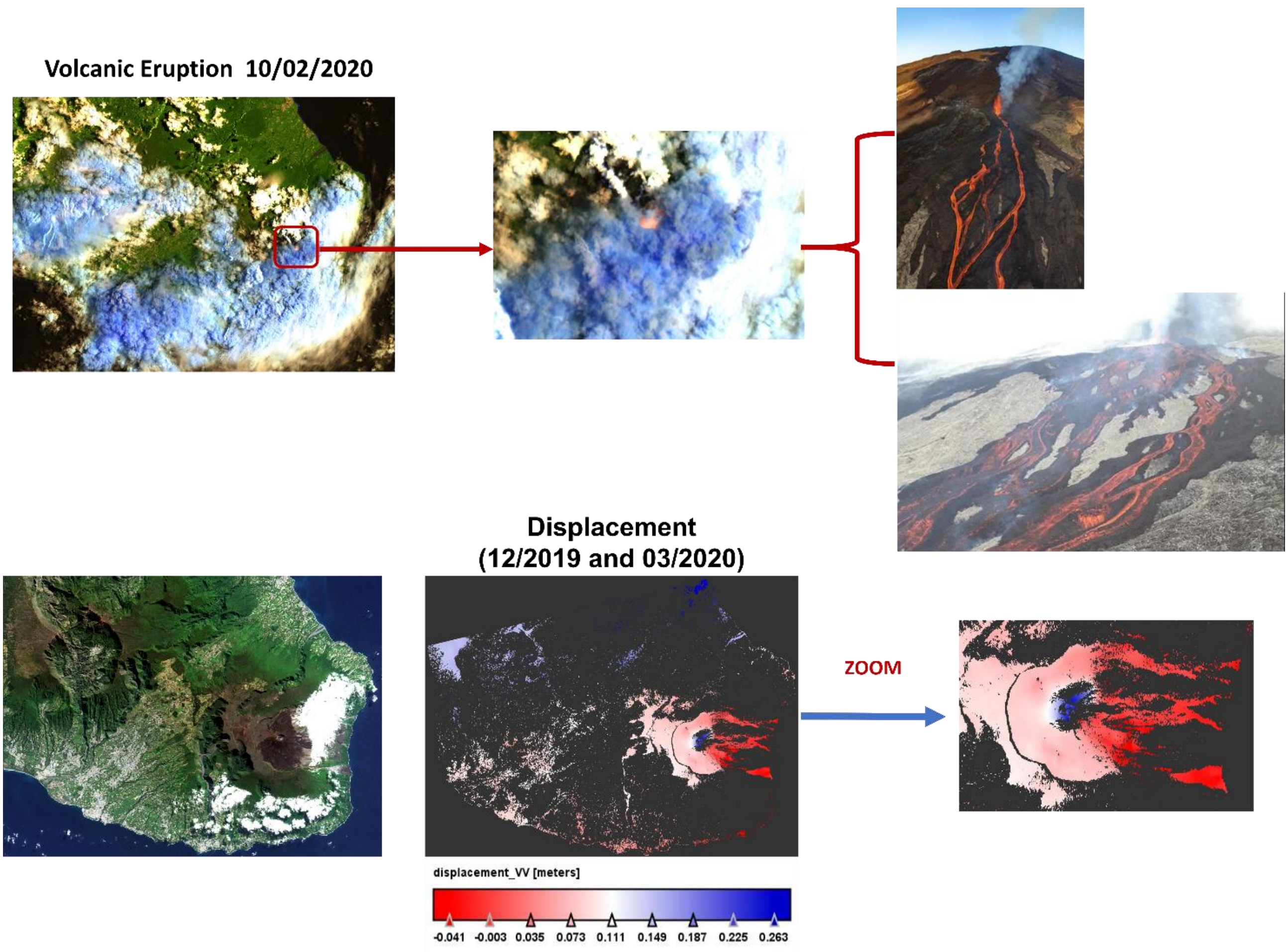


1 : Geocoded Coherence **2 :** Geocoded Mask out Displacement

3.4.3 Results



Interferogram & Displacement - (between 12/2019 and 03/2020)



Volcanic Eruption 10/02/2020 & Displacement - (between 12/2019 and 03/2020)

These illustrations show terrain displacements after the volcanic eruption of Peak of the Furnace (eastern side of Réunion island) that occurred on February 10th 2020, computed on MUNDI VM with the SNAP toolbox from a set of ascending Sentinel-1 SLC pair (resp 2019/12/12 and 2020/03/05).