In a first step, select one band of the Sentinel-2 product in the *Product Explorer* and select the **Geo-Coding** tool φ,λ from the menu bar. A new window will open (Figure 6) which shows you the coordinate reference system of the dataset. Analysis -> Geo-Coding

Sentinel-2 products are stored in the corresponding UTM zone in which they are located. This projection is based on metric units (instead of degrees) and divides the earth into 60 zones with a width 6d of longitude. The UTM zone of the Sentinel-2 product in this tutorial is shown in the Geo-Coding window: Here, it is zone 32 North, as indicated in the line highlighted in Figure 6:

```
PROJCS["WGS 84 / UTM zone 32N"
```

This means, the Sentinel-1 data (currently unprojected) should be projected into the same coordinate reference system.

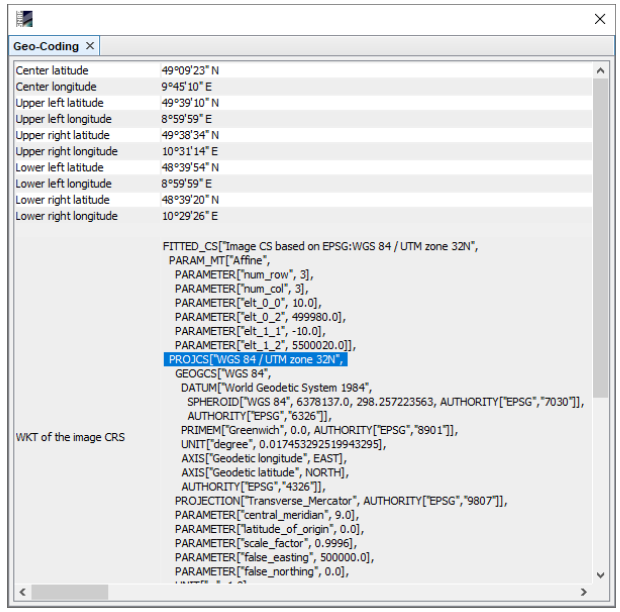



**Figure 6: Geo-Coding of Sentinel-2**

# *Preprocessing of Sentinel-1*

## *Create a Subset*

To reduce the loaded data to the area of interest, select the Sentinel-1 product in the *Product Explorer* and open the open the *Subset* operator (under *Raster*). A separate window might open ("Creating thumbnail image"), but this takes quite a long time, so it is ok to **Cancel** this window.

Switch to the Geo Coordinates tab and enter the following numbers (Figure 7):

- North latitude bound: 48.498
- West longitude bound: 9.058
- South latitude bound: 49.10
- East longitude bound: 9.50

Confirm with **Run** and repeat the step for the second S1 image.

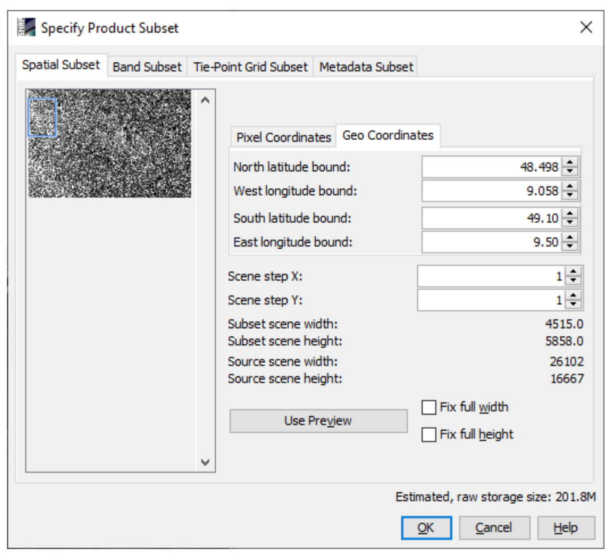



**Figure 7: Sentinel-1 subset**

A new product is shown in the *Product Explorer*, starting with `subset_0_of_S1B`. This product is only of temporary nature and lost after SNAP is closed. Yet, it can be used as an input for the next step so that only the subset area is radiometrically calibrated.

## *Radiometric calibration*

Radiometric calibration converts backscatter intensity as received by the sensor to the normalized radar cross section (Sigma0) as a calibrated measure taking into account the global incidence angle of the image and other sensor-specific characteristics. This makes radar images of different dates, sensors, or imaging geometries comparable.

Open the *Calibration* operator (under *Radar* > *Radiometric*) and use the subset which was created in the previous step as an input.

Select a suitable output folder and enter `S1_20190818` as the output name. All other settings can be left on default. SNAP uses the image metadata to calibrate the image as described in [this documentation](). After completion, the output product is added to the Product Explorer.

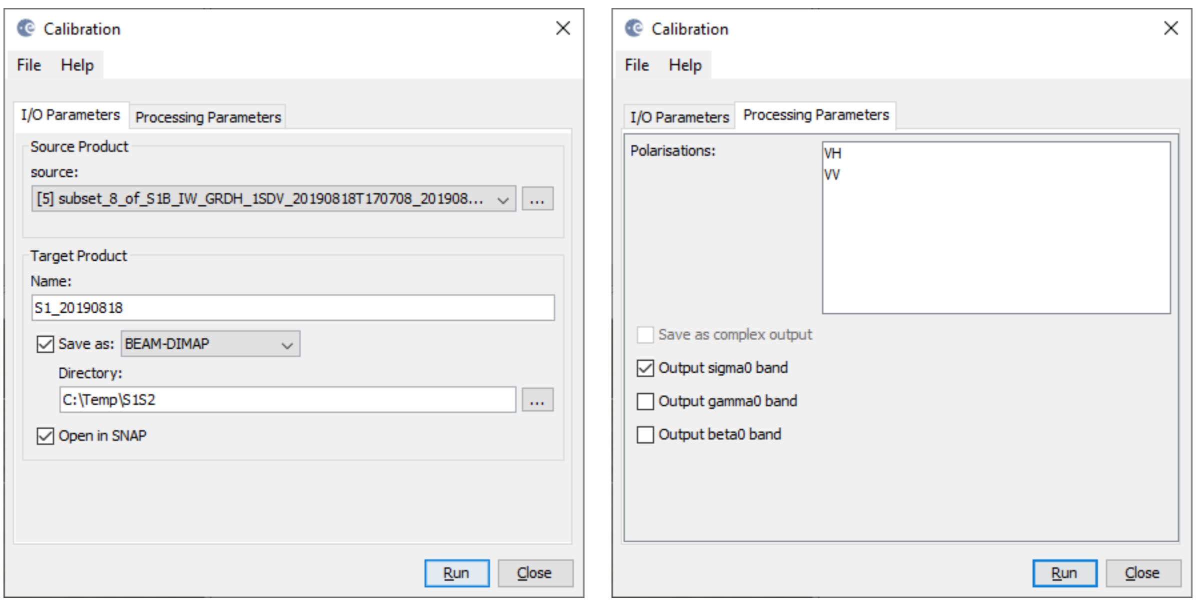



**Figure 8: Radiometric Calibration**

## *Speckle Filtering*

Speckle is a systematic effect emerging from positive and negative contributions of surfaces to the measured backscattered signal. It is often described as "salt and pepper" effect which complicates the interpretation and analysis of the image. A series of speckle filters exist, all have their pros and cons and it is often a good idea to test the different filters and the effect of their parameter settings to find the configuration which is best for the application.

Extensive reviews and comparisons of speckle filters are provided by Dong et al. (2000), Touzi (2002), and Lee et al. (2009).
In this tutorial ,the Lee Sigma filter published by Lee et al. (2009), which uses two different window sizes to estimate the presence and intensity of speckle (). It minimizes speckle while maintaining sharp edges where they can be detected.

The filter can be found under *Radar* > *Speckle Filtering* > *Single Product Speckle Filtering*.

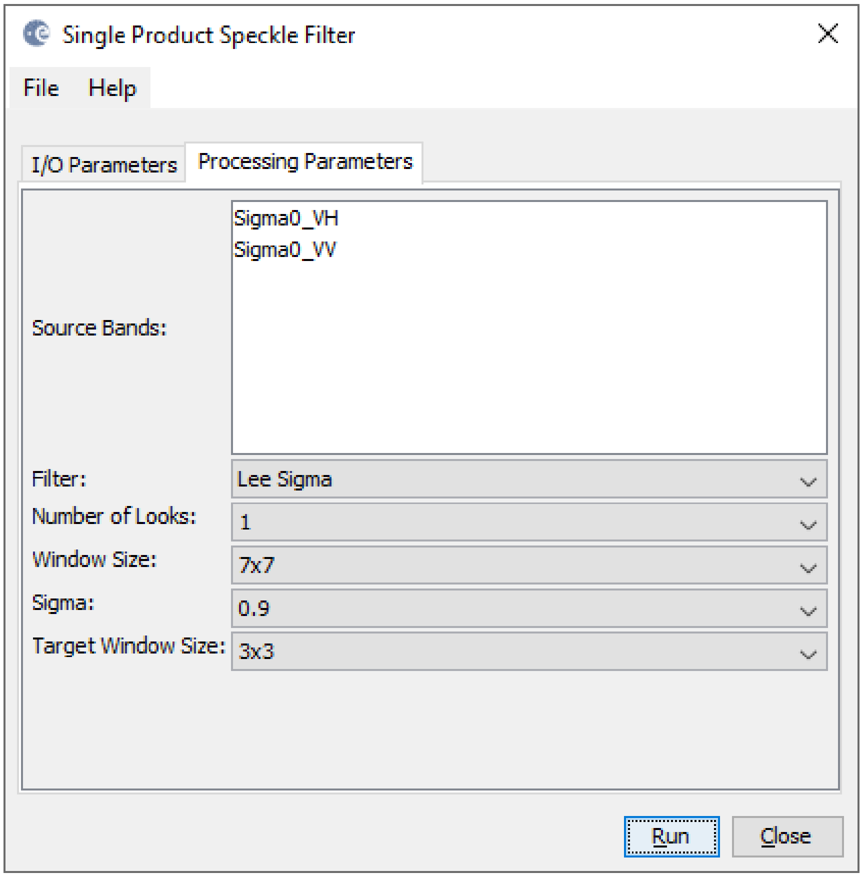



**Figure 9: Lee Sigma speckle filter**

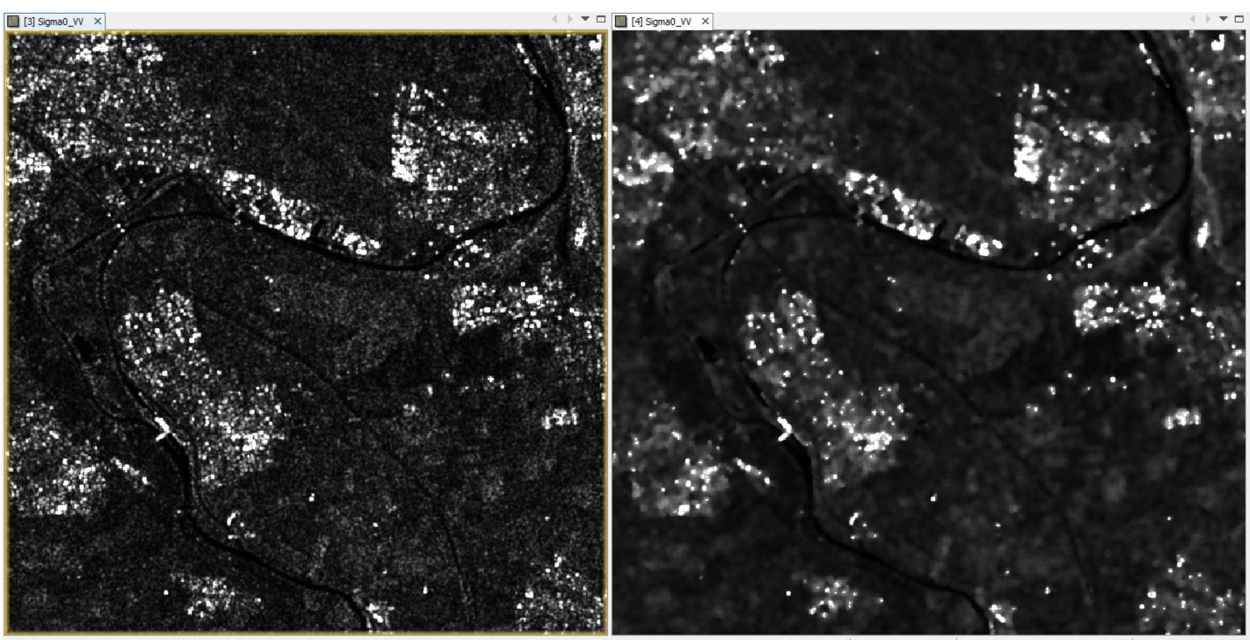


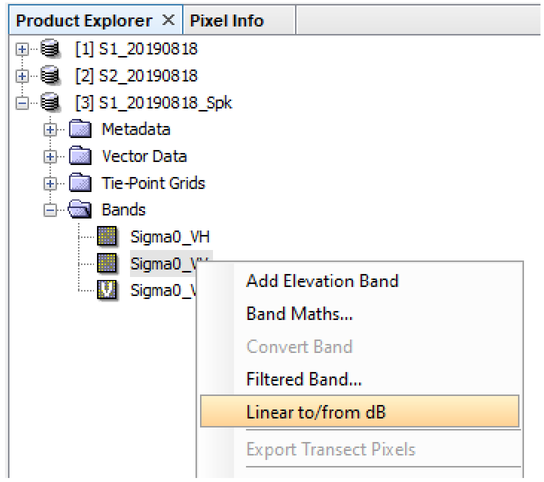
**Figure 10: Sentinel-1 image before (left) and after (right) speckle filtering**

## *Conversion to dB scale*

As highlighted by the statistics tool $\Sigma$, the values of Sigma0_VV roughly range between 0 and 2380, with a mean of 0.219 (Figure 11, top). This means that a very small proportion of very bright pixels distorts the actual value distribution. This is not ideal in a statistical sense and makes the image very dark, because values of smaller than 1 have similar grey values.

To achieve a more normal distribution of values, the log function is applied to the radar image. It translates the pixel values into a logarithmic scale and yields in higher contrasts, because the bright values are shifted towards the mean while dark values become stretched over a wider color range (Figure 11, bottom).

The value range of calibrated dB data is -35 to +10 dB.



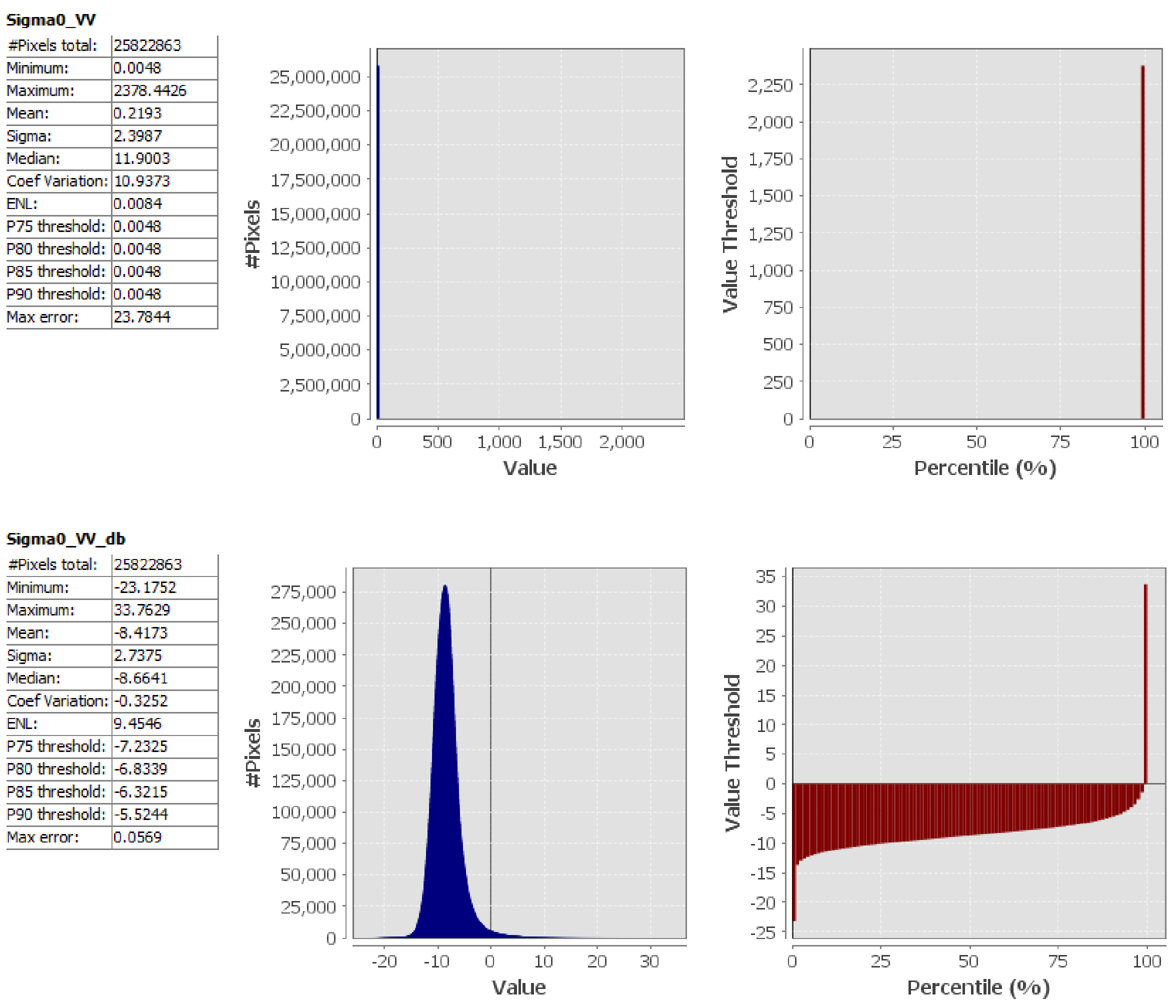




**Figure 11: Image statistics of power (top) and logarithmic (bottom) scale**

To convert VV polarization into dB scale right-click on the filtered bands and select Linear to/from dB. This creates a new virtual band for with the extension _db. Repeat this for the VH polarization and compare the products (Figure 12).

This step is not ultimately required, and it does not change the information content of the image, but it is advisable when image contrasts matter.

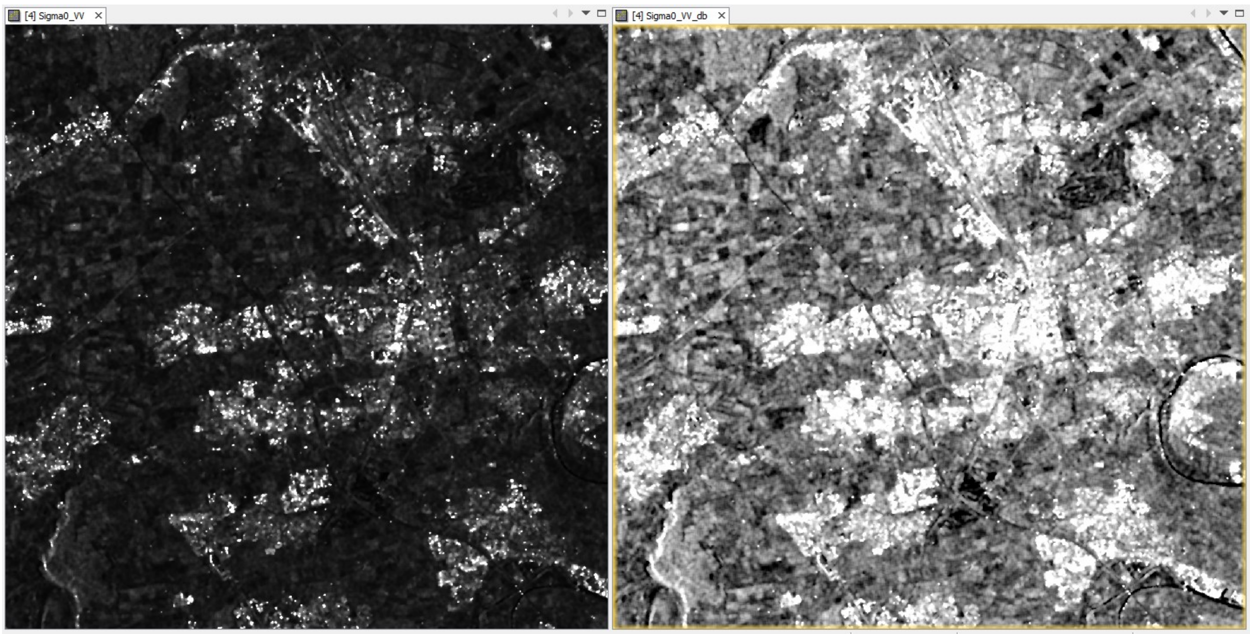



**Figure 12: Sentinel-1 Sigma VV before (left) and after (right) conversion to dB scale**

## *Terrain Correction*

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

Geocoding converts an image from slant range or ground range geometry into a map coordinate system. Terrain geocoding involves using a Digital Elevation Model (DEM) to correct for inherent geometric distortions, such as foreshortening, layover and shadow (Figure 13). More information on these effects is given in the [ESA radar course materials](ESA radar course materials).

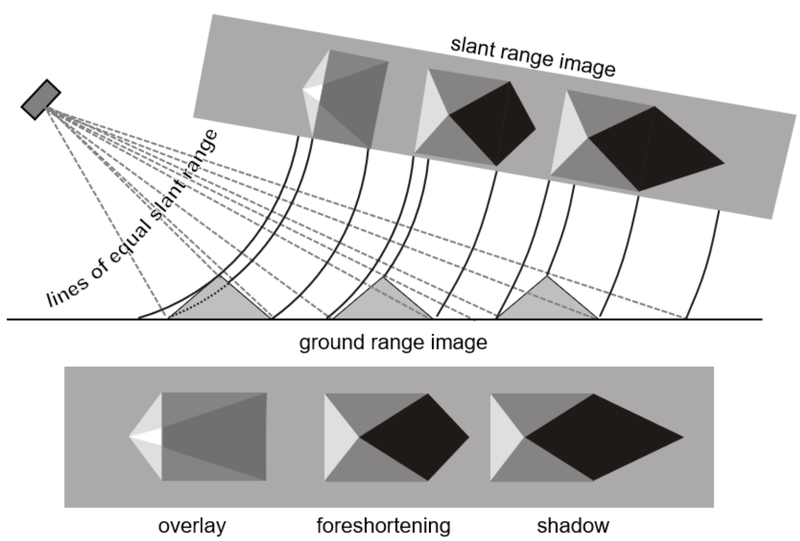



**Figure 13: Geometric distortions in radar images ([Braun 2019](Braun 2019))**

Open the *Range Doppler Terrain Correction* operator (under *Radar* > *Geometric* > *Terrain Correction*) and select the filtered product as input product. In the Processing Parameters tab chose the two dB products as Source Bands and select **SRTM 1Sec HGT (AutoDownload)** as input DEM.

As we terrain correct the data in dB scale, bilinear resampling of logarithmic data will lead to false backscatter values. Therefore, we select **NEAREST_NEIGHBOUR** as Image Resampling Method. Alternatively, the conversion to dB could be done after terrain correction.

Select **UTM zone 32N** as the Map Projection and click on **Run** to start the terrain correction. SNAP now establishes a connection to an external elevation database to download all SRTM tiles required to fully cover the input dataset. The output is a terrain corrected and geocoded Sentinel-1 product in dB scale.

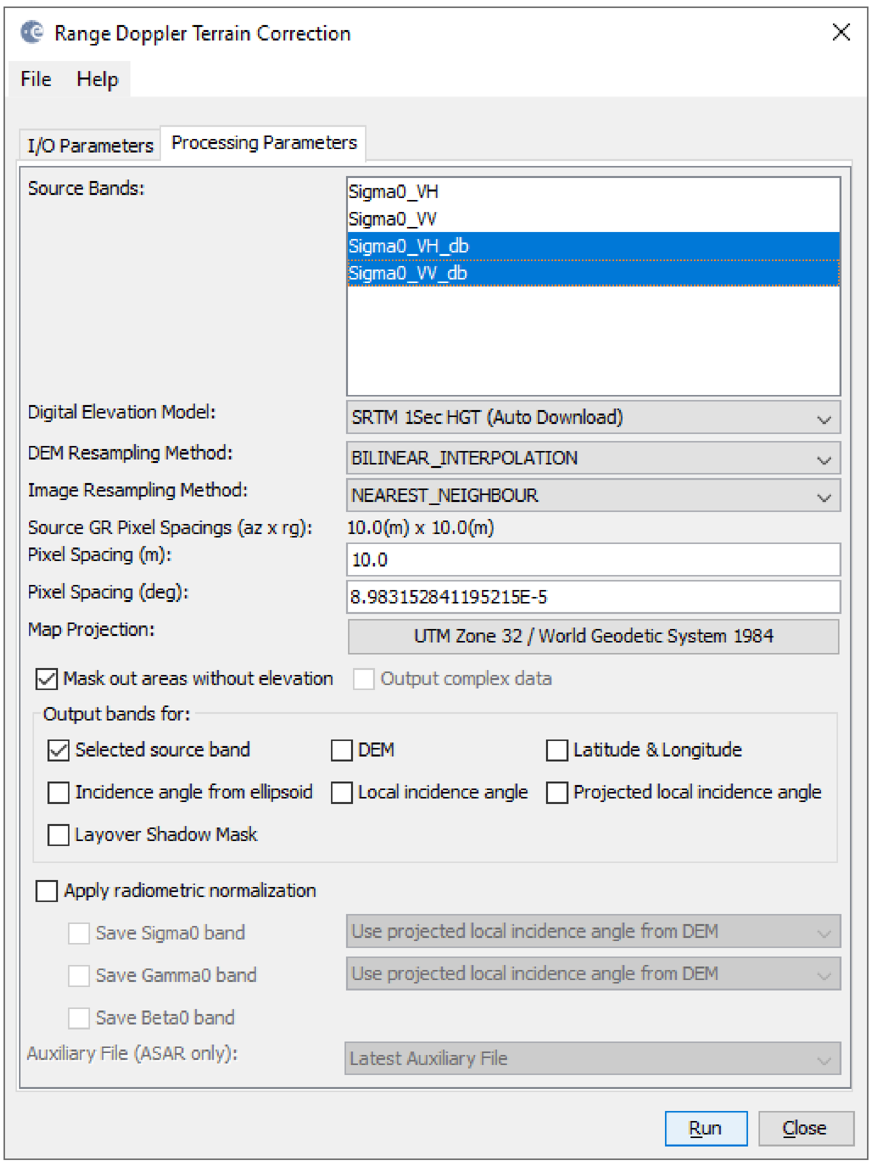



**Figure 14: Range Doppler Terrain Correction**

## *Create ratio band (optional)*

To reduce the imbalance of bands (2 for Sentinel-1, 13 for Sentinel-2), a ratio is calculated between the two polarizations using the Band Maths operator (Figure 15). Note: As the data was transformed into dB scale, any ratio becomes a difference according to the laws of logarithm. Enter Sigma0_ratio_db as an input name, uncheck the option "Virtual (save expression only, don't store data) and enter the following expression (optionally via **Edit Expression**):

```
Sigma0_VV_db - Sigma0_VH_db
```

A new band is created in the product S1_20190818_Spk_TC. Click *File* > *Save Product* to make the changes permanent. Afterwards, an RGB composite can be created from these three bands (Figure 16) to visualize the results. The radar product is now ready to be merged with other data.

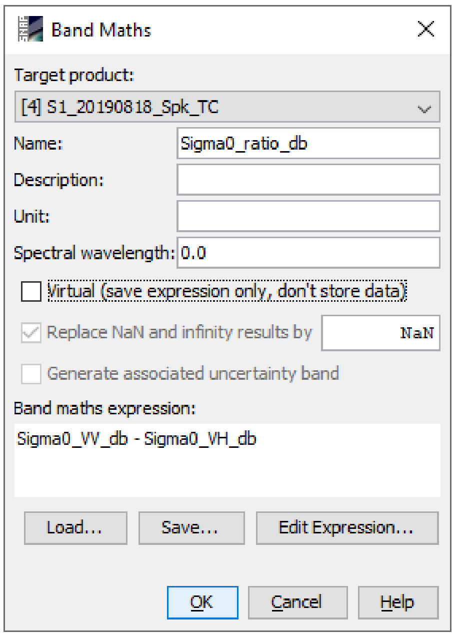



**Figure 15: Sentinel-1 polarization ratio**

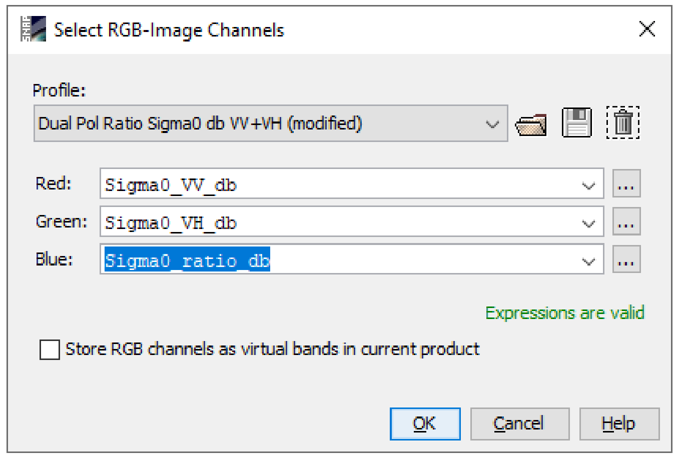



**Figure 16: RGB of Sentinel-1**

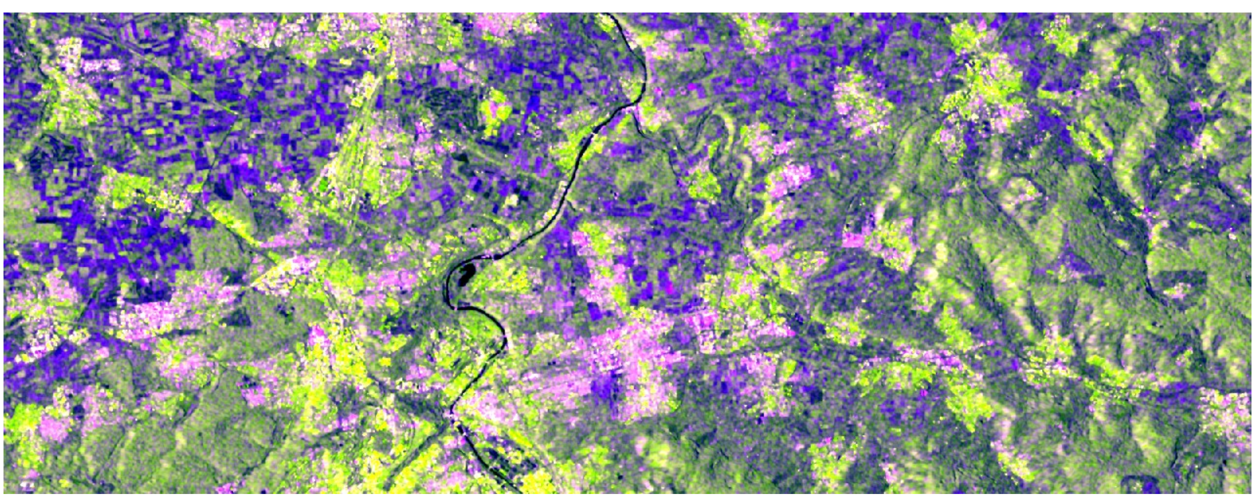


**Figure 17: RGB composite in db scale of VV (red), VH (green) and VH-VH (blue)**

# Preprocessing of Sentinel-2

## Import the product

Extract the file S2A_MSIL2A_20190818T103031_N0213_R108_T32UNV_20190818T135455.zip which was downloaded from the Copernicus hub as described earlier in this tutorial. A new folder ending with .SAFE is generated which contains the metadata file to correctly load the raster stack into SNAP.

Use *File* > *Import* > *Optical Sensors* > *Sentinel-2* > *S2-MSI L2A* (alternatively S2-MSI *L1C* if no L2A is available), select the file MTD_MSIL2A.xml (Figure 18) and confirm with **Import Product**.

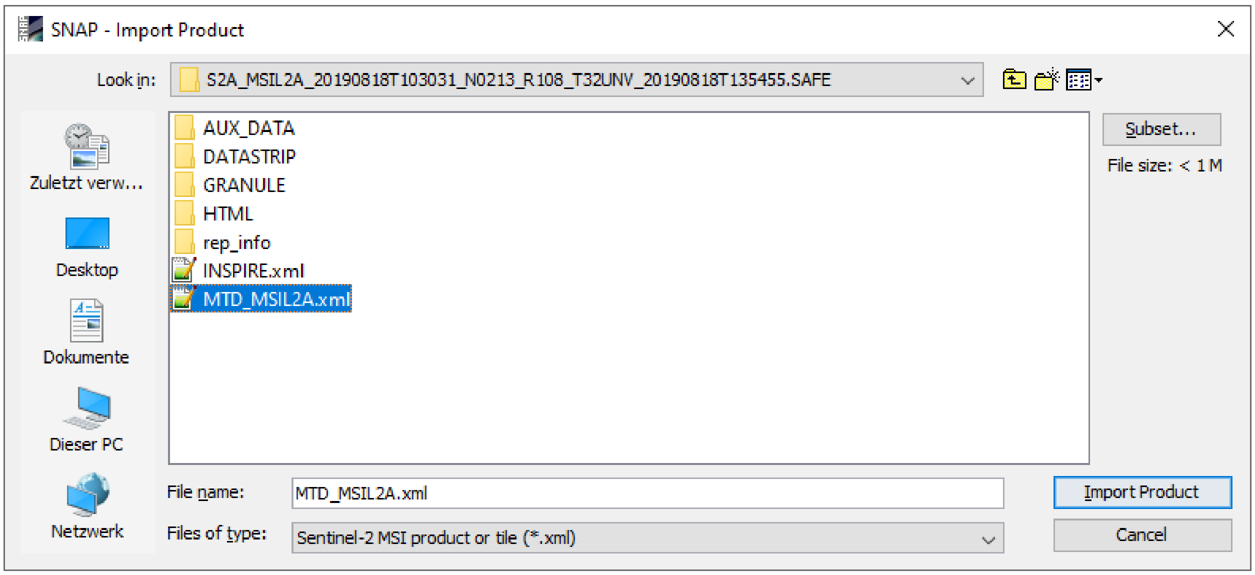



**Figure 18: Import of Sentinel-2 product as subset**

## Create a subset

A subset allows to reduce the amount of data to be processed in the following. Select the Sentinel-2 product in the Product Explorer and navigate in the menu *Raster* > *Subset…*
A separate window might open ("Creating thumbnail image"), but this takes quite a long time, so it is ok to **Cancel** this window.

In the Spatial Subset tab Switch to the Geo Coordinates tab and enter the following numbers:

- North latitude bound: 48.95
- West longitude bound: 9.0
- South latitude bound: 48.70
- East longitude bound: 9.40

In the *Band Subset* tab only select the spectral bands (excluding B8A, Figure 19, right). Un-check all quality indicators and other bands which follow in the list, so they will not be part of the output product.

**Note**: It is easier to click **Select none** and then check the boxes for the 12 main bands.

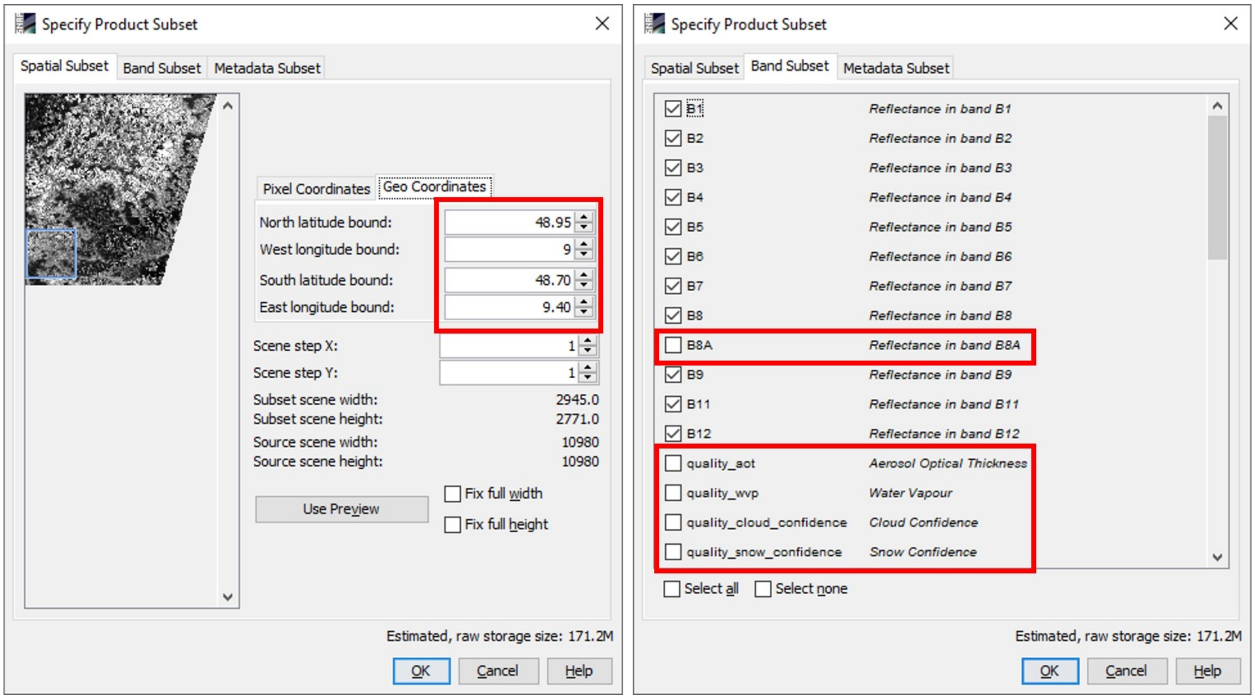



**Figure 19: Sentinel-2 subset**

Confirm with **OK**. A new product is shown in the *Product Explorer*, starting with `subset_S2A`. As it is only a virtual product, so now we save it with *File > Save Product as >* `S2_20190818_subset.dim`

This can now take a while because both previously defined steps (Resampling and Subset) are now finally applied to the original zipped Sentinel-2 product (Figure 20).

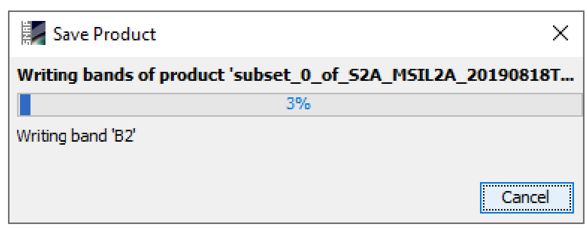



**Figure 20: Saving the virtual S2 product**