SENTINEL-1 Toolbox

SAR Basics Tutorial

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SAR Basics Tutorial

The goal of this tutorial is to provide novice and experienced remote sensing users with step-by-step instructions on working with SAR data with the Sentinel-1 Toolbox.

For further details on operator parameters and algorithmic descriptions, please refer to the online help available within the software.

In this tutorial you will calibrate, multilook, speckle filter, and terrain correct SAR data products.

Sample Data

For this tutorial, we will use the Fine Quad Polarization SLC Radarsat-2 sample dataset covering the Wesenberg area in Germany.
The file is provided by the European Space Agency (ESA) and can be downloaded here.
More sample data by ESA: https://earth.esa.int/eogateway/missions/radarsat/sample-data

Open a Product

Step 1 - Open a product: Use the  **Open Product** button in the top toolbar and browse for the location of the **Fine Quad RADARSAT-2** product.

Select the **product.xml** file and press **Open Product** (Figure 1. If your product is contained within a zip file, the Toolbox will also be able to open the product simply by selecting the zip file. If you encounter problems with opening data, select a specific reader under File > Import > SAR sensors.

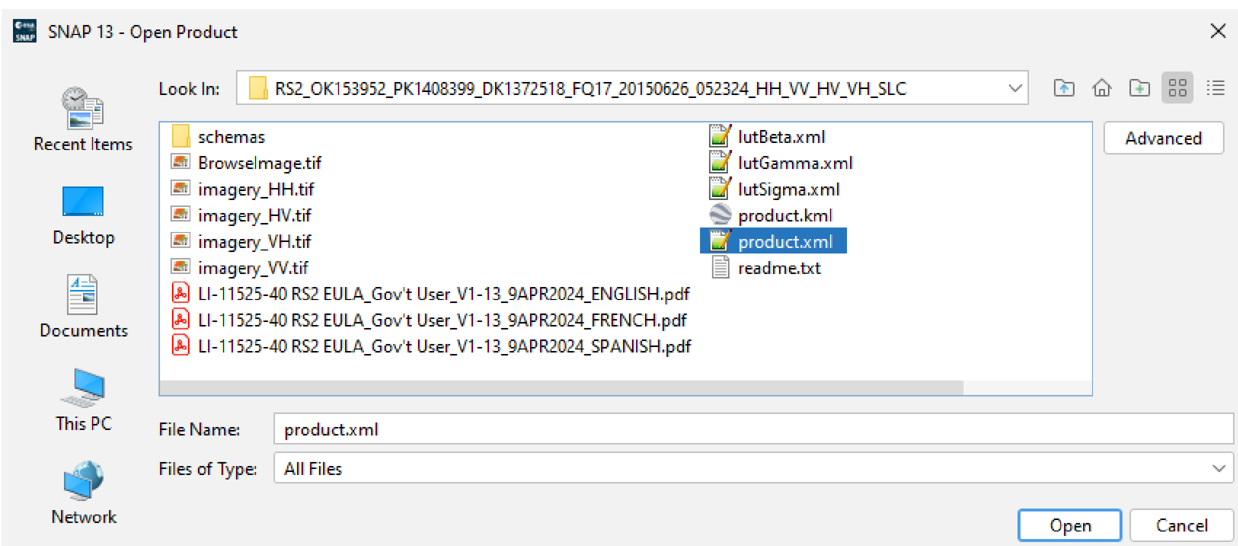


Figure 1: Open the product.xml

In the *Products View* you will see the opened product which consists of Metadata, Vector Data, Tie-Point Grids, Quicklooks and Bands (which contains the actual raster data, organized by polarization).

Double-click on the **Intensity_HH** band to view the raster data. The product is a RADARSAT-2 Single Look Complex (SLC) data product which means that it is stored and displayed in slant geometry (as measured by the side-looking sensor) and has not been multi-looked. Accordingly, the data can appear stretched in the azimuth direction (y axis) and contain a lot of noise.

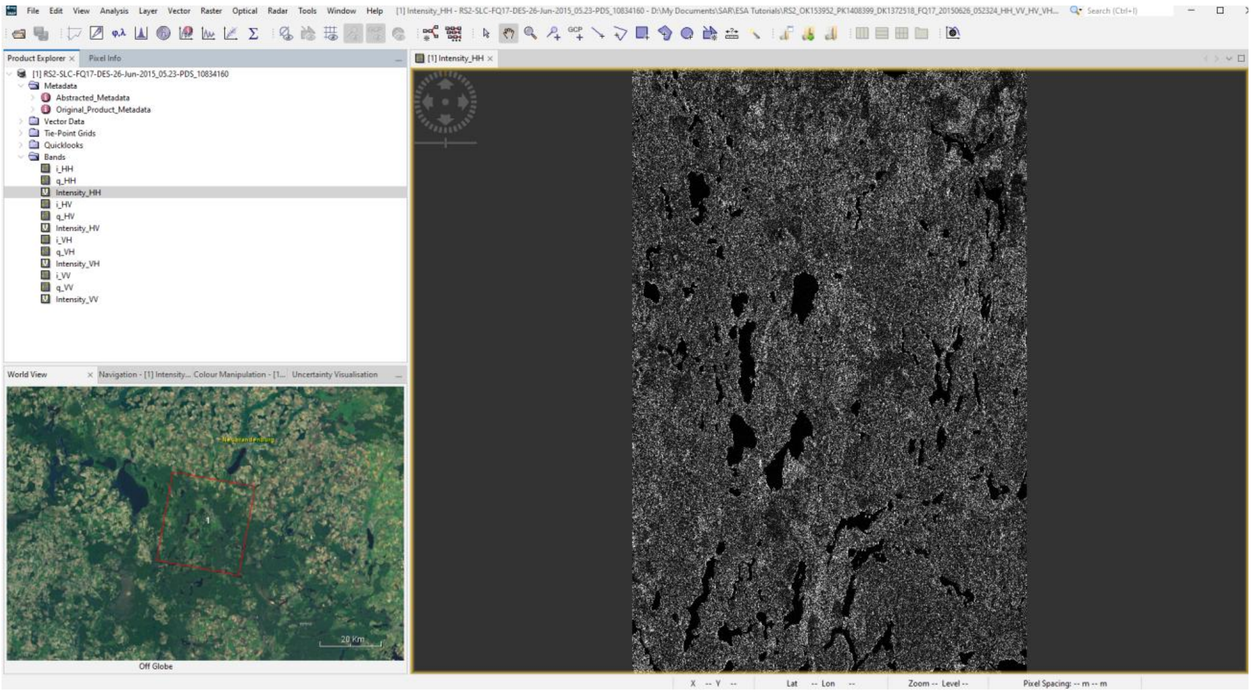
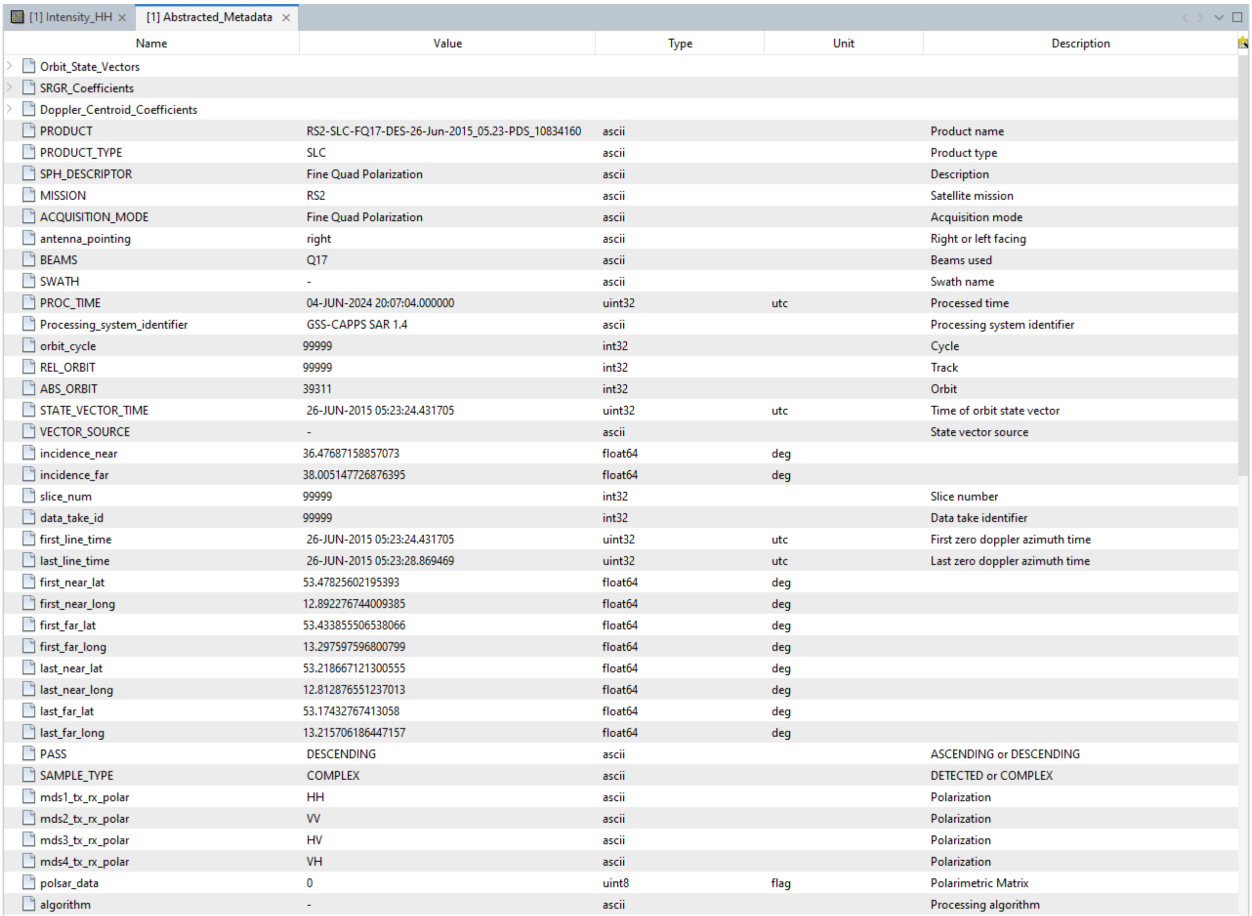


Figure 2: Product view

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. If you miss any items in your user interface, you can activate them in the menu under *View* and *Tool Windows*.

You can find information on the product under Metadata > Abstracted Metadata (Figure 3). As shown, the image was acquired in descending orbit at HH polarization and contains complex (i+q) information.



Name	Value	Type	Unit	Description
Orbit_State_Vectors				
SRGR_Coefficients				
Doppler_Centroid_Coefficients				
PRODUCT	RS2-SLC-FQ17-DES-26-Jun-2015_05.23-PDS_10834160	ascii		Product name
PRODUCT_TYPE	SLC	ascii		Product type
SPH_DESCRIPTOR	Fine Quad Polarization	ascii		Description
MISSION	RS2	ascii		Satellite mission
ACQUISITION_MODE	Fine Quad Polarization	ascii		Acquisition mode
antenna_pointing	right	ascii		Right or left facing
BEAMS	Q17	ascii		Beams used
SWATH	-	ascii		Swath name
PROC_TIME	04-JUN-2024 20:07:04.000000	uint32	utc	Processed time
Processing_system_identifier	GSS-CAPPS SAR 1.4	ascii		Processing system identifier
orbit_cycle	99999	int32		Cycle
REL_ORBIT	99999	int32		Track
ABS_ORBIT	39311	int32		Orbit
STATE_VECTOR_TIME	26-JUN-2015 05:23:24.431705	uint32	utc	Time of orbit state vector
VECTOR_SOURCE	-	ascii		State vector source
incidence_near	36.47687158857073	float64	deg	
incidence_far	38.005147726876395	float64	deg	
slice_num	99999	int32		Slice number
data_take_id	99999	int32		Data take identifier
first_line_time	26-JUN-2015 05:23:24.431705	uint32	utc	First zero doppler azimuth time
last_line_time	26-JUN-2015 05:23:28.869469	uint32	utc	Last zero doppler azimuth time
first_near_lat	53.47825602195393	float64	deg	
first_near_long	12.892276744009385	float64	deg	
first_far_lat	53.433855506538066	float64	deg	
first_far_long	13.297597596800799	float64	deg	
last_near_lat	53.218667121300555	float64	deg	
last_near_long	12.812876551237013	float64	deg	
last_far_lat	53.17432767413058	float64	deg	
last_far_long	13.215706186447157	float64	deg	
PASS	DESCENDING	ascii		ASCENDING or DESCENDING
SAMPLE_TYPE	COMPLEX	ascii		DETECTED or COMPLEX
mds1_tx_rx_polar	HH	ascii		Polarization
mds2_tx_rx_polar	VV	ascii		Polarization
mds3_tx_rx_polar	HV	ascii		Polarization
mds4_tx_rx_polar	VH	ascii		Polarization
polsar_data	0	uint8	flag	Polarimetric Matrix
algorithm	-	ascii		Processing algorithm

Figure 3: Metadata view

Calibrating the Data

To properly work with the SAR data, the data should first be calibrated. This is especially true when preparing data for mosaicking where you could have several data products at different incidence angles and relative levels of brightness.

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.

The corrections that get applied during calibration are mission-specific, therefore the software will automatically determine what kind of input product is opened and what corrections need to be applied based on the product’s metadata. Calibration is essential for quantitative use of SAR data.

Step 2 - Calibrate the product: From the **Radar** menu, go to **Radiometric** and select **Calibrate**.

The source product should be the imported product, the target product will be the new file you will create. Also select the directory in which the target product will be saved (here: `C:\Temp`)

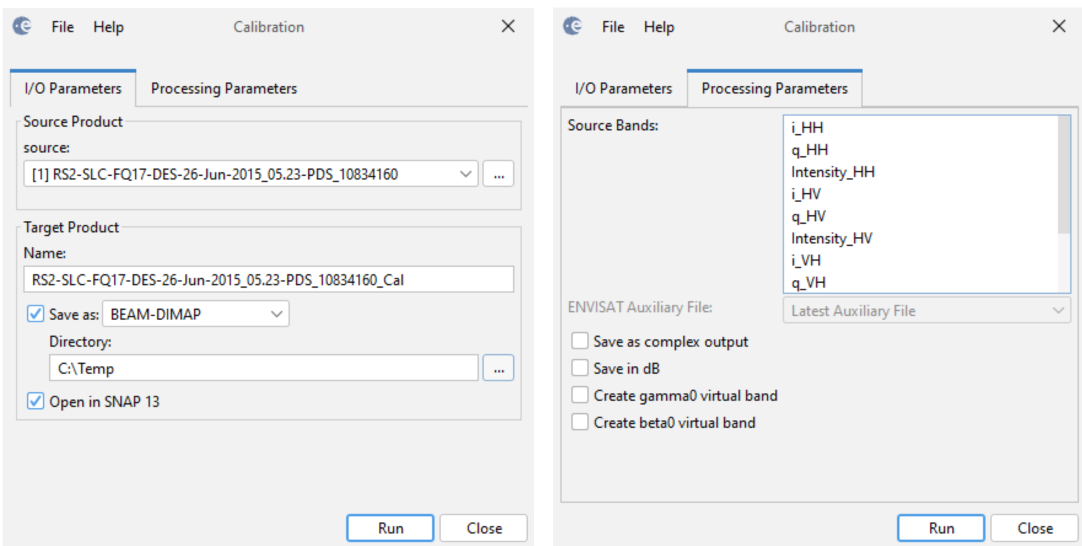


Figure 4: Radiometric calibration

If you don’t select any source bands, then the calibration operator will automatically select all real and imaginary (i, q) bands. Make sure that “Save as complex output” is not selected, so that the calibration operator will produce a single Sigma0 band per real and imaginary pair. In case of interferometric or polarimetric analyses, you should select “Save as complex output”.

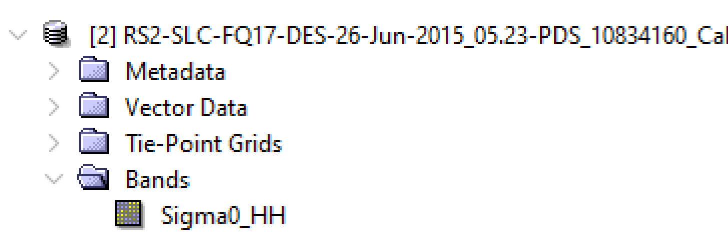


Figure 5: Calibrated product

Multilooking

Multilook processing is an **optional step** and can be used to produce a product with nominal image pixel size.

Multiple looks may be generated by averaging over range and/or azimuth resolution cells improving radiometric resolution but degrading spatial resolution. As a result, the image will have less noise and approximate square pixel spacing after being converted from slant range to ground range.

Step 3 - Multilook the data: From the **Radar** menu, select **SAR Utilities** and then **Multilooking**.

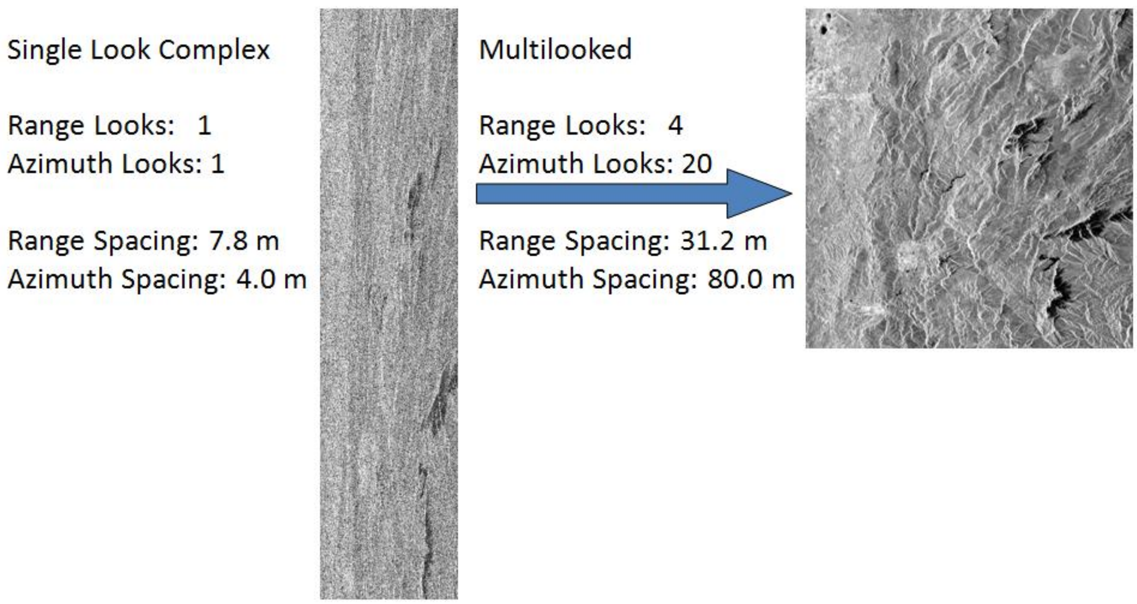


Figure 6: Multilooking and SLC Product

In the **Multilook** dialog, select the calibrated data as an input and the **Sigma0_HH** band to only produce an output for this band (Figure 7).

Specify the number of range looks while the number of azimuth looks is computed based on the ground range spacing and the azimuth spacing.

In this case, the azimuth and ground resolution is similar so that 2 range looks will require 3 azimuth looks (resulting in a ground spatial resolution of around 16 m), but depending on the incidence angle, this ratio can be larger (e.g. 1 range looks require 8 azimuth looks). In the end, the data has square pixels. As a side effect, speckle is reduced.

Press **Run** to begin processing.

When complete, a new product will be created and will be available in the **Products View**.

In the new product, open the **Sigma0_HH** band (Figure 8). Depending on the ratio of range and azimuth resolution before multilooking image my now look more proportional; however, it still contains a lot of speckle.

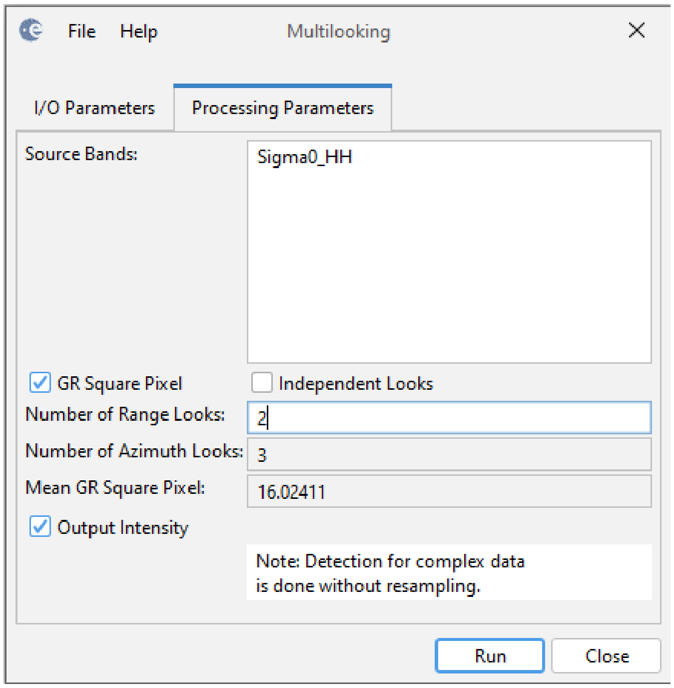


Figure 7: Multilooking of the calibrated data

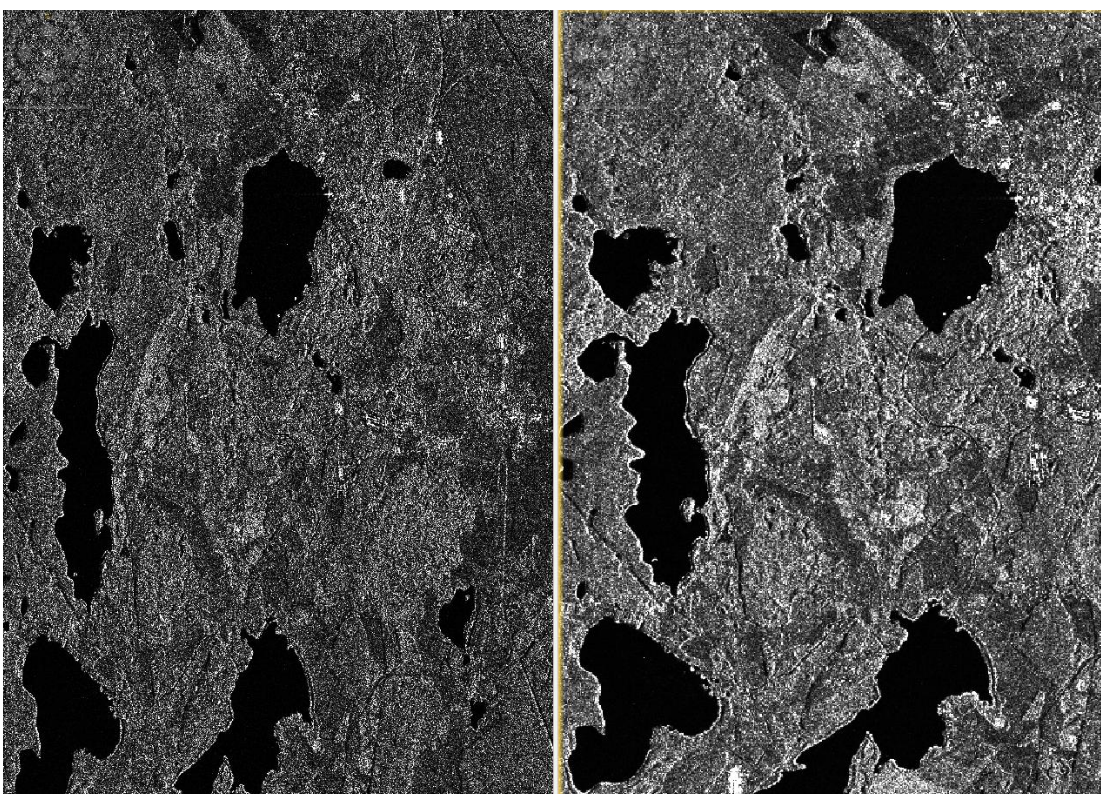


Figure 8: HH polarization before (left) and after multilooking (right)

Speckle Reduction

Speckle is caused by random constructive and destructive interference resulting in salt and pepper noise throughout the image.

Speckle filters can be applied to the data to reduce the amount of speckle at the cost of blurred features or reduced resolution. Extensive reviews and comparisons of speckle filters are provided by [Dong et al. (2000)](), [Touzi (2002)](), and [Lee et al. (2009)]().
The choice for a best filter often depends on the type of data, its spatial resolution, the degree of inherent speckle, and the application.

Step 4 – Speckle Filtering: Select the multilooked product and then select **Speckle Filtering/Single Product Speckle Filter** from the **Radar** menu.

From the **Speckle Filtering** dialog, select the multilooked product as input. In the second tab select the **Refined Lee** speckle filter. The Refined Lee filter averages the image while preserving edges. It has no parameters to set, while others require the definition of a kernel size and other parameters. The effect of different filters and their parameter configurations has to be explored by careful comparison to find the best solution for the respective case.

Press **Run** to process.

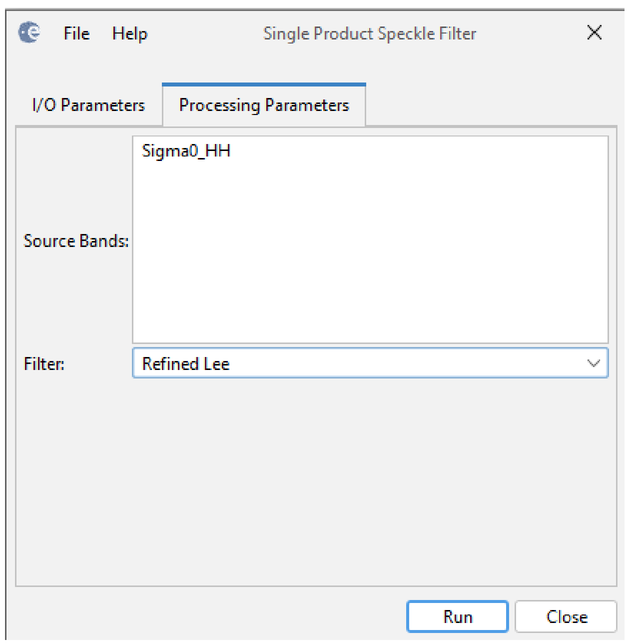


Figure 9: Speckle filtering

Open the newly created speckle filtered product. You can use the Split Window tools to compare different products (Figure 10).

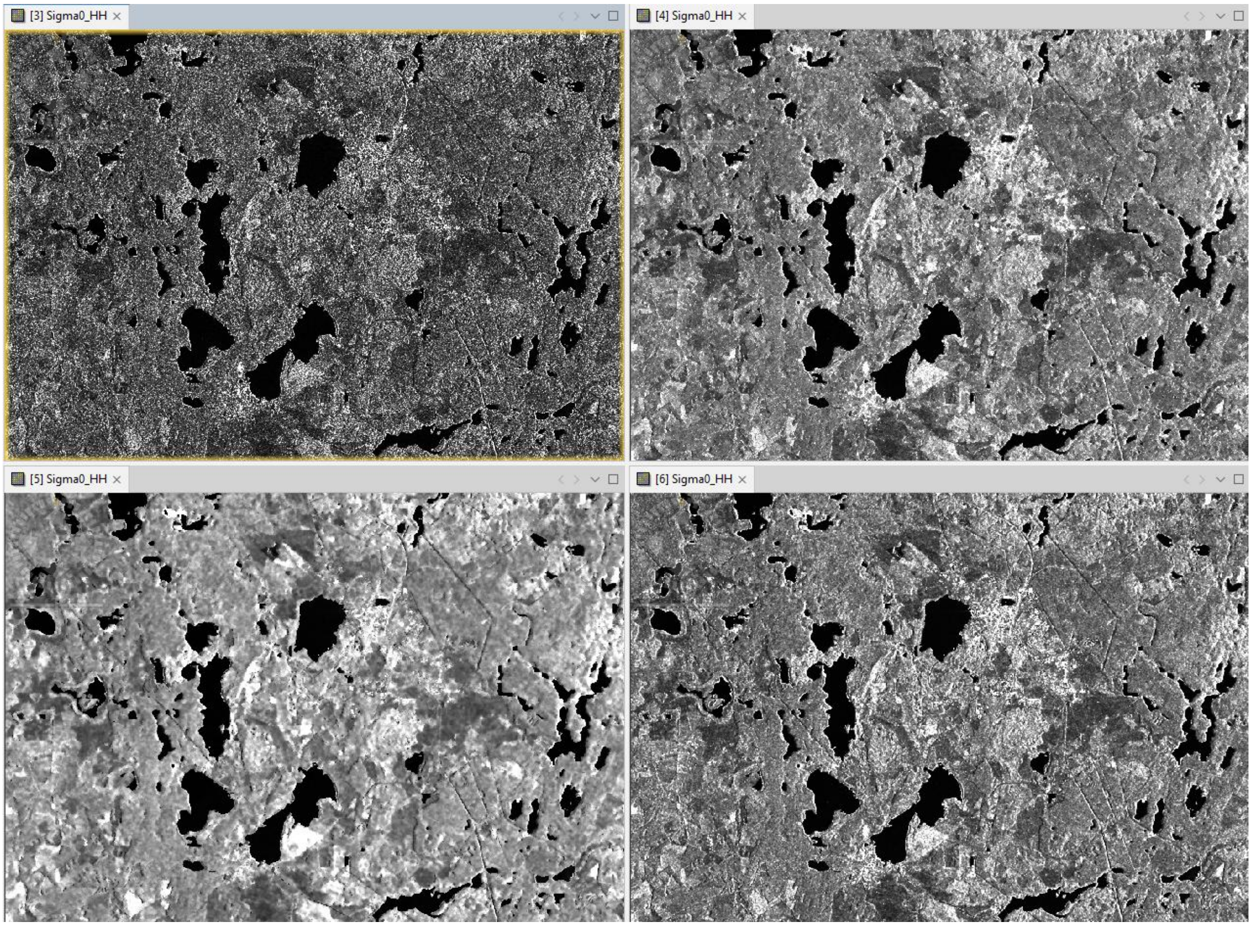


Figure 10: Sigma0_HH before speckle filtering (top left), after Refined Lee filter (top right), after IDAN filter (bottom left), and after Frost filter (bottom right)

The final processing step which we will perform on this product will be terrain correction. You can select the filter product which you like most.

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 11). More information on these effects is given in the ESA radar course materials.

Foreshortening

- The period of time a slope is illuminated by the transmitted pulse of the radar energy determines the length of the slope on radar imagery.
- This results in shortening of a terrain slope on radar imagery in all cases except when the local angle of incidence (θ) is equal to 90˚.

Layover

- When the top of the terrain slope is closer to the radar platform than the bottom the former will be recorded sooner than the latter.
- The sequence at which the points along the terrain are imaged produces an image that appears inverted.
- Radar layover is dependant on the difference in slant range distance between the top and bottom of the feature.

Shadow

- The back-slope is obscured from the imaging beam causing no return area or radar shadow.

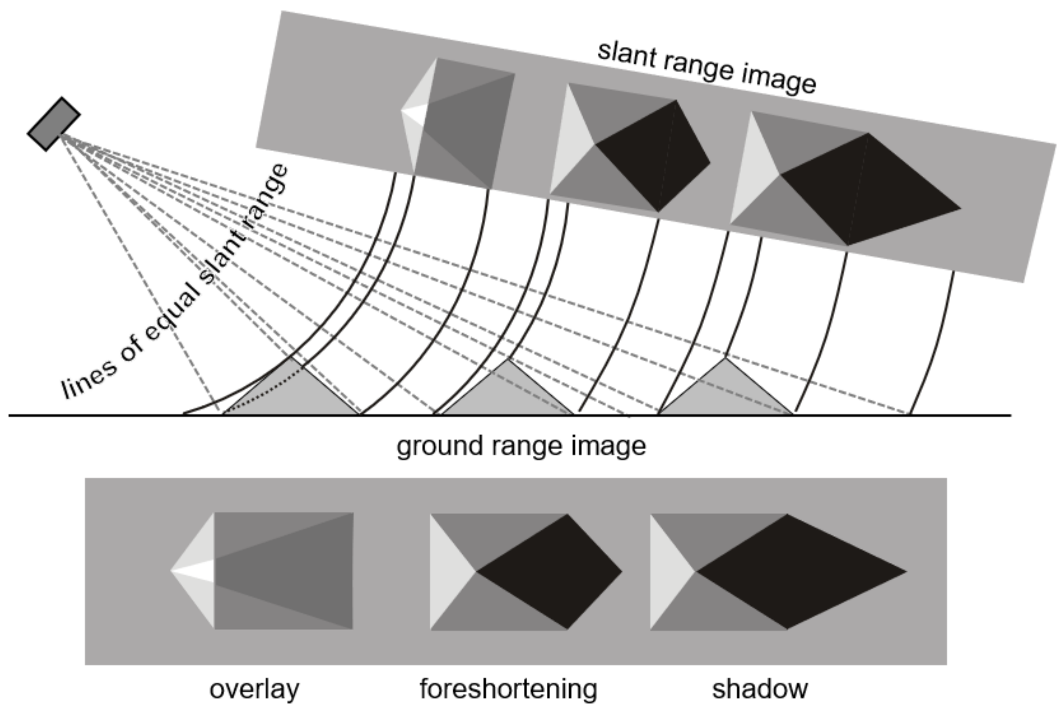


Figure 11: Geometric distortions in radar images (Braun 2019: https://publikationen.uni-tuebingen.de/xmlui/handle/10900/91317)

Step 5 - Terrain Correction: Select the speckle filtered product and then select **Range-Doppler Terrain Correction** from the **SAR Processing/Geometric** menu.

By default, the terrain correction will use the SRTM 3Sec DEM (90 m pixel spacing). You can also select a DEM of higher resolution (SRTM 1Sec HGT (AutoDownlad) 30 m pixel spacing). The software will automatically determine the DEM tiles needed and download them automatically from internet servers.

The default output map projection is Geographic (based on Latitude/Longitude), but you can also select a UTM zone.

If you don't want ocean areas removed (based on the DEM values), disable "Mask areas without elevation"

Press **Run** to process.

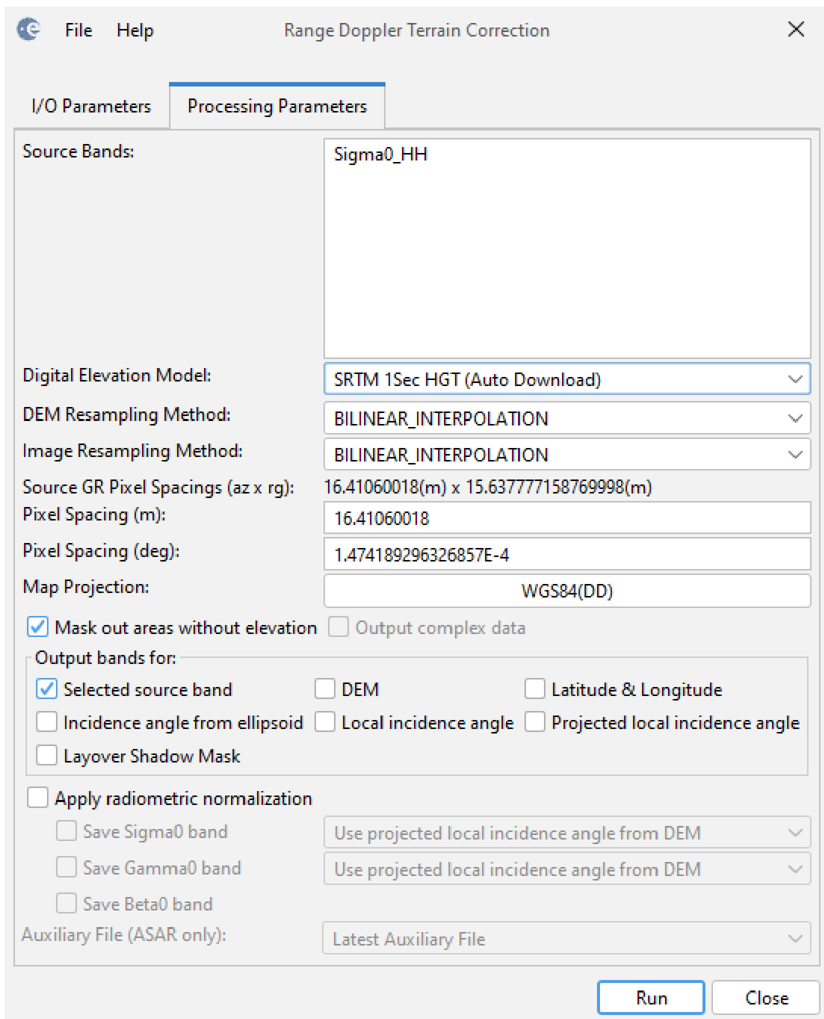


Figure 12: Range Doppler Terrain Correction

Open the terrain corrected product. You will see that the terrain correction has worked when the image is rotated (facing north) and the image boundaries are stretched in mountainous areas (Figure 13).

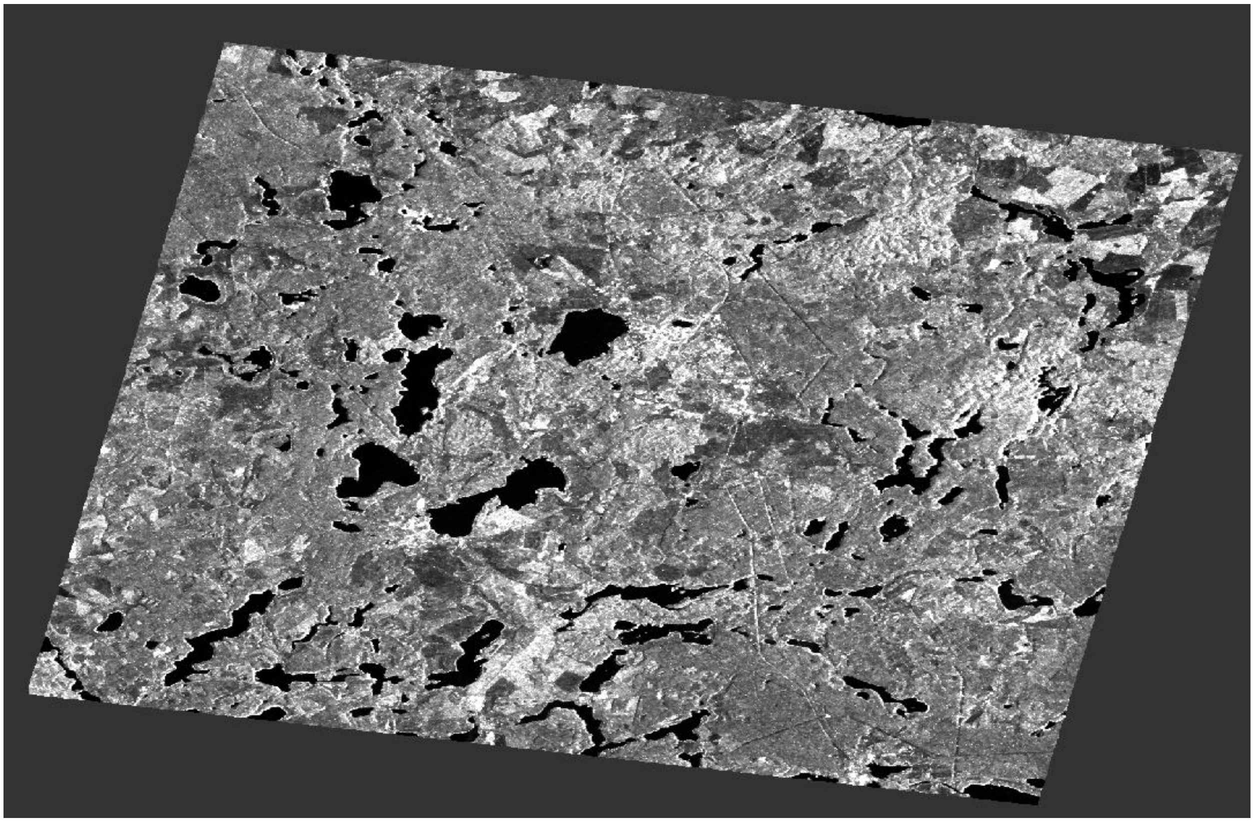


Figure 13: Terrain corrected image

Conversion to dB scale

As Sigma0 values show the backscatter intensity in linear scale, the majority is dark while only a small proportion is bright. This is not ideal in a statistical sense and can make image interpretation difficult, because values of smaller than 1 have similar grey values.

To achieve a 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 (**Fehler! Verweisquelle konnte nicht gefunden werden.**, bottom).

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

Step 6 – Conversion to dB scale: To view the image in decibel scaling, right-click on the terrain corrected **Sigma_HH** band and select **Linear to/from dB** to convert the data using a virtual band (Figure 13 and Figure 14).

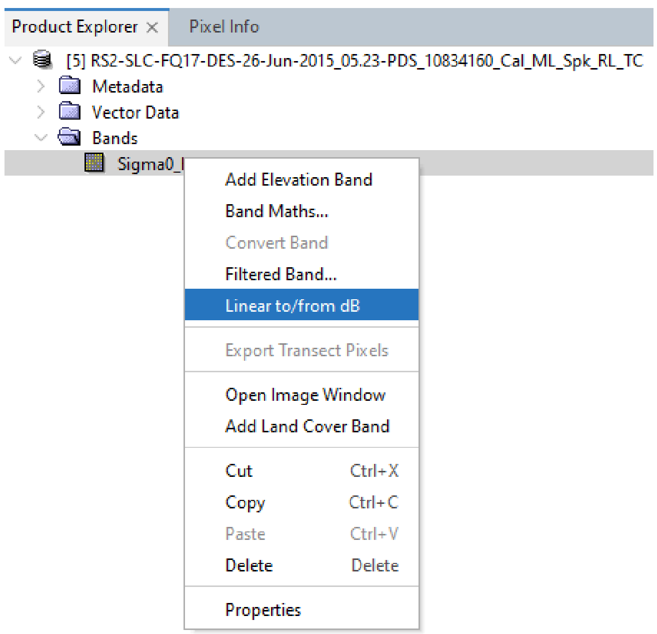


Figure 14: Conversion to dB scale

A new virtual band will be created with the expression 10*log10(Sigma_HH). Double-click on the new **Sigma_HH_dB** band to open it (Figure 15).

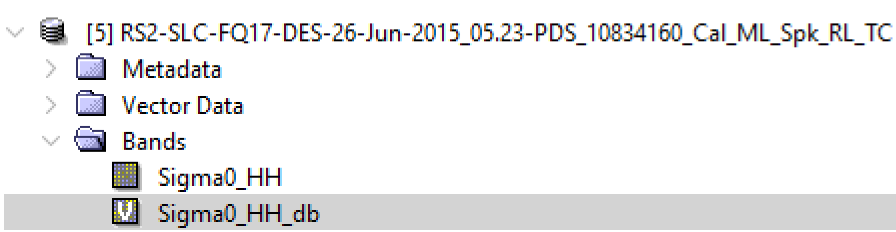


Figure 15: Log-scaled backscatter intensity

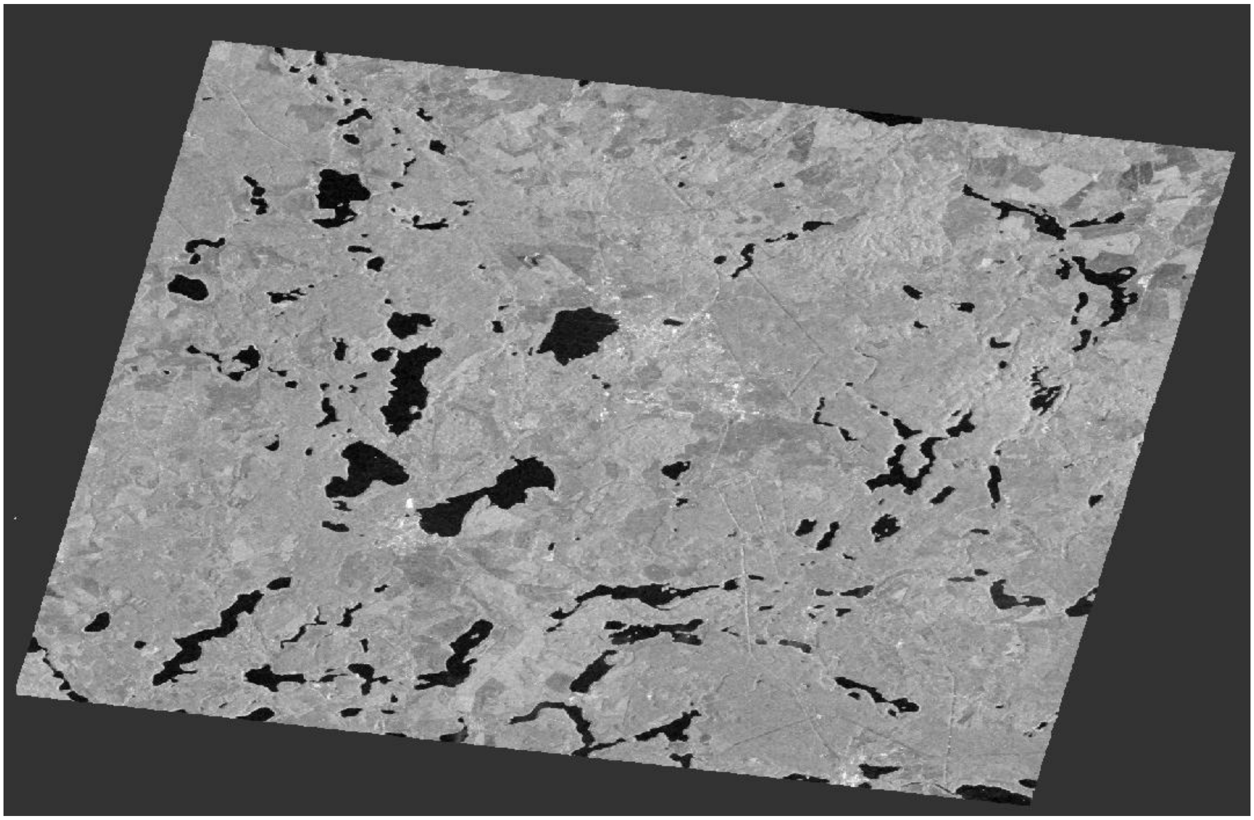


Figure 16: Sigma0 in dB scale

You will see that the values of calibrated dB data roughly range between -25 and +5 dB (Figure 17).

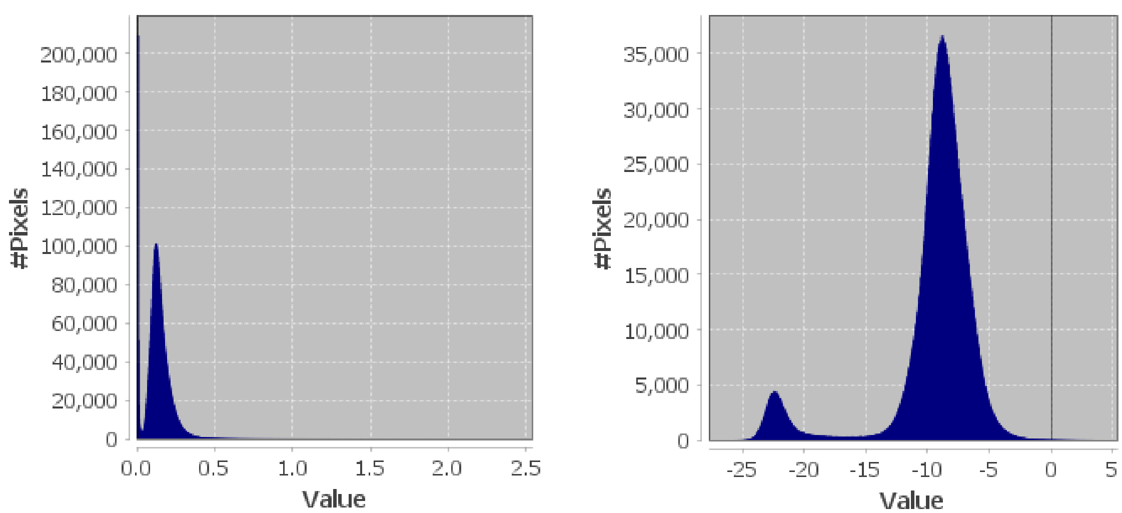
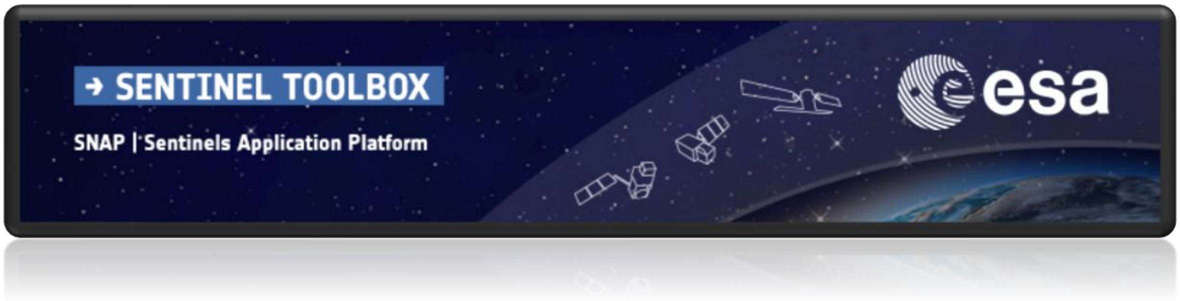


Figure 17: Histogram before (left) and after conversion to dB scale (right)



For more tutorials visit the Sentinel Toolboxes website

http://step.esa.int/main/doc/tutorials/

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