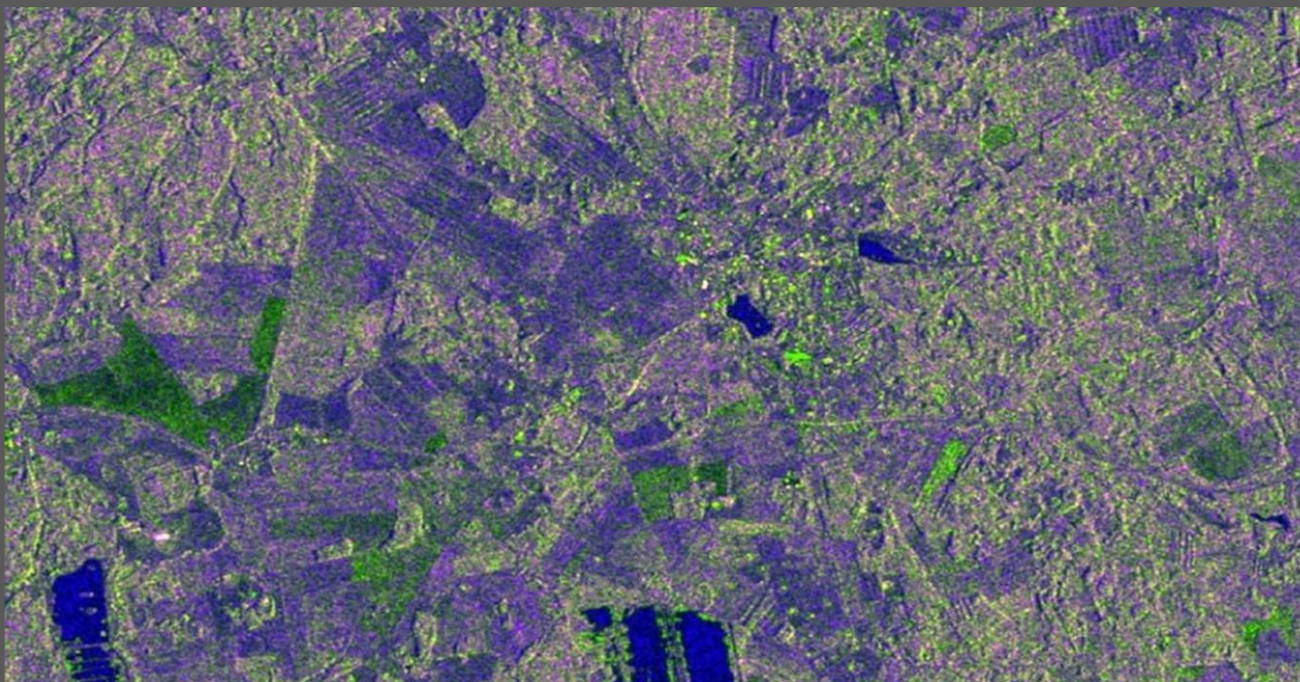

Radar Image Processing

Advanced Remote Sensing

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Contents

Objective
To process Sentinel 1 (RADAR) imagery for detection of burned forested area.

Study Area
Andalusia region, Spain

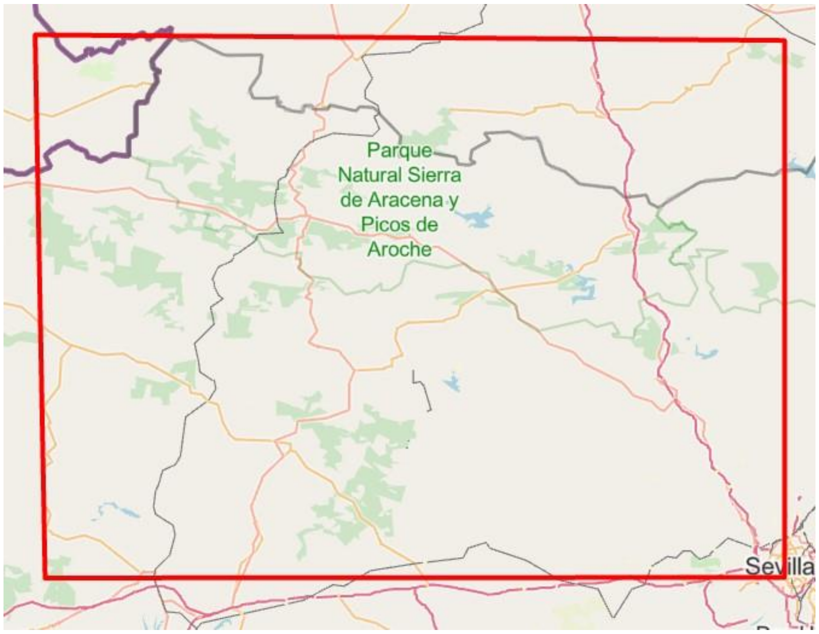


Figure 1: Study Area

Data used
The following data were used for analysis in this exercise:

- S1B_IW_GRDH_1SDV_20170702T062605_..._027894_6DA0 (pre-image)
- S1B_IW_GRDH_1SDV_20170819T062608_..._00C576_066C (post-image)
- Subset point [(X, Y), (X, Y)] = [(14504,5504), (23408,13248)]

Methodology
Data Visualization
<u>Step 1: Adding the radar data and shapefile to SNAP</u>

For the detection of the burnt area with the change detection technique in radar, we were provided with two Sentinel 1 datasets and a shapefile for that area. These datasets in this report are represented as pre-image and post-image. The provided data must be in a compressed format which automatically will get extracted in the product explorer window.

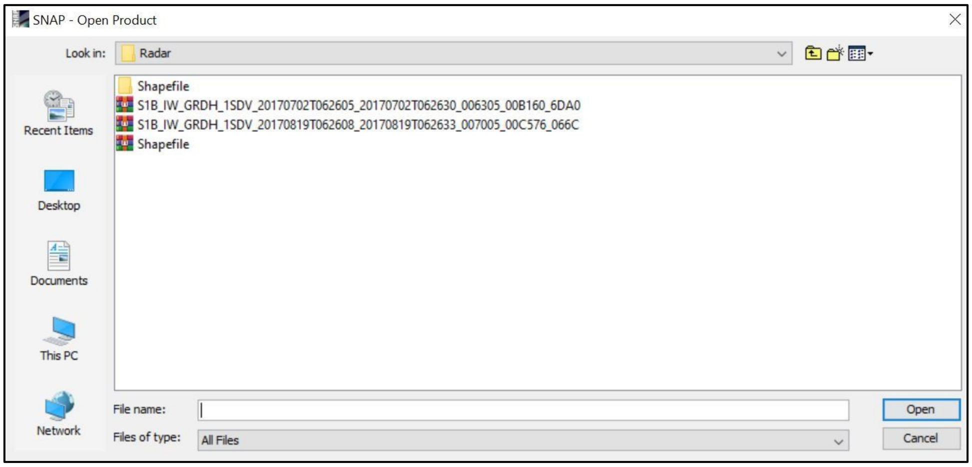


Figure 2: Browsing Radar Data

But the case was different for loading vector data. Here when selecting Import ESRI Shapefile under vector window we select only the .shp format file. The layer list loaded in the system is visualized in product explorer window.

[Note: If the shapefile exists in compressed format, it has to be decompressed.]

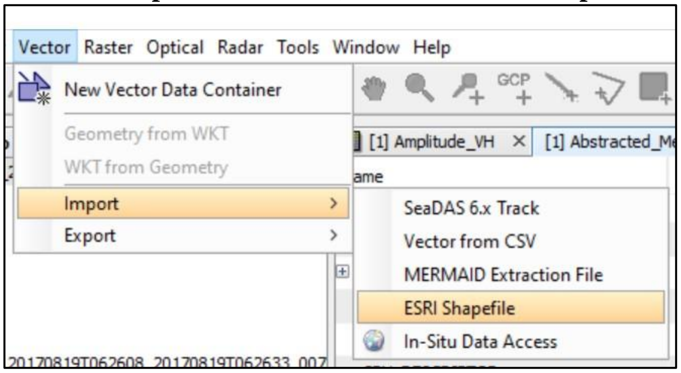


Figure 3: Browse Vector data

Step:2: Visualize the metadata:

The detailed information of each dataset could be obtained when doubling clicking on Abstracted_Metadata from Metadata folder. Here user can visualize information about the pass information regarding the motion of the satellite, polarization of beam, look angle etc. The metadata information provided is mostly based on the characteristics of satellite measurement and data collection properties which helps users to understand the acquisition conditions and use the data carefully.

Name	Value	Type	Unit	Description
first_far_lat	38.73613739013672	float64	deg	
first_far_long	-7.24326252756088	float64	deg	
last_near_lat	36.82093811035156	float64	deg	
last_near_long	-4.614579766841203	float64	deg	
last_far_lat	37.23432540893555	float64	deg	
last_far_long	-7.547427866283565	float64	deg	
PASS	DESCENDING	ascii		ASCENDING or DESCENDING
SAMPLE_TYPE	DETECTED	ascii		DETECTED or COMPLEX
mds1_tx_rx_polar	VH	ascii		Polarization
mds2_tx_rx_polar	VV	ascii		Polarization
mds3_tx_rx_polar	-	ascii		Polarization
mds4_tx_rx_polar	-	ascii		Polarization
polsar_data	0	uint8	flag	Polarimetric Matrix
algorithm	-	ascii		Processing algorithm
azimuth_looks	1.0	float64		
range_looks	5.0	float64		
range_spacing	10.0	float64	m	Range sample spacing
azimuth_spacing	10.0	float64	m	Azimuth sample spacing

Figure 4: Visualize Metadata

- *VV: vertically transmit vertically received*
- *VH: vertically transmit and horizontally received*

- *Polarization (pre-image): VH and VV*
- *Flying Direction(pre-image): descending (North to South) direction with right look*
  - *Polarization(post-image): VH and VV*
- *Flying Direction(pre-image): descending (North to South) direction with right look*

Step 3: Visualize bands

The radar instrument produces regular pulses of energy, of a known wavelength where waves are vibrating in a predetermined orientation (polarization) and measures the backscattered wave contribution in a given polarization. In Sentinel-1 it has a like-polarization and cross-polarization.

In the band folder of each dataset, there were two differently polarized data, VV and VH with a total of 4 bands: Amplitude VV, Amplitude VH, Intensity VV and Intensity VH for each image.

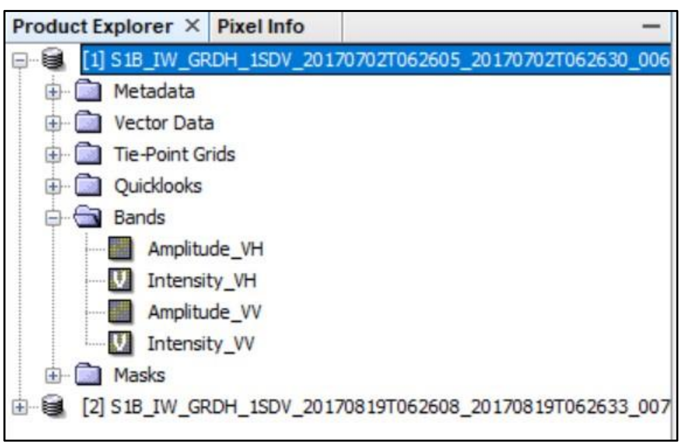


Figure 5: Visualize band information in layer list

Step 4: Inspect the Intensity VV and VH band

Intensity band is the product of amplitude, where Intensity = amplitude^2. Intensity should be used for any processing and calibration because it represents the reflectance of the surface than that of the amplitude of the signal and the range of the data in intensity is much higher than amplitude which increase the so-called radiometric resolution making it more sensitive to different parameters. For example, if the amplitude from two different object is 0.4 and 0.5 the difference is very low but when we use intensity the values become 0.16 and 0.25 which shows the clear separation those objects.

It was observed that there was more brightness in amplitude band as in compared to intensity band but the contrast of intensity band was higher than the amplitude band which made intensity band more suitable for further analyzing of information.
Further, when visually inspecting among Intensity VV and VH band it was observed that more details were recorded in the VV band at the moment whereas there was some form of noise in case of VH which might have been due to cross-polarization.

All the bands from the image were visualized simultaneously, using the Tile Horizontally tool. The image shown below is all the bands of pre image:

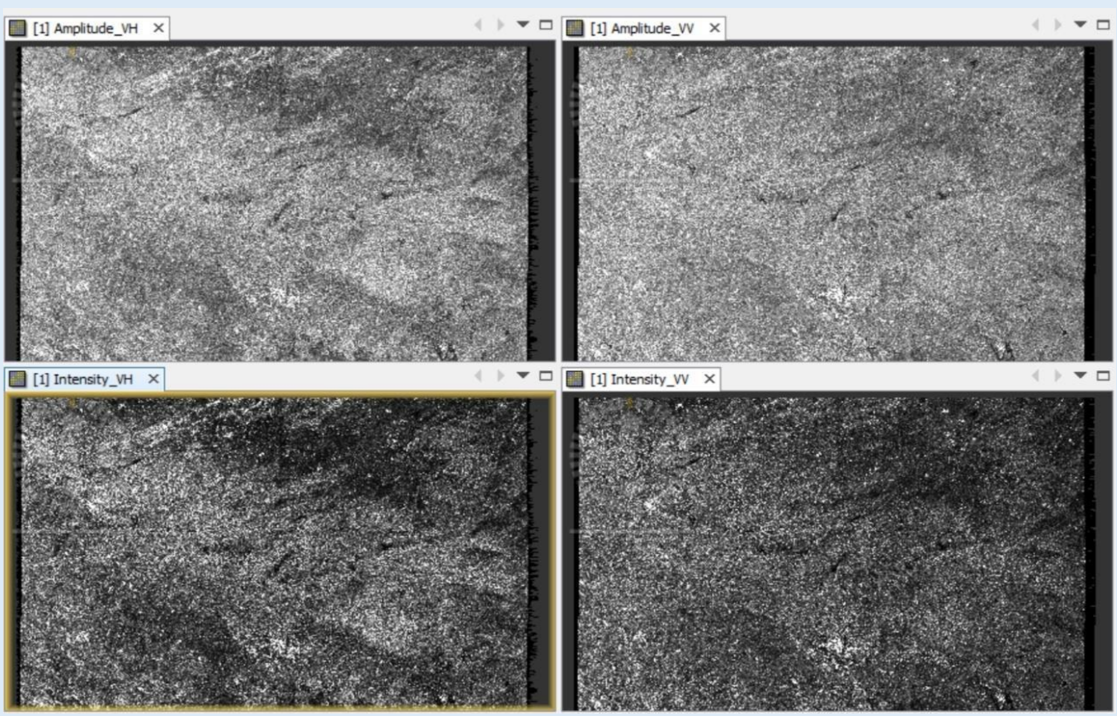


Figure 6: RGB vs Intensity VH vs Intensity VV

The image was displayed in RBG by placing intensity VV band in red channel, intensity VH in green channel and ratio of intensity VV to intensity VH in blue channel to see the color image and make more visual understanding of the geographic setup as well as availability of different features.

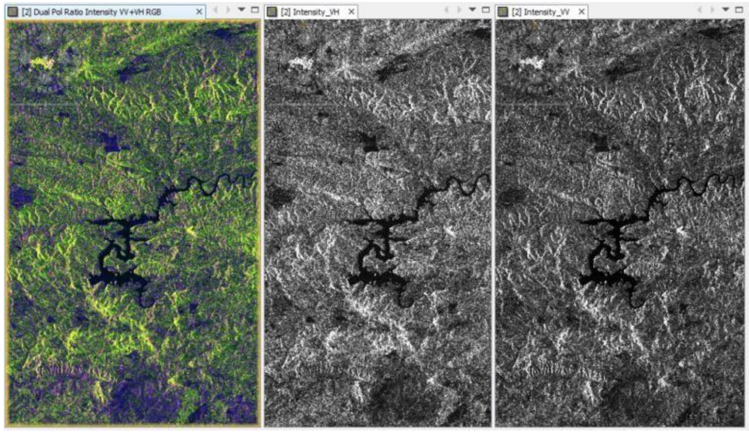


Figure 7: Available band of preimage

Since Backscattering is the amount of signal reaching back to the antenna and reflection is the property of the surface to reflect the signal, a very reflective surface is the least backscattering in radar image, calm water surface corresponds to dark pixels because all the transmitted waves are reflected to different direction than that of the antenna. To visualize such different features in the ground, the image was visualized in RBG by placing intensity VV band in the red channel, intensity VH in green channel and ratio of intensity VV to intensity VH in the blue channel.

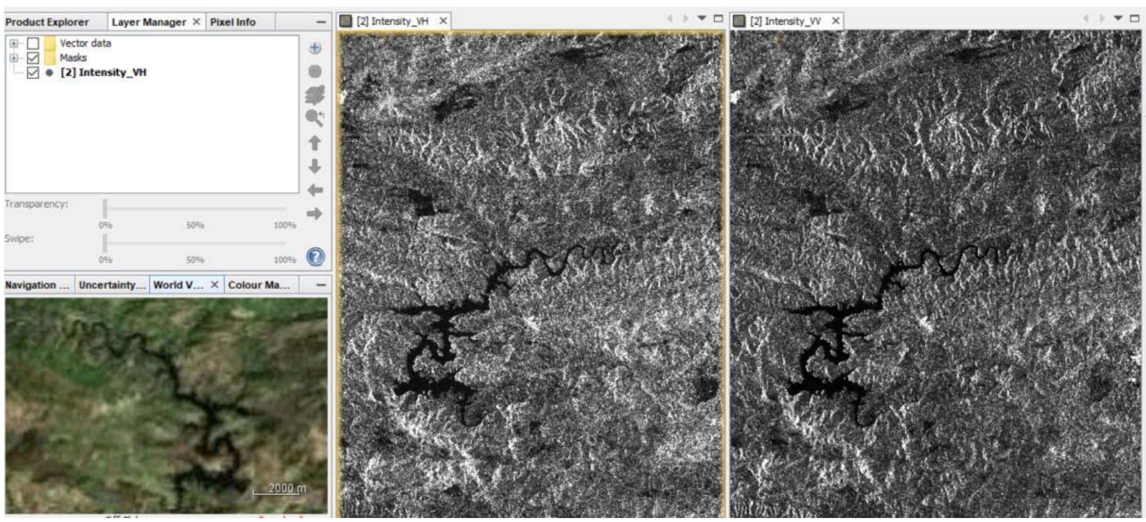


Figure 8: Water Surface

The image was inverted (mirrored) because it is oriented in the same way it was acquired and our satellite path was descending orbit which caused the image look like inverted because of the look direction and backscattering geometry of the satellite. Due to the image acquisition This will be corrected when doing terrain correction later in the workflow. As the level of backscatter is high for the manmade objects or very rough surface, it is assumed that the screenshot showed below is of Urban areas.

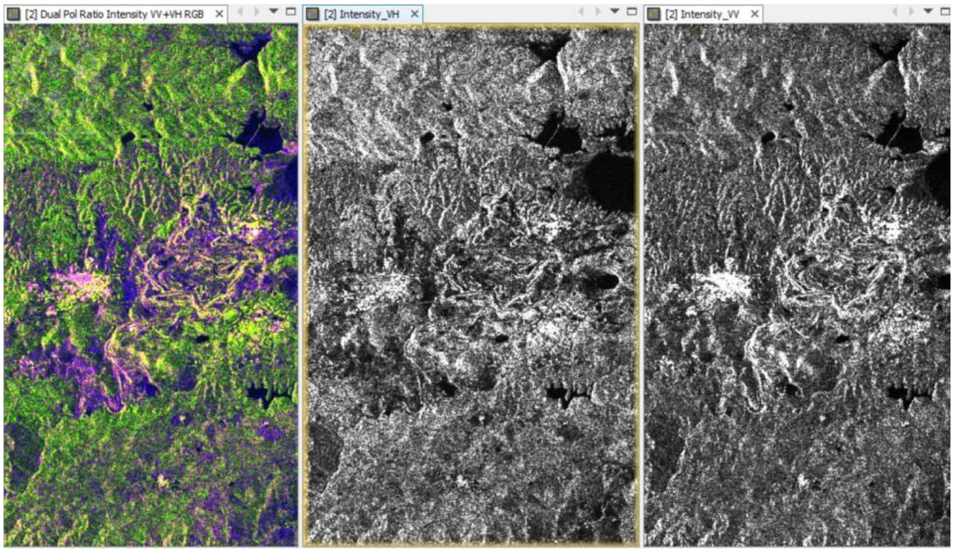


Figure 9: Urban Areas

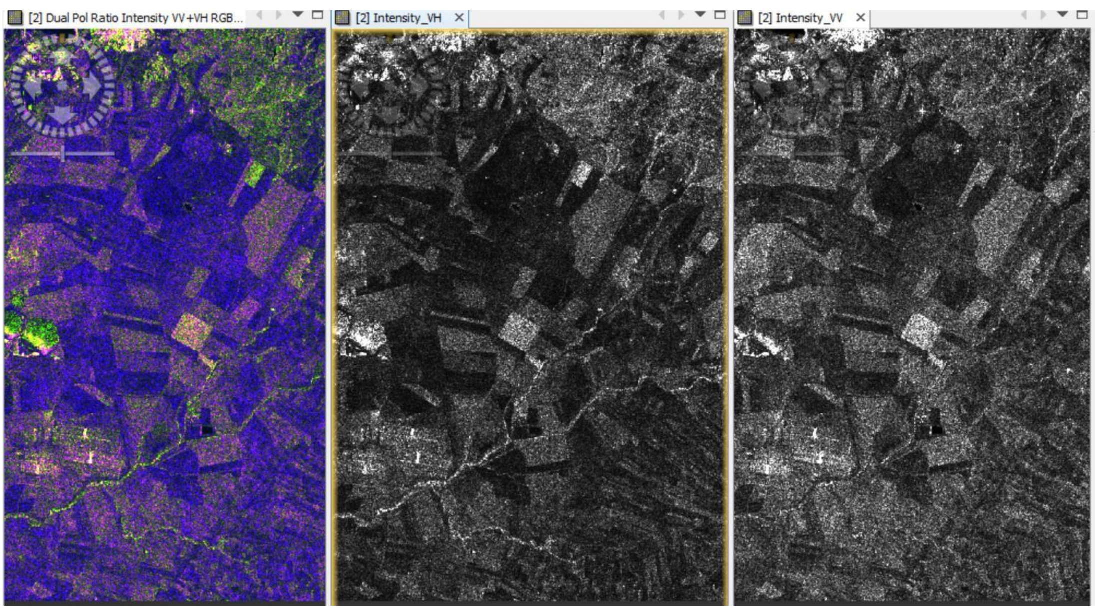


Figure 10: Agricultural Area

Fig 9 shows the area with moderate backscatter so it should be either medium level of vegetation, agricultural crops or moderately rough surface. We can also predict that the line like feature might be the gravel road.

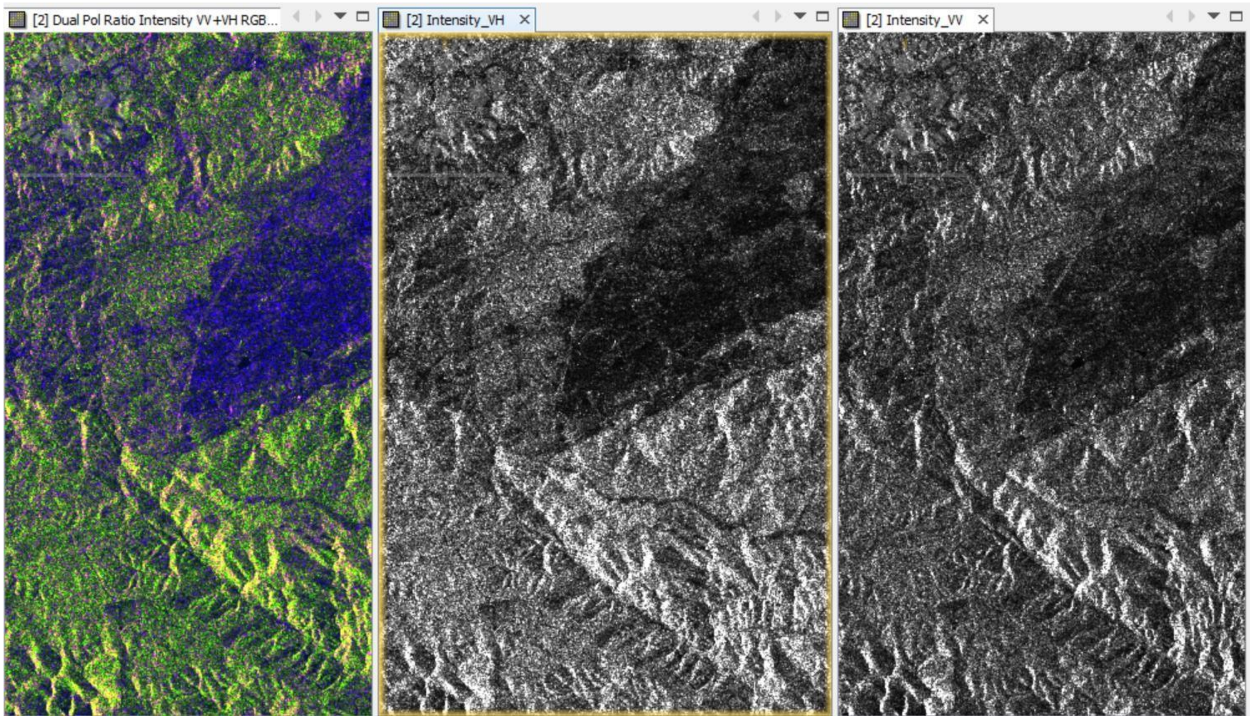


Figure 11: Forest Areas

In fig 10 depicted as forest few regions have moderate backscatter whereas few have low backscatter and it is expected in case of dense vegetation and medium level of vegetation.

<u>Step 5: Subset the data to given shapefile with the data</u> Since the image was quite big, it could take time in the processing so we subset the image to the area of interest. Though we had a shapefile we choose in self-defining the Pixel Coordinates to maintain consistency in everyone's product output.

Selecting subset from the dropdown menu of raster and input the coordinates, rest of the parameter were set as default. The same process was repeated for both pre and post image of that place.

<u>Step 6: Check the subset product</u>

An observation about the software SNAP was its ability to add process name/prefix to the end of the input product name as its output product name.

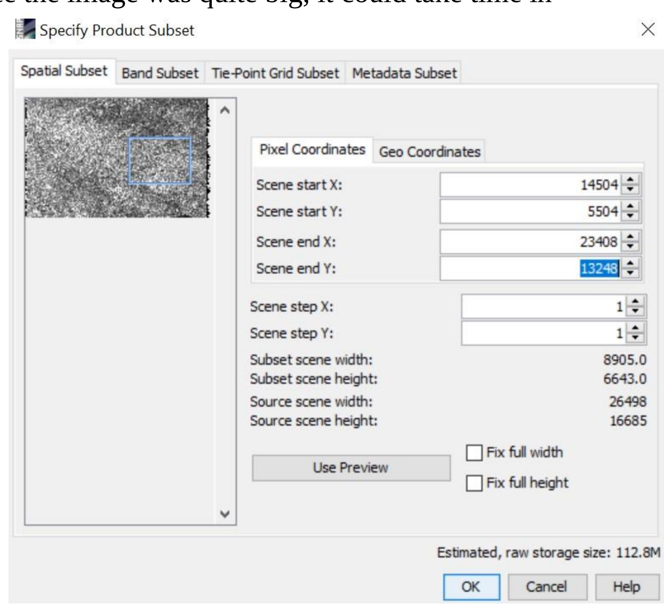


Figure 12: Subset image

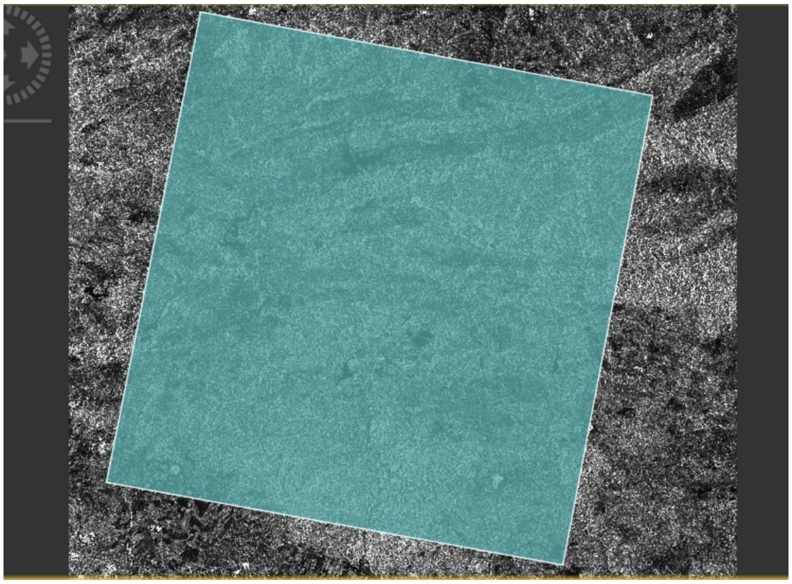


Figure 13: Subset image

Preprocessing

The processing phase includes all the steps essential for quantitatively analyzing the images. As it is important for comparing images from different sensors, modalities, processors or images acquired at different times.

Step 7: Orbital File Correction

Orbital Correction was done initially to the subset image.

It was studied that Orbit state vectors, contained within the metadata information of radar products are generally not accurate. The precise orbits of satellites are determined after several days and are available days-to-weeks after the generation of the product. The operation of applying a precise orbit available in SNAP allows the automatic download and update of the orbit state vectors for each SAR scene in its product metadata, providing an accurate satellite position and velocity information. Therefore, orbit file correction is done because it provides accurate satellite position and velocity information that corrects the orbit position of the image.

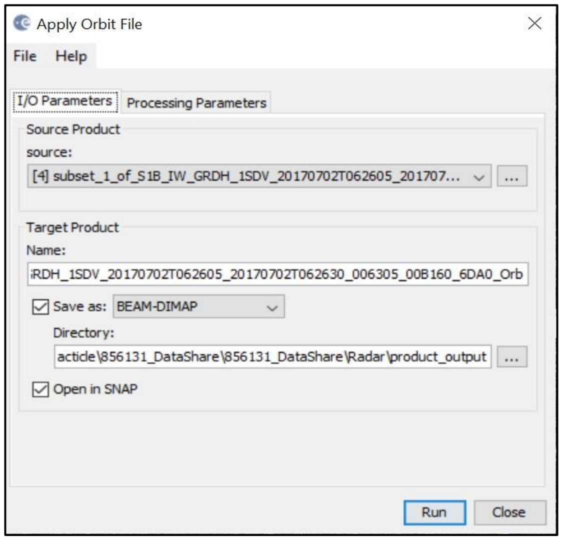


Figure 14: Apply Orbit Correction

For Orbit File Correction, in the pop-up window when selecting Apply Orbit file parameters were default and here the orbit state vectors were from Sentinel precise which gets automatically downloaded when performing the correction.

Step 8: Radiometric Calibration

The objective in performing calibration is to create an image where the value of each pixel is directly related to the backscatter of the surface. So, we make that we correct any type of calibration issue that is introduced because of relief or displacement or of antenna pattern calculation.

We learned that radiometric calibration corrects many different radiometric distortions due to signal loss as it propagates, non-uniform antenna pattern, the difference in gain, saturation and speckle.

Thus, to perform calibration on the image we selected it by highlighting then chose to calibrate from the drop-down list of Radiometric. The two channels (VV and VH) were selected in Processing Parameters and verified that Sigma0 is checked. After calibration, when the opening of the two new bands obtained: Sigma0_VV and Sigma0_VH, which were converted into decibels (dB), we visualized two products in parallel. Conversion into dB was used to provide quantitative results.

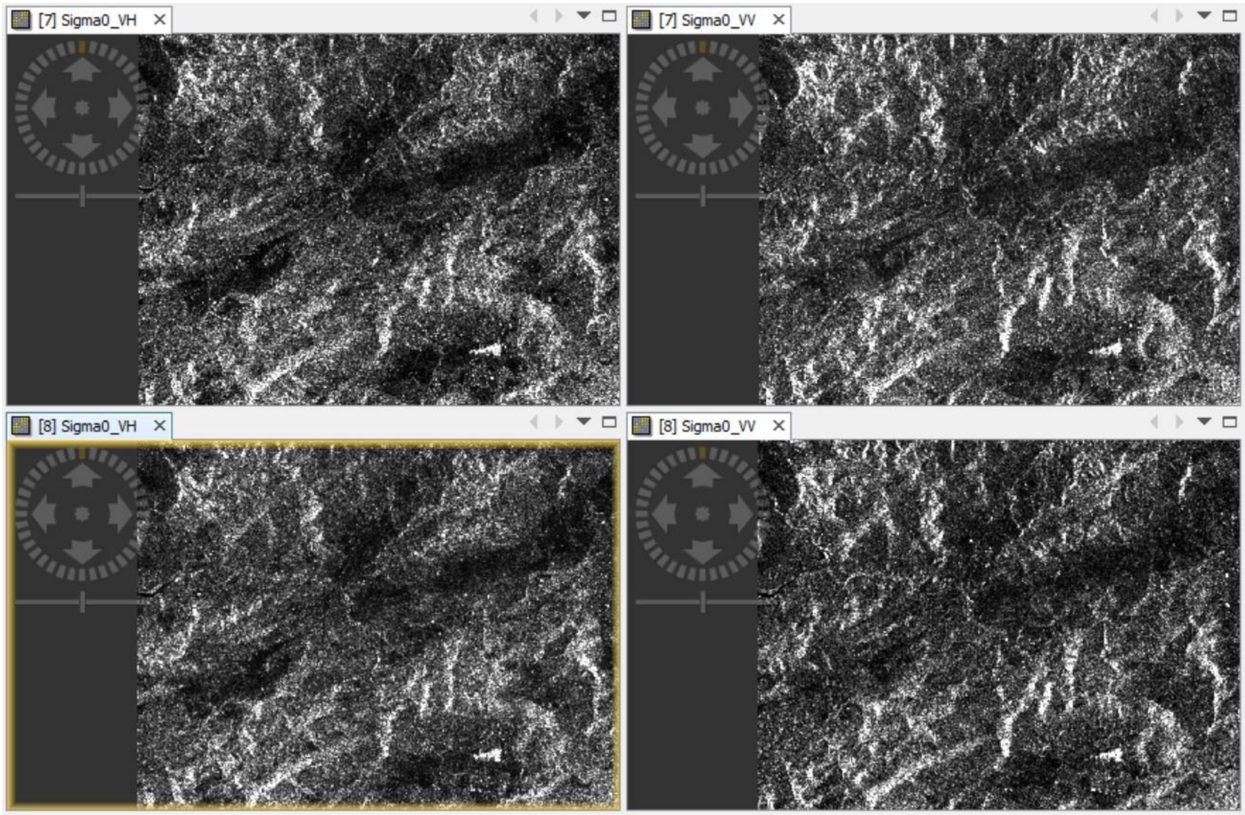


Figure 15: Radiometrically Calibrated Image for pre-image and post-image

- *Backscatter is the portion of the outgoing radar signal that the target redirects directly back towards the radar antenna and is a measure of reflective strength of a radar target known as backscattering coefficient. Its usual notation is Sigma$_0$ (s_0).*

  Mathematically, $s_0(dB) = 10.\log \log_{10}(energy\ ratio)$
  Where, energy ratio=$\frac{energy\ received\ by\ the\ sensor}{energy\ reflected}$

  Sigma nought can be a positive number if there is a focusing of backscattered energy towards the radar (rough surface) or Sigma nought can be a negative number if there is a focusing of backscattered energy away from the radar (e.g. smooth surface), thus making it suitable for quantitative analysis.

- *Beta Nought is the radar brightness (or reflectivity) coefficient. The reflectivity per unit area in slant range and it is dimensionless. Beta naught image formation needs the DN values of image pixels and it does not require incident angles of the pixels.*

  Mathematically, $\beta_0(dB) = 20\log_{10}(dB) - k(dB)$ *Where,*

  k is calibration constant of radar image Beta0 is used only *if user don't have information about the incidence angle*

(required for Sigma0) or when they want to perform

Terrain Flattening afterwards which only takes Beta0.

- *Gamma is the backscattering coefficient normalized by the cosine of the incidence angle.*

Mathematically, $gamma_0(dB) = 10log_{10}(DN^2)$

The Gamma0 of the calibration module is based on this formula and uses the cosine of the local incidence angle. It was observed that Gamma0 could be a very interesting output if user calibrate before Beta0 and then apply the Terrain Flattening.

Step 9: Image Co-registration

To measure and quantitatively analyze the change between these two images, a Co-registration is required. It was observed that the method of Co-registration is done in a few cases where the intention is to study two or more images in a series, typically to understand change. For this topic, since we wanted to detect changes due to forest fire, images needed to be perfectly aligned with each other.

The co-registration is the process in which the multiple images are aligned together at the same location based on different feature and their georeferencing parameters.

Both the pre-image and post-image were co-registered and 4 out images were received under single stacked folder. It was observed that these images had sharp edges.

Figure 16: Co-registered Image

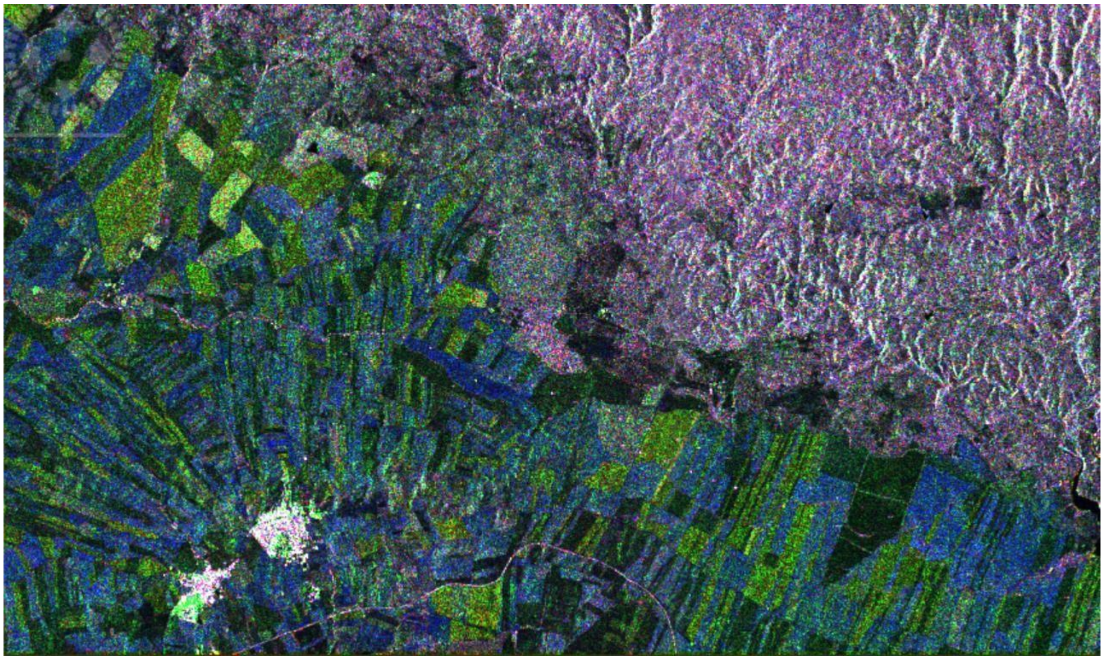


Figure 17: Co-registered RGB image

Processing

<u>Step 10: Change Detection</u>

To identify the burned area, we applied the Change Detection technique implemented in the SNAP toolbox by running the Change Detection pop up box from SAR Application under Radar for two images were generated from the stacked image in the process with VH and VV polarization.

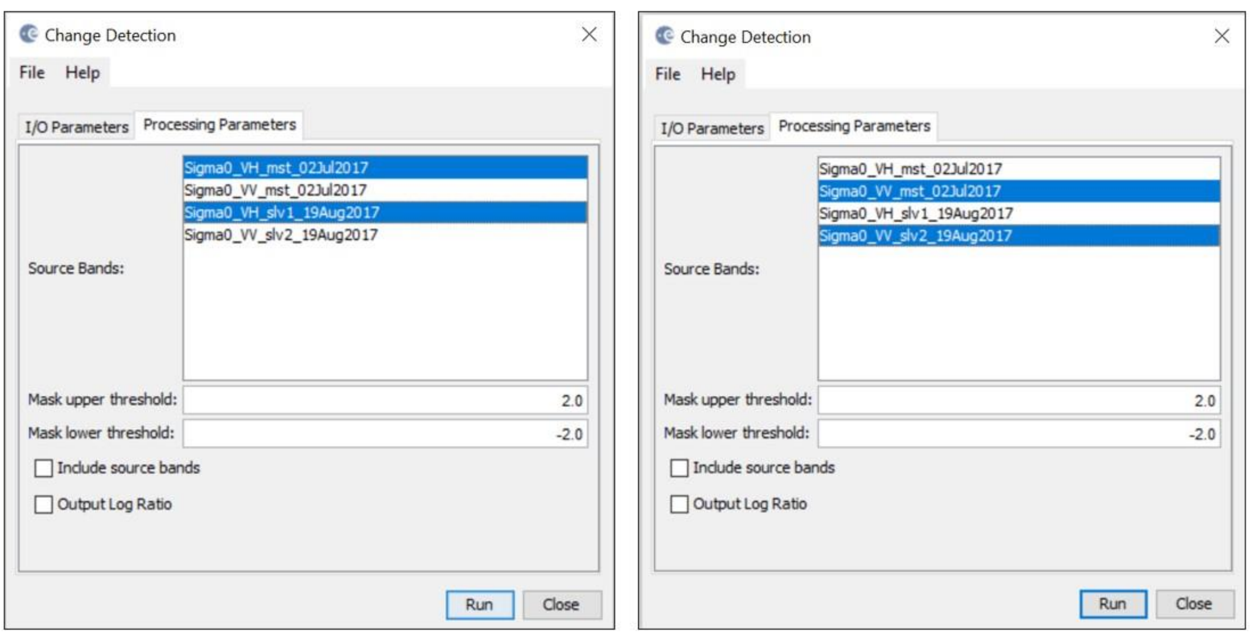


Figure 18: Change Detection

[Note: During Change Detection process I preferred in subtracting the log likelihood of post-image from pre-image so that the changes will be highlighted with bright pixels and it is easy to differentiate/identify i.e.

$$\textbf{Change Detection} = log(I_{pre-image}) - log(I_{post-image})\textbf{].}$$

When comparing the images obtained from Change Detection Technique for VH and VV more details for the area where changes happened could be better identified and since it was a forest area and changes are seen now in those locations, we can say that these are the burned area. The second reason to predict the location as the burned area is due to its brightness an d pixel value difference. Also, after burning the land must have been dry and rough and thus appearing brighter.

When analyzing the histogram of the final image obtained plotted for log10, it was observed that the point of change varied from a range of 0.64 to 1.96.

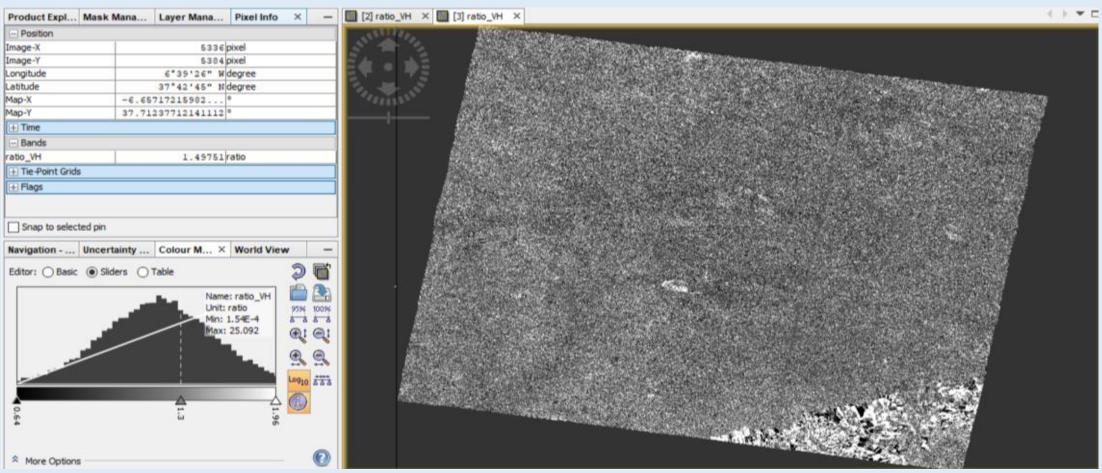


Figure 19: Histogram for Change Detection Image

However, uneven distribution was identified in between VV and VH band i.e., in VV band more area was bright and of almost same value whereas the area previously encountered bright was not present much in VH as shown in the fig 19.

Also, from the final product produced where we identify numerous locations with changed feature, we conclude that since we performed Change Detection Technique and variation in the pixel in few more location other than the forest area was observed, a reason could be some basic changes occurred in the place such as growth of new plant, reduction in the moisture of the soil, creation of new feature etc.

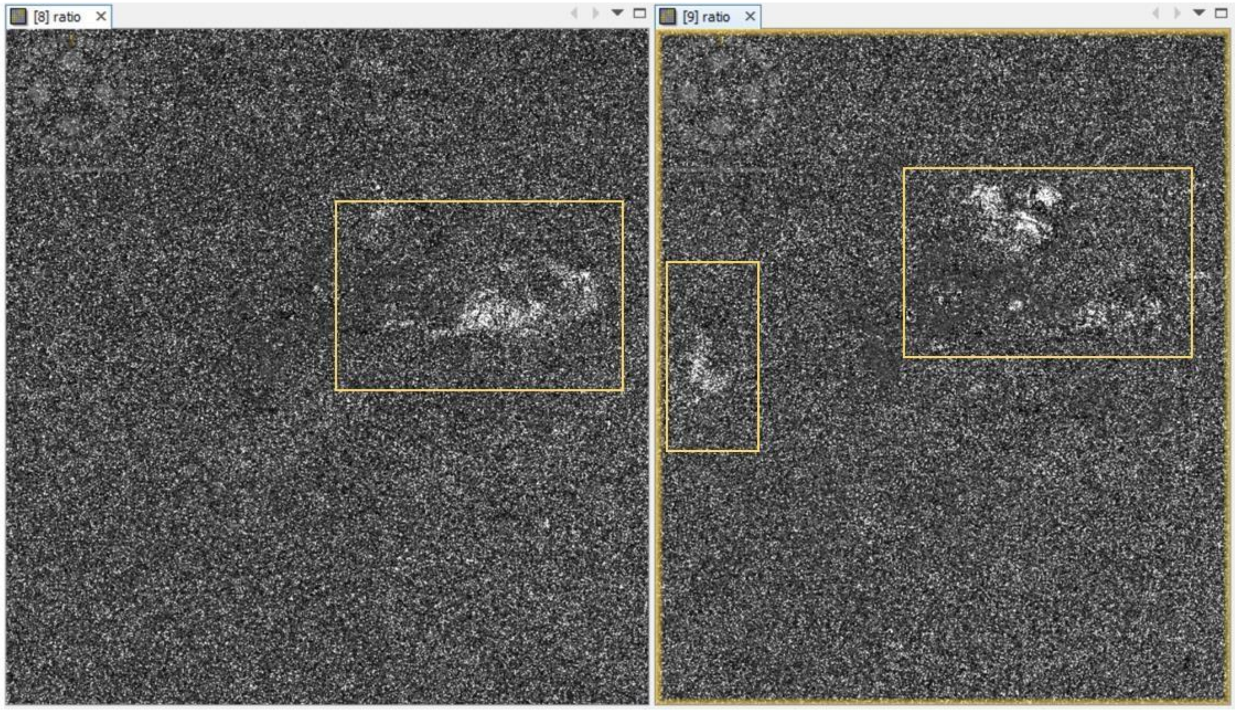


Figure 20: Changed location for VH against VV

In order to verify the area identified as the area that had forest fire, cross check was done with the information provided by the Copernicus Emergency Management Service "El Campillo" site. A geotiff image produced by the service was available, we overlayed the geotiff file with the output of our location.

Then it was observed that the brighter portion next to the forest area visualized in the VV channel was an industrial area. This change was not detected in VH image, so we can conclude that VH could be a better solution when visualizing forest fire.

Fig.20 gives a comparison of our product for the burned area with the product provided by Copernicus Emergency Management Service and the grid gives a clear picture of the location

After obtaining the changed map we compared the results with the Copernicus emergency data in the fire location where we can observe that the change is higher than that of the other locations where the changes is very low or negligible (blue areas) and the white area shows the higher amount of changes in the backscattering from the locations with burnt area as shown in Figure 21.

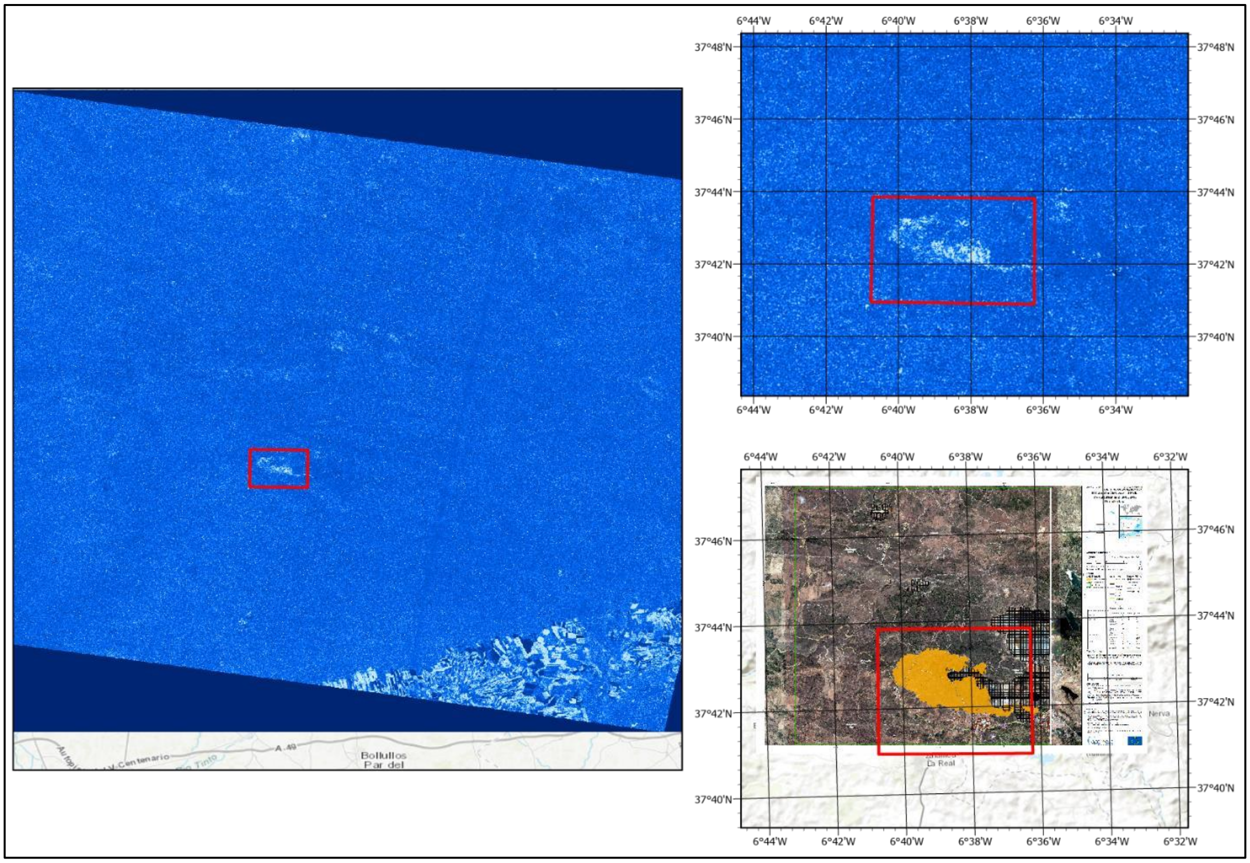


Figure 21: Forest Fire Zone

Step 11: Geometric Correction

Range doppler terrain correct was used to calibrate or correct from any sort of displacement from the terrain. As previously seen when comparing the data from the world-view the image was inverted and to improve this geometric correction is applied.

Range Doppler terrain correction is a correction of geometric distortions caused by topography, such as foreshortening and shadows, using a digital elevation model to correct the location of each pixel. The Range-Doppler terrain correction makes use of available orbit state vector information in the metadata, the radar timing annotations, and the slant to ground range conversion parameters together with the reference digital elevation model data to derive the precise geolocation information. It needs DEM to do this so in the processing parameter tab it uses default SRTM 3sec or we can specify as our wish if we have. Then it will show the image in the correct orientation/direction.

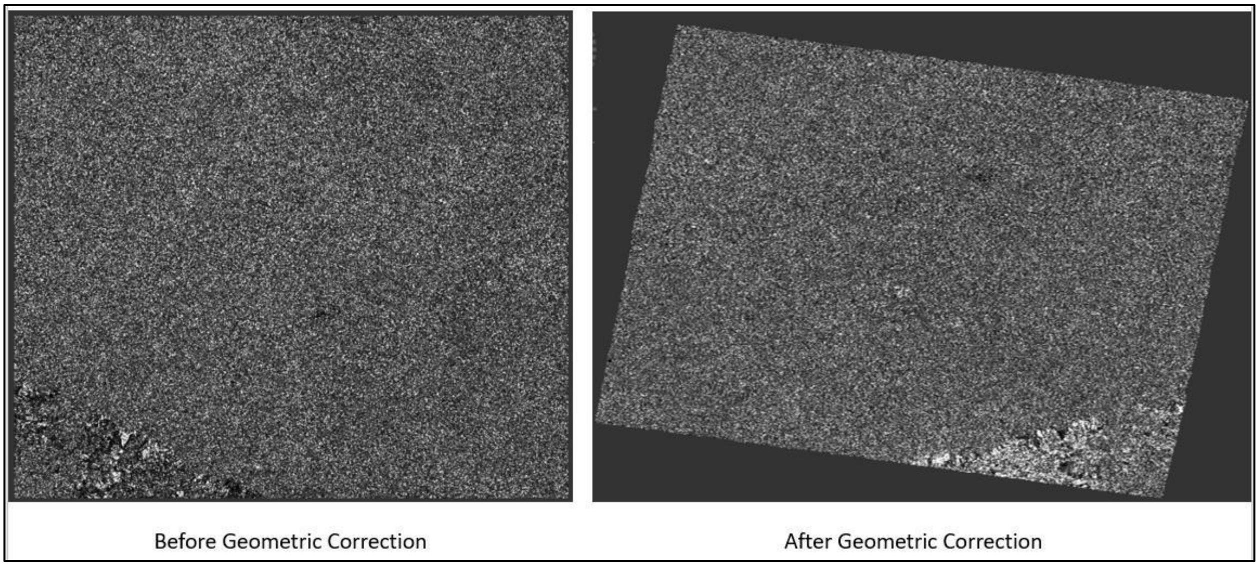


Figure 22: Applying Geometric Correction

Step 12: Speckle Filtering

Speckle makes interpretation of image difficult because of the salt and pepper effect that corrupts information about the surface. There are two ways for it: Speckle Filtering or Multi look. It is done mostly for visual interpretation by avoiding salt pepper noise in the image so that it will allow us to find derive more information.

In this process, we used the commonly used Lee filter by specifying the window size 7x7 and look like 1. It was observed that the larger the number of looks and more the size of the window, the more you reduce the resolution of the image.

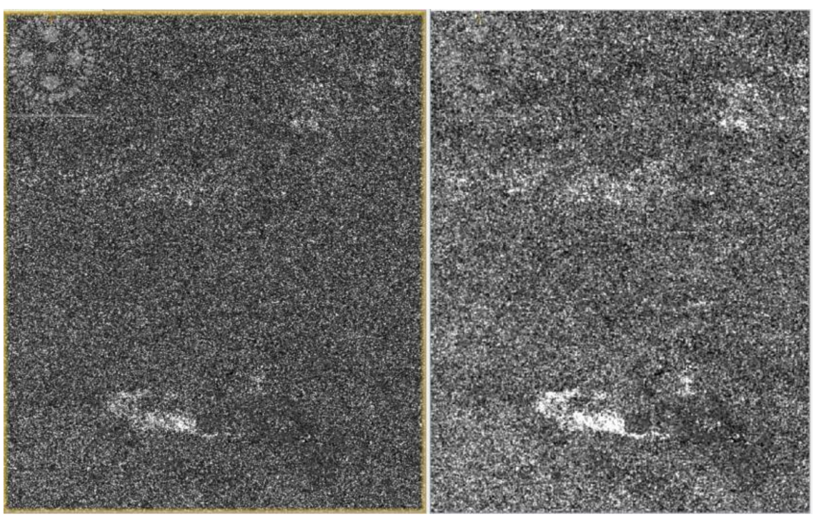


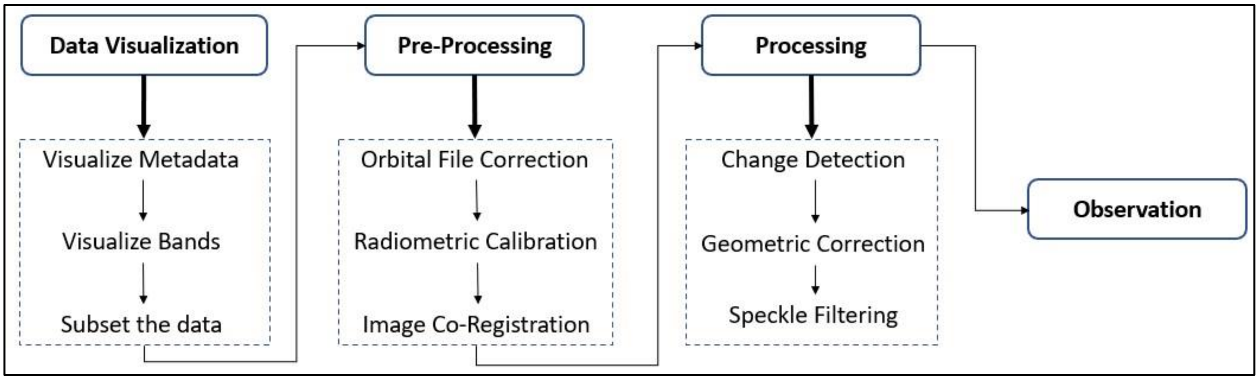
Figure 23: Before and After Speckle Filter

In the image shown above, the left is the VH image before filtering and to its right is after filtering. We can see that high amount of salt pepper effect has been reduced and details can be better identified.

From the workflow perspective here, filtering is done after change detection to make it easier and efficient so that we can do just once and also eliminate the chance of missing valuable information. If we do beforehand, we had to filter both images and both images might lose some kind of information.

Workflow:

The whole process workflow includes:



Conclusion:

Hence, from two images, one acquired before the forest fire and the other acquired after fire, we Co-Register the images and detect the changes. Changes at various location in the area of Interest was observed for both VH and VV channel. But better result for the burned area was depicted in the VH channel when compared with the product provided by the Copernicus Emergency Management Service.