SAPIENZA
UNIVERSITÀ DI ROMA

EODA

HW 3: SURFACE DETECTION FROM SAR SENTINEL 1 DATA

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1 EARTHQUAKE DETECTION BY SAR DIFFERENTIAL INTERFEROMETRY for Amatrice Earthquake in central Italy on 24 August 2016

In this first section, Sentinel 1 mission, which consist on SAR iterferometry, will be used to study the effects of the Amatrice earthquake over the ground on 24/08/2016. This earthquake has been the most significant, in the last two decades, that affected the Italian peninsula after the Aquila earthquake in 2009. In order to accomplish the study, SAR sentinel Imagery will be used. SAR interferomerty requires the utilization of two different products acquisitions: the master, which represents the Pre-Event acquisition (21/08/2016), and the slave, that instead is the Post-Event acquisition (02/09/2016).

- **Pre-Event:** S1A_IW_SLC__1SDV_20160821T051116_20160821T051143_012694_013F33_53E5.SAFE
- **Post–Event:** S1A_IW_SLC__1SDV_20160902T051117_20160902T051144_012869_014526_DFB4.SAFE

1.1 Data band exploration and geolocation for IW2/IW3 subswaths for master/slave images

Sentinal 1 products are splitted into 3 subswaths (IW1, IW2, IW3). And, because is a dual polarisation product, each subswaths as two polarisation, VH and VV. Moreover, the instrument used for Sentinel 1 products, generates 9 stripes called burst for each subswath.

The images below shows the master and slave images on 2 subswaths (IW2, IW3) and 2 polarisation (VH, VV):

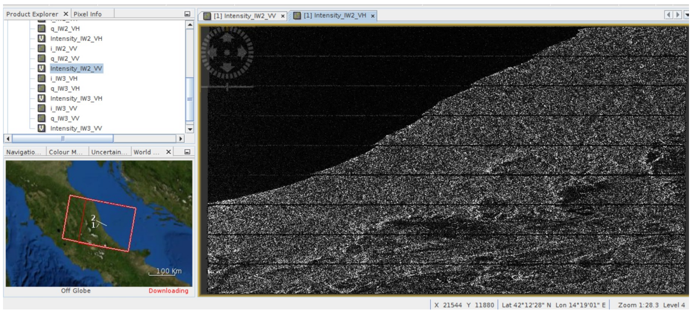


Figure 1: Master Intensity IW2 VH

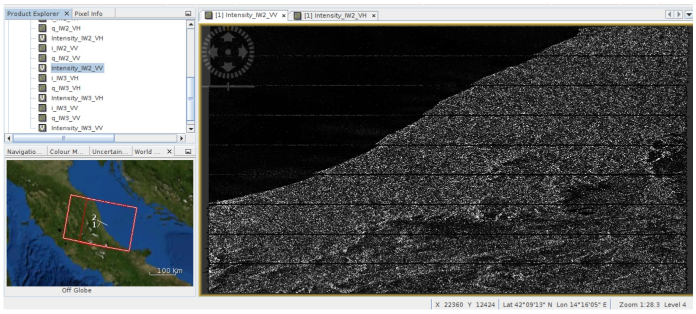


Figure 2: Master Intensity IW2 VV

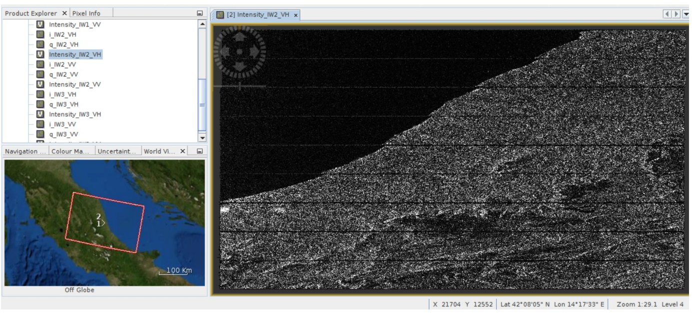


Figure 3: Slave Intensity IW2 VH

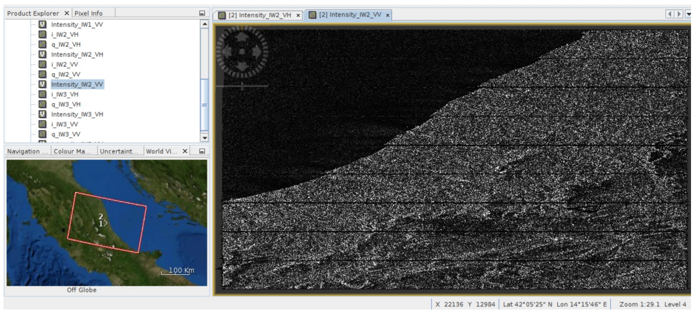


Figure 4: Slave Intensity IW2 VV

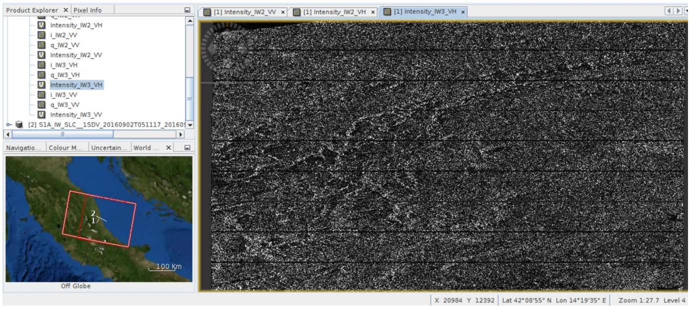


Figure 5: Master Intensity IW3 VH

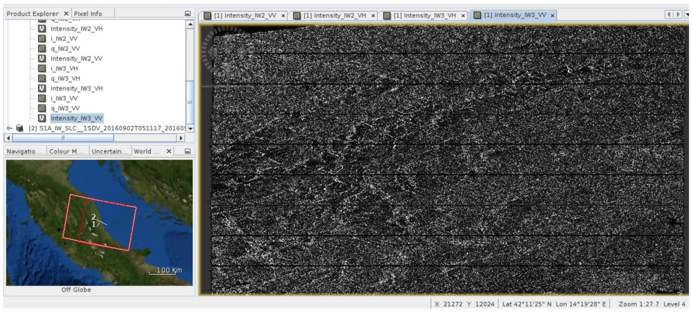
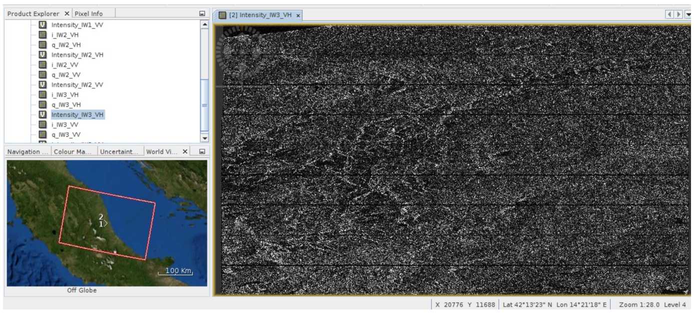
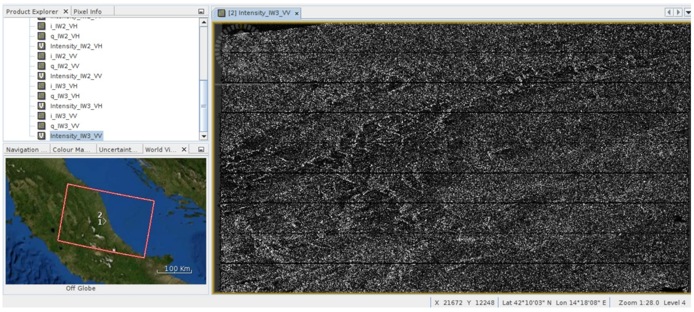


Figure 6: Master Intensity IW3 VV



Slave Intensity IW3 VH



Slave Intensity IW3 VV

1.2 Subswath/burst TOPSAR splitting

Due to the fact that the images cover a wider area (the one highlighted by a yellow polygon in the images reported below) than the one that has been affected by the earthquake, the study will be performed by considering only 1 polarisation (VV), 2 subswaths (IW2, IW3) and only the 2 bursts that covers the affected areas. As a consequence, this will allow to focus on the most hit areas and will also speed up the computation during the analysis.

Only polarisation VV will be used for interferogram because is the one that provides more coherence in terms of quality.

The splitting of the product can be performed by using a dedicated operator implemented in SNAP, called **S-1 TOPS Split**. In particular, for IW2 subswaths only burst 5 and 6 will be used, whereas for IW3 only 6 and 7. The action of choosing different bursts comes from the fact that the two subswaths are a bit shifted, so it is also necessary to shift the bursts in order to mitigate this shifting. The subswath IW1 is not considered because it doesn't cover the area affected by the earthquake.

Figures 7, 8, 9 and 10 show the splitting for Master and Slave products.

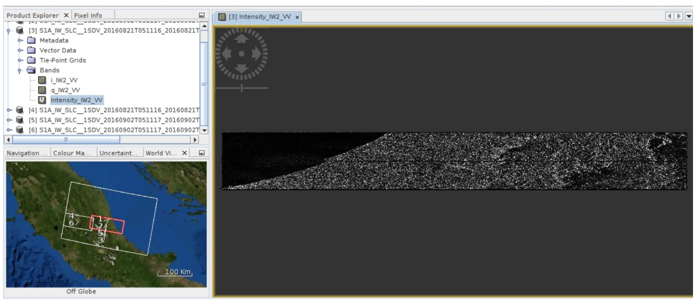


Figure 7: Master: IW2, VV & Bursts (5,6)

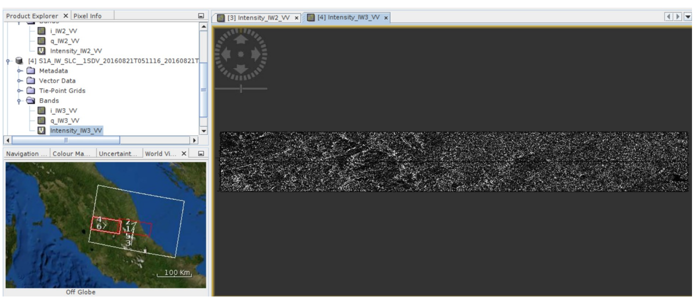


Figure 8: Master: IW2, VV & Bursts (6,7)

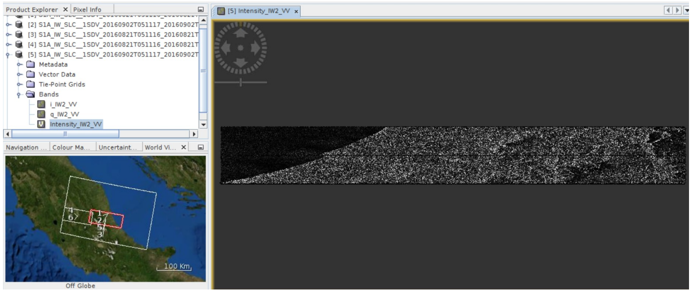


Figure 9: Slave: IW2, VV & Bursts (5,6)

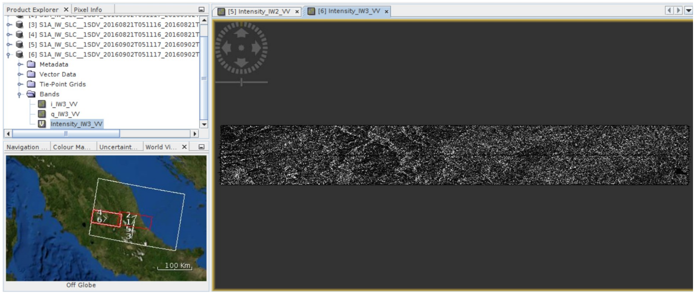


Figure 10: Slave: IW2, VV & Bursts (6,7)

1.3 Orbit precising and interferogram generation/backgeocoding

In order to perform, and also to have a precise registration of the image, we need to use the precise orbital information that is not immediately available in the source product. This information can be easily retrieved by ESA quality Sentinel-1 web server. Thanks to the **Apply-Orbit-File** operator implemented in SNAP, this operation doesn't require a manual action. The operator allows to choose the Polynomial Degree (set in this case == 3)for the interpolation of the orbit. Of course, orbit precising has to be performed on both Master and Slave products before performing Back-Geocoding.

Once the orbit processing has been performed, on both Master and Slave, the two products are passed as input for the Back-Geocoding, which is the operation needed to register the Master and the Slave acquisitions. This is performed with the help of **Digital Elevation Model(DEM)** that uses the shuttle radar topography mission(SRTM) downloadable by the NASA program. The Back-Geocoding operation allows to choose the Resampling Algorithm, in order to have more accurate results, based on the specific purpose (in this case BICUBIC_INTERPOLATION has been selected), but also the Resampling Type. In this case it has been chosen the BISINC_21_POINT_INTERPOLATION", that preserves very well the phase information of the Slave Images.

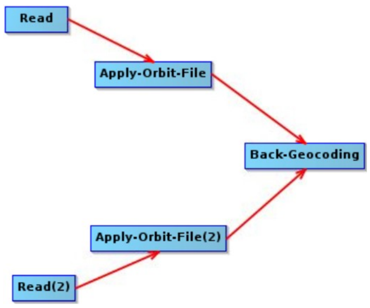


Figure 11: Pipeline for OrbitPrecison and Back-Geocoding

1.4 Spectral-diversity enhancement and TOPSAR deburting

Enhancement Spectral-diversity (ESD) is necessary to compensate some art-factorial issues that appears in the areas among two different and consecutive bursts. So, in order to avoid the discontinuity of the phase, this operator is inserted in the pipeline that will be responsible to study the overlapping area among the two consecutive bursts and try to remove eventual phase jumps.
So, the ESD method exploits the overlapped area of adjacent bursts. It computes an average estimation over a number of windows in every overlapped area, and returns this average as the final azimuth offset.

The last pipeline step, before writing the new product, is the **TOPSAR deburting**. This operation is necessary because two consecutive bursts have a discontinuity, but what is necessary is a contiguous coverage of the ground.So here, what is also performed is merging the consecutive bursts.

Figure 12 shows the entire pipeline used to register the Master and Slave acquisitions. This is done because if two images are perfectly registered between each other, the difference of the phase can be performed. So, thanks to this information, in case we have a deformation we can derive that from the interferometric phase.

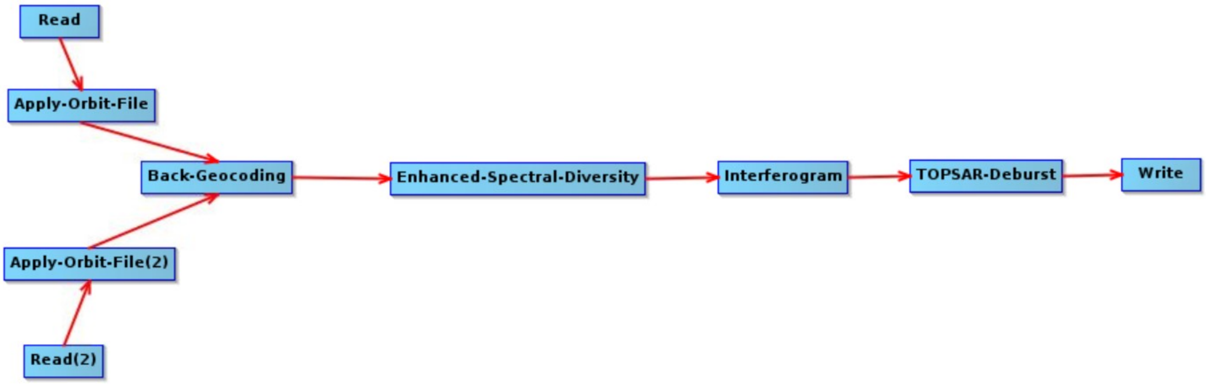


Figure 12: Graph Builder: TOPSAR Coreg Interferogram.xml

1.5 Interferogram flattening and coherence generation

As can been seen from Figure 12, there is the **Interferogram** operator that has not been described before. This operator is necessary to compute the Interfermetric phase. What is immediately done is also to subtract the contribute of the flat earth, due to the fact that the earth is not flat and this affects the phase returned to the signal. The operator allows also to compute the coherence estimation product. It is the cross-correlation coefficient which is computed among the previously registered Master and Slave acquisitions. It provides information about the quality of the interferogram but can be also used to understand how the two acquisitions are similar between each other.
Since it is required to return the coherence product in square pixel, the coherence range window is set to 10 and the coherence azimuth window to 3.

The pictures below show the interferometric phase and the coherence that have been generated at the end of the pipeline for the two subswaths, IW2 and IW3. By looking at the interferometric phase it is difficult to extract significant information , this is due to the fact that other steps need to be applied. Looking at the coherence, the black part represents the less coherent point whereas the white are the most coherent.

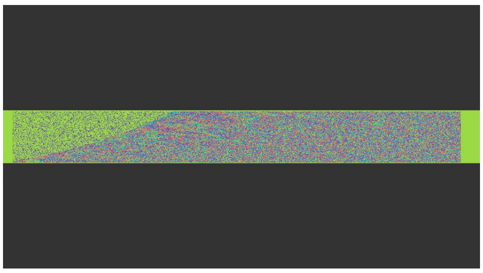


Figure 13: Interferometric phase IW2

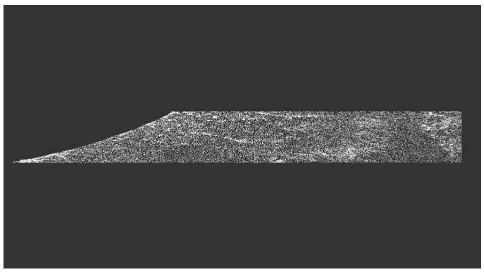


Figure 14: Coherence IW2

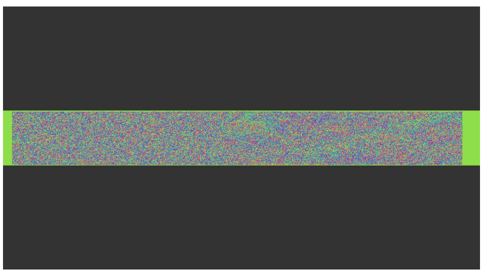


Figure 15: Interferometric phase IW3

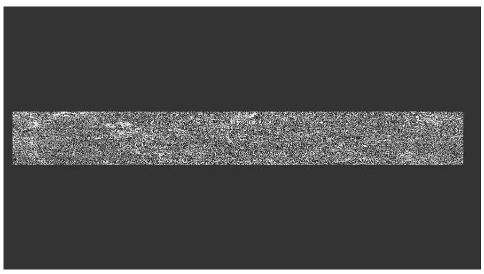


Figure 16: Coherence IW3

1.6 Topographic phase subtraction and ROI subsetting

Now that the interferogram for both IW2 and IW3 have been computed, it is necessary to merge them and subtract the topographic phase, which is simulated using a digital elevation model. At the end of this stage what will be returned is the phase given by the contribution of the displacement, atmosphere and eventual noise only.

The pipeline for topographic phase subtraction and ROI subsetting is shown in the figure below.

- **TOPSAR-Merge** is used to perform the merging operation.
- **TopoPhaseRemoval** is used to subtract the topographic phase.
- **Subset** is used to select only the area of interest among the two subswaths. The ROI(Region of Interested) has been selected by using the this polygon shape: ((13.5 42.88, 13.1 42.88, 13.1 42.58, 13.5 42.58, 13.5 42.88, 13.5 42.88))

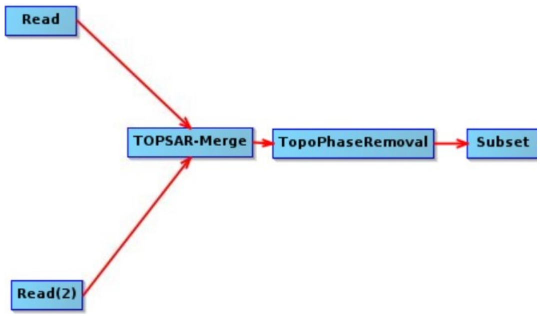


Figure 17: Topographic phase subtraction and ROI subsetting pipeline

Figure 18: ROI subsetting

1.7 Phase filtering and multilooking

GoldsteinPhaseFiltering is the operator used to perform filtering on the interferogram.
After that, it also necessary perform Multilooking operation, since up to now we are still working on the slant range direction, meaning that we are working on the view angle of the SAR instrument with respect to the surface.Moreover, we are still working with the original resolution of the SAR product. This is necessary due to the fact that SAR images appears speckled with inherent speckle noise. So, in order to reduce this inherent speckled appearance, multilooking operation is performed, that consists on combining several images as if they correspond to different looks of the same scene. The multilooked image is produced by space-domain averaging of a single look image with a specific 2D kernels by convolution. The multilook operator works by averaging a single look image with a small sliding window.
At the end of this step will be returned pixel of the ground around 30 meters resolution.

The Figure below shows the entire pipeline used to perform topographic phase subtraction, ROI subsetting, phase filtering and multilooking.

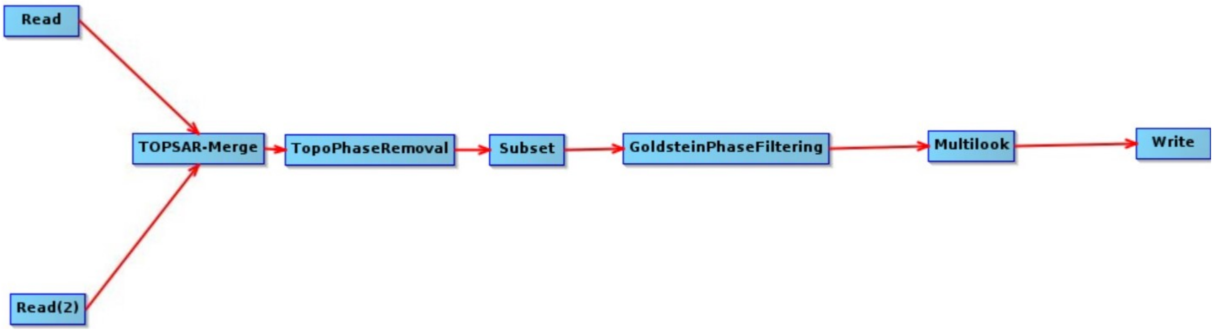


Figure 19: Graph Builder for topographic phase subtraction, ROI subsetting, phase filtering and multi-looking.

Figure 20 shows the generated product at the end of the pipeline described at figure 19. As the figure shows, fringes now are visible. Each fringe corresponds to a displacement of half of the wavelength ($\frac{\lambda}{2}$). Since in C band of Sentinel 1 Mission λ= 5 to 6 cm, so every fringe corresponds to a displacement of around 2.75cm. Because there are 5 fringes, it is possible to infer a relative displacement of around 15cm (2.75x5).

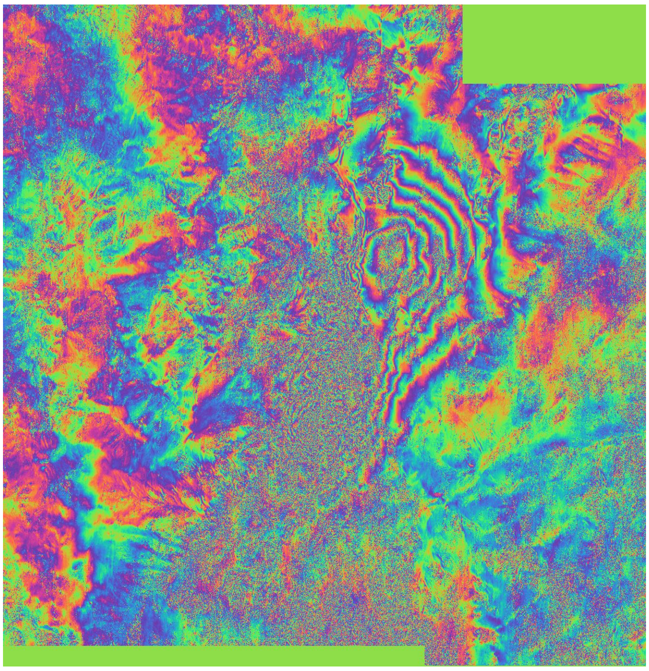


Figure 20: Fringe displacement

1.8 No-data subsetting for smaller ROI

As it is possible seeing from figure 20, there are two completelly green rectangles. These are generated because there is not a perfect match between the selected bursts that were overlapped, so it is necessary delete these rectangles because represent no-data areas. For that reason, it is necessary to subset again the product, by taking into consideration a smaller ROI. This subsetting is performed by using the Spatial Subset from View tool implemented in SNAP. The figure 21 shows the no perfect overlapping that generates the no-data regions, figure 22 reports the Spatial Subset from View tool used to perform the subsetting to discard no-data regions whereas figure 23 shows the subsetted area without the two regions with no data.

Figure 21: No perfect overlapping

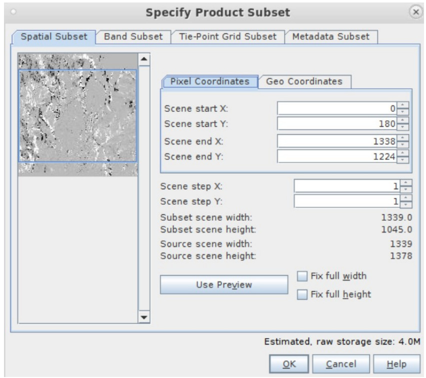


Figure 22: Spatial Subset from View tool

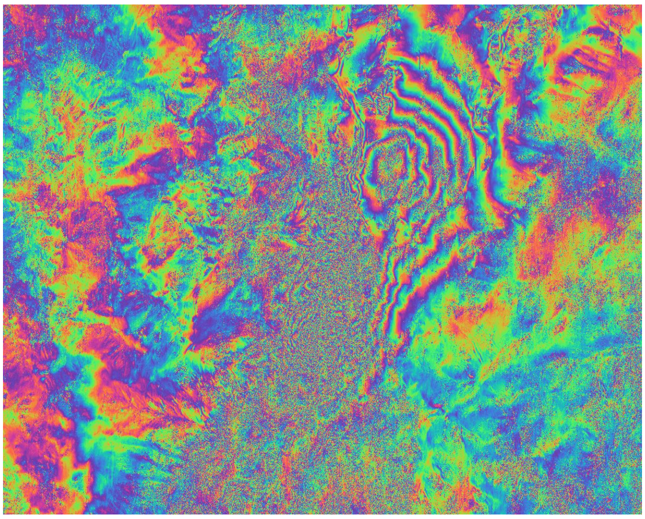


Figure 23: Subsetted fringes displacement

1.9 Phase-unwrapping by SNAPHU external operator

Now that fringes displacement have been returned, it is necessary to unwrap them automatically. Now, that there is only the contribution of the displacement each fringe (phase cycle), as said before, corresponds to the ration of half of the wavelength. Since it is tedious to count each phase cycle, that can be actually possible only for relative displacements (by fixing two points and calculating the fringes between those points), there are algorithms that perform this operation. This process generates a map that can be converted in a displacement map where WE PASS FROM PHASE UNIT (RADIANCE OR DEGREE) TO DISPLACEMENT UNIT (METERS OR CM).

In order to do that, it has been used the unwrapping operator SNAPHU. It is an external tool that has to be invoked by command line. In SNAP, there is the SNAPHU Export operator that has to be called in order to prepare the data that has to be passed as input for the SNAPHU tool, and it also creates the folder directory where the output will be stored once generated. Once the unwrapped phase image is generated has to be imported in SNAP, by using the SNAPHU Import operator, in order to plot it. Figure 24 shows the unwrapped phase image.

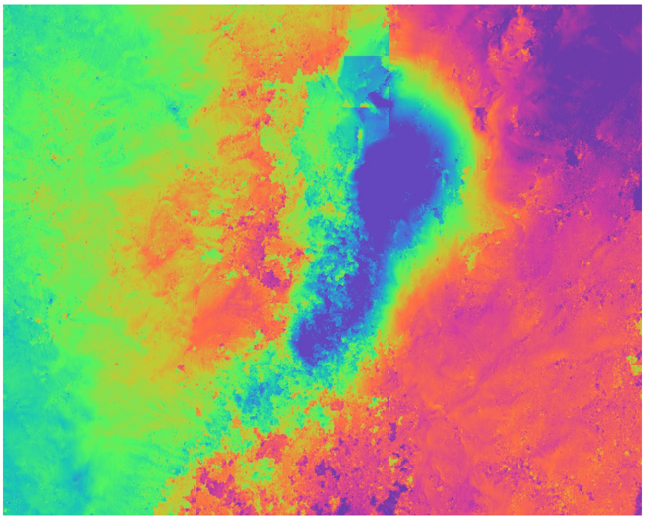


Figure 24: Unwrapped phase image

1.10 Phase-to-displacement conversion along line-of-sight (LOS)

Due to the fact that the output of the SNAPHU tool is the unwrapped phase image, it is necessary to convert this unwrapped map into a displacement map. The conversion can be performed by using the Phase-to-Displacement operator implemented in SNAP.
Figure 25 shows the displacement map. As it is possible seeing from the pin manager window, the pin in the red pin in the blue area shows a negative displacement of around 14 cm that is close to 15, the one inferred before at point 1.7.

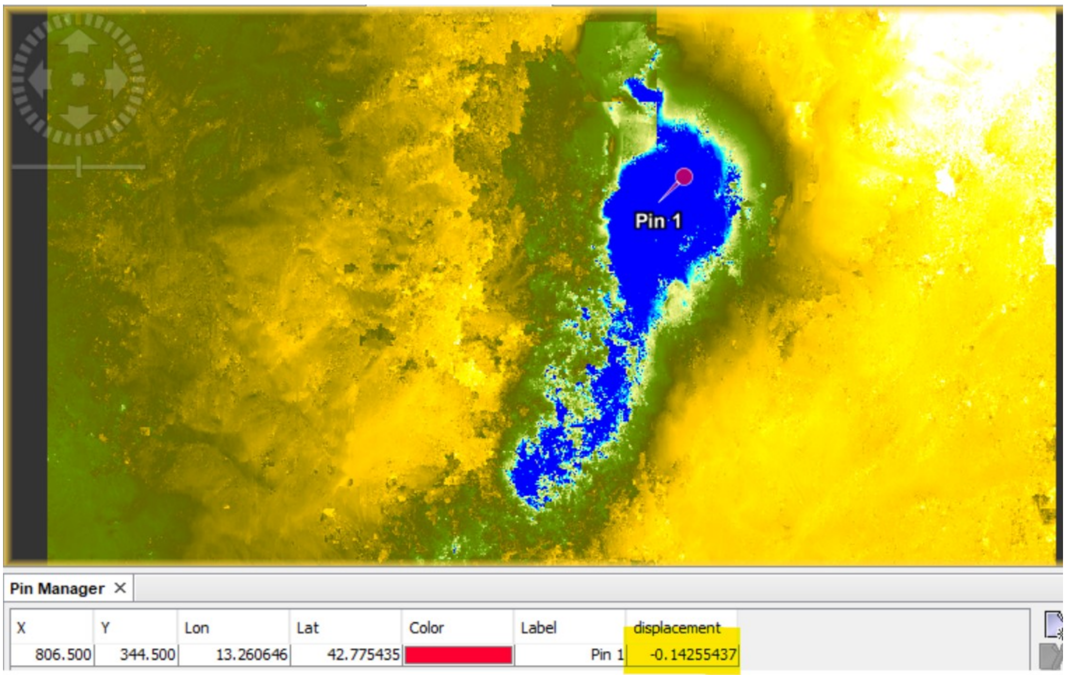


Figure 25: Displacement Map

1.11 Terrain-correction projection and false-color visualization

As it is possible seeing from the above picture, the image is still on the radar geometry, so it is necessary to display the displacement map with the Terrain correction projection. i.e the square pixel should corresponds to the ground. The projection can be performed by calling the Range-Doppler-Terrain-correction operator in SNAP. The operator takes in input the displacement map and for the parameters all the default one has been maintained and used.

Moreover, by performing color manipulation it can be possible display the projected displacement map in a more accurate way in order to better visualize the deformation. In particular, as can be seen from the Figure below, the color JET palette has been chosen and the thresholds are set as described by the histogram. The red areas are the one with the highest negative displacements (i.e. a ground subsidence) of around 13-14 cm, whereas the blue areas shows an uplift of the ground. However, the blue area at the bottom center of the image just represents coherence loss and not an actual deformation of the ground blamed to the earthquake. This comes from the lack of quality of the signal that leaded to generate these errors during the unwrapping stage.
This can be proofed by comparing the displacement map with the coherence of the image. As this last shows, the bottom central area is actually black highlighting a lack of the signal.

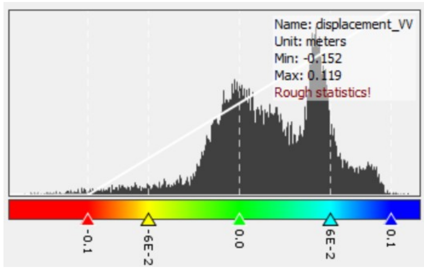


Figure 26: histogram JET palette

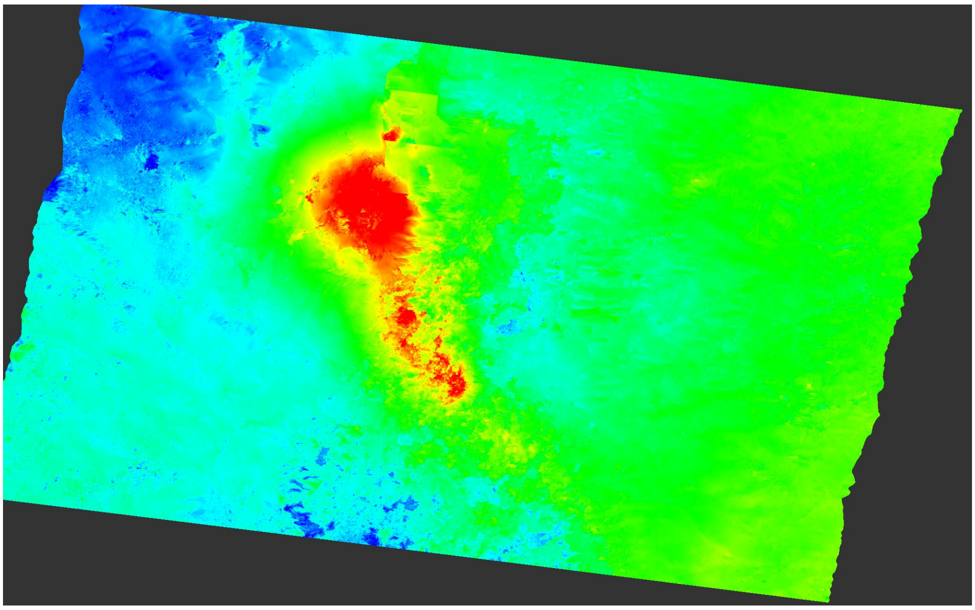


Figure 27: Displacement Map Terrain Correction

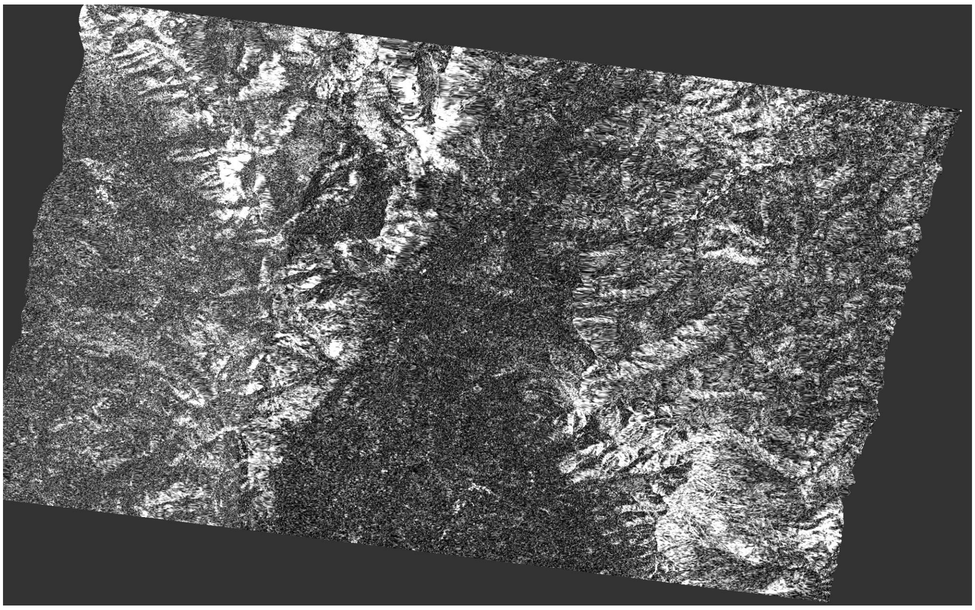


Figure 28: Coherence Terrain-Correction

1.12 Exporting the terrain-corrected map as KMZ and visualizing on G-Earth.

As can be seen from the Figure above, the geometry of the image has been changed congruently with the ground. Now, that the displacement map has been projected, it can be exported as KMZ and be visualized in Google-Earth

The Figure below shows the displacement map projected to the terrain displaying the cities that have been strongly hit by the earthquake (Accumoli, Arquata del Tronto, Pescara del Tronto, Castelluccio)

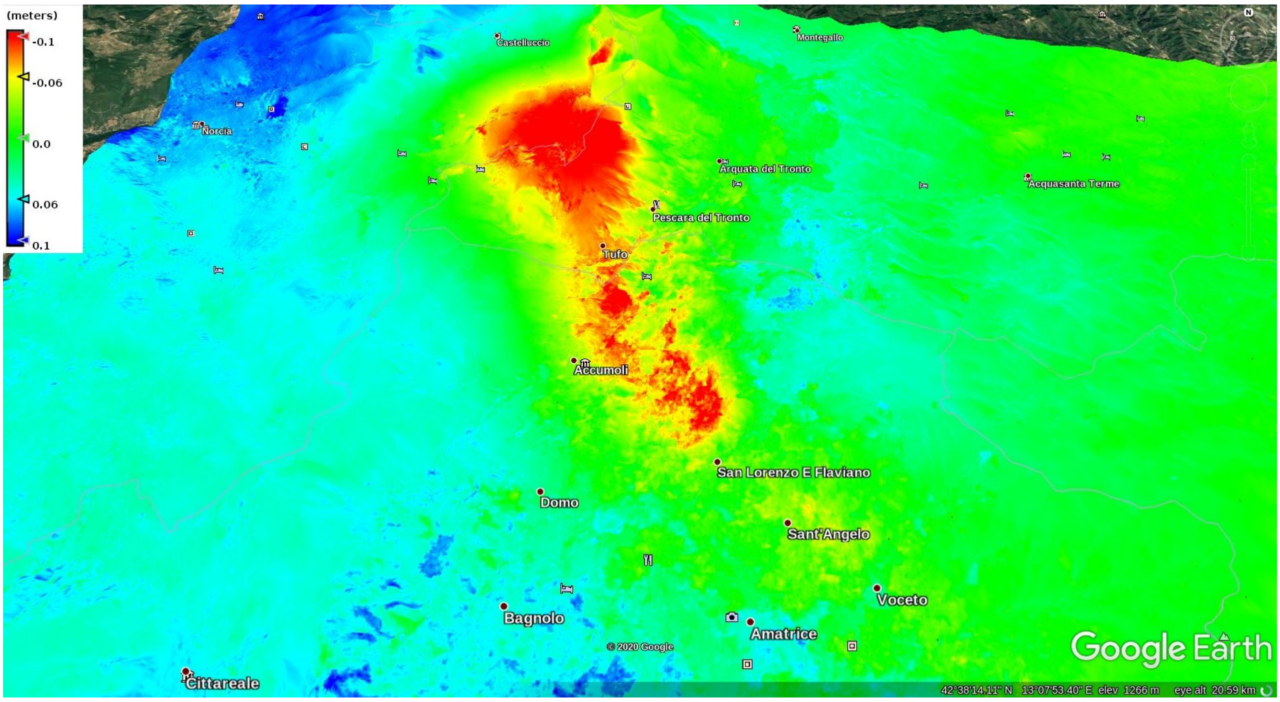


Figure 29: Google-Earth visualization

2 SHIP DETECTION BY SAR BACKSCATTERING. Messina strait in southern Italy on 28 January 2020

For this second section, Sentinel 1 SAR data will be used to perform ship detection in Messina strait. The data, that will be used for accomplish this task, have been also acquired in the interferomentry mode, as for the ones used for displacement detection, but they are an upper level product in the sense that they have been already ground range detected(GRDH). The data have been acquired January 28 of 2020:

- S1A_IW_GRDH_1SDV_20200128T050429_20200128T050454_030996_038F5D_4119.SAFE

2.1 Data band exploration and subsetting for ROI

By taking a look at the product bands, it is possible seeing that the product structure is different than the one present in the SLC product used before for displacement detection. In fact, the GRDH product contains only the amplitude and the calculated intensity (which is a virtual band). Moreover, SLC products are divided into subswaths and bursts whereas in GRDH products they are already merged.

As first step, it is necessary to subset the product in order to speed up the computation and focus more on the Messina strait. In order to do that it has been used the Spatial Subset tool view window. Figures 30 and 31 shows the subsetted area and the pixel coordinates used to subset the product.

Figure 30: Messina strait (intensity VV)

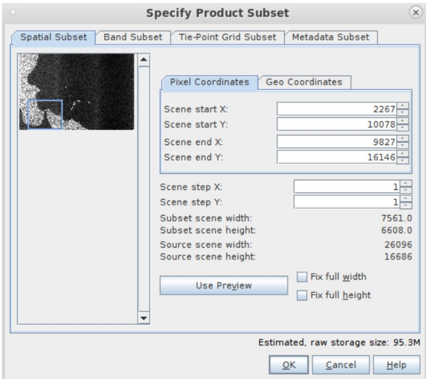


Figure 31: Spatial Subset from View tool

2.2 Orbit precising

Before running the Ocean Detection Object Algorithm, it is necessary to perform another pre-processing step, the Orbit precising. This is done due to the fact that the product metadata orbit state vectors of SAR products are not accurate, so it is essential to polish them with the precise orbit files that are available days after the generation of the products. The Apply Orbit Correction tool provides an accurate satellite position information. Thanks to this information, the orbit state vectors in the product metadata can be update.

2.3 Land-sea masking and calibration

Now that the orbit correction has been applied on the data, it is possible to start performing the Ocean Object Detection pipeline in order to seek out objects inside the the Messina strait.

The first brick of the workflow is the Land-Sea-Mask operator. Due to the fact the goal is to detect objects in the sea, it is necessary, using this operator, to masked out the land. It is also allowed to extend the shoreline (land contour) of a certain amount of pixels in order to avoid false alarm along the cost. For that reason a quite big shoreline (= 50 pixels) has been applied. Figure 32 shows the Land-Sea-Mask settings.

As second preprocessing step, it is required to do calibration of the product, in order to pass from the amplitude of the signal to a product which is related to the actual back-scatter coefficient of the target surface. For this particular problem, it has be chosen an output of $\sigma = 0$ band and the utilization of only VH polarization. Figure 33 shows the Calibration settings.

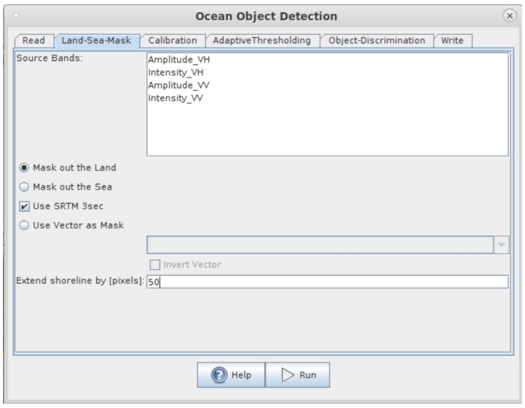


Figure 32: Land-Sea-Mask window

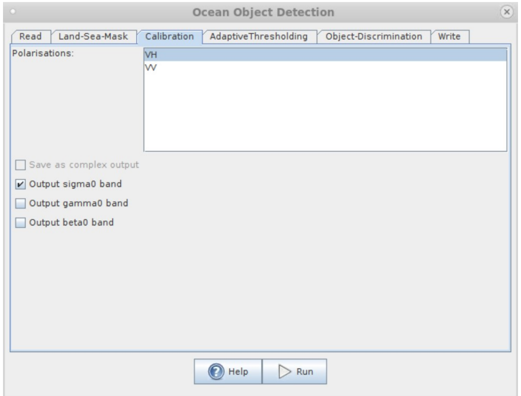


Figure 33: Calibration window settings

2.4 Adaptive thresholding by appropriate windowing and probability of false alarm (PFA)

The core of the pipeline is performed by an adaptive algorithm used to do object detection: the Adaptive Threshold Algorithm. Here, every pixel is surrounded by three windows:

- **target window:** window is set to be as the size of the smallest object to detect.
- **guard window:** windows size is about to the size of largest object.
- **background window:** windows size large enough to estimate accurately the local statistics.

The algorithm works by computing a difference deviation between the possible target and the background and, if the difference is significantely high, then the pixel/pixels inside the target window is a possible target object candidate . It starts by first computing the t (detector design parameter) from the user selected PFA (probability of false alarm) from the formula $PFA = \frac{1}{2} - \frac{1}{2}erf(\frac{t}{\sqrt{2}})$. Then computes the background mean and standard deviation (μ_b, σ_b) using the pixels in the background ring; and also the mean target window value μ_t. Then, if $\mu_t > \mu_b + \sigma_b t$ it means that the central pixel is a possible candidate for being the target object. This process is repeated by moving all windows by one pixel to detect the next pixel.

2.5 Object discrimination by min-max sizing and conversion to decibels (dB)

The last step of the object detection workflow is the Object Discrimination operation. As it has been highlighted in the previous step, the Adaptive Threshold Algorithm returns possible pixel objects candidates, so this process is used to discard false detection based on target measurements. Object Discrimination operator takes in input 2 values:

- **Minimum Target Size (m):** a target with a dimension smaller than this threshold is discarded.
- **Maximum Target Size (m):** a target with a dimension larger than this threshold is discarded.

The Object Discrimination Operator as first step clusters contiguous detected pixels into a single cluster. Cluster width and length information are extracted and, based on these extracted information, clusters that are bigger or smaller than the input user discrimination criteria (Minimum Target Size and Maximum Target Size) will be discarded.
Figures 34 and 35 show respectively the Adaptive Threshold and Object Discrimination windows settings:

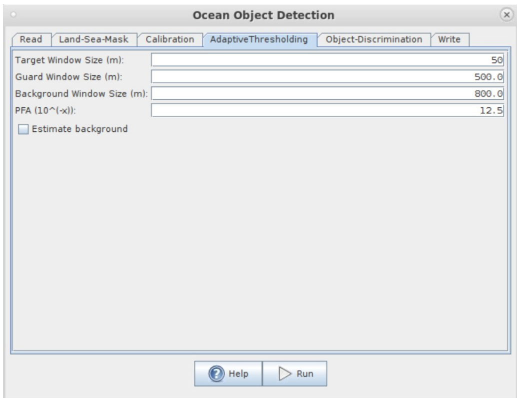


Figure 34: Adaptive Threshold window settings

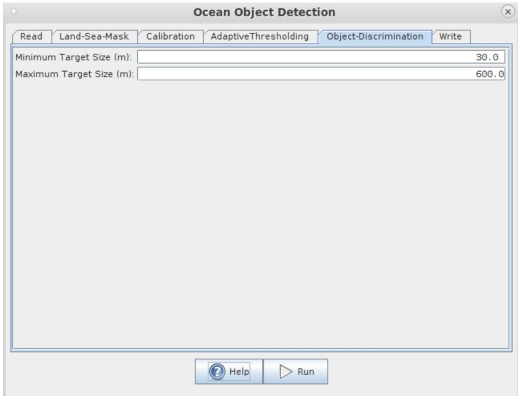


Figure 35: Object discrimination window settings

Lastly, it is necessary to perform some color manipulations in order to better highlight objects. But, in order to easily adjust the colors, the band is changed in decibels. The conversion is done by right clicking on the product band and choosing the Linear to/from DB operator. Once it is done, the histogram scale is changed in order to have as much black as possible the background. In fact, the white is set to 0, the grey is set to -5 and the black to -15. As it is possible seeing from Figures below, very bright pixels (white) represents objects that should mostly be ships.

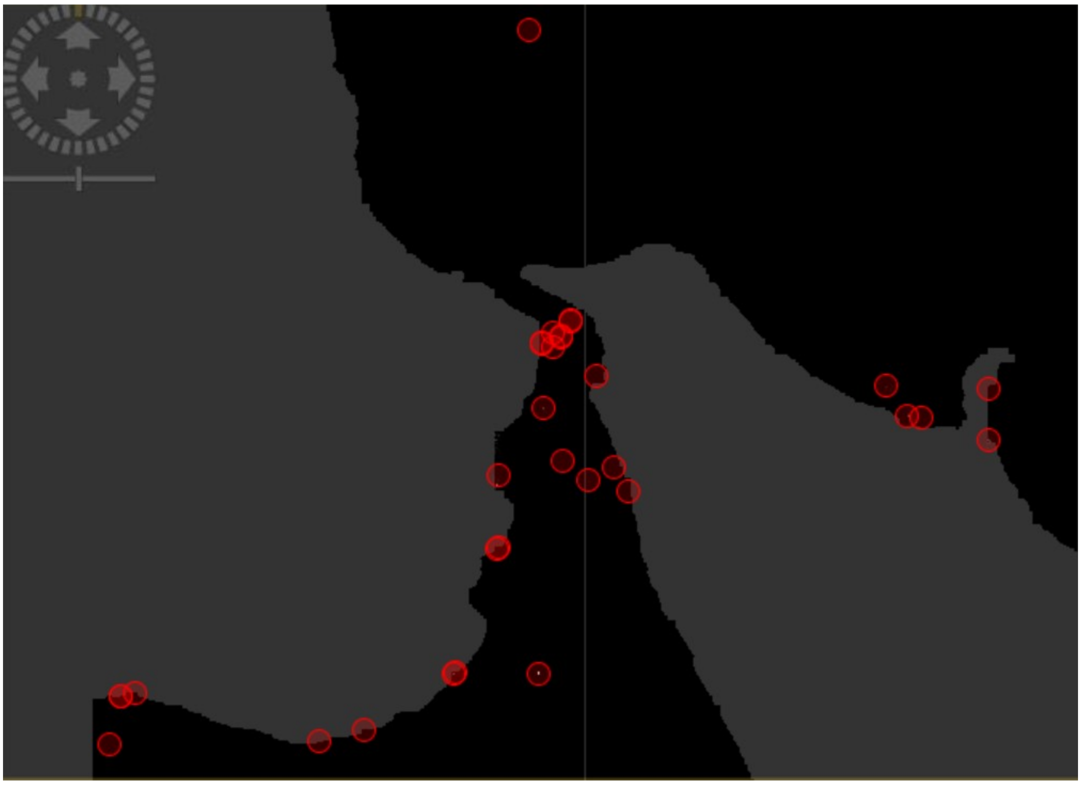


Figure 36: Red circles represent detected objects (mostly surfing ships)

Under Vector Data product section, it is possible to find the ShipDetection table containing more precised information about all the detected objects. These info can be used to better differentiate among all the objects and get their coordinates (lat-long). For example, Figure 37 below shows the 4^{th} target ship detected, whereas Figure 38 highlight more object information.

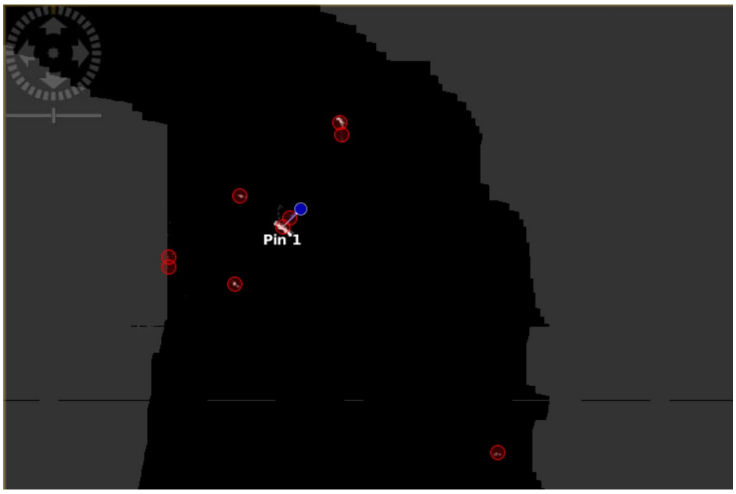


Figure 37: 4^{th} pinned ship

ShipDetections	geometry	Detected_x	Detected_y	Detected_lat	Detected_lon	Detected_width	Detected_length	style_css
target_000	POINT (3354 268)	3354	268	38.438	15.693	120	260	fill: #ff0000; ...
target_001	POINT (3666 2495)	3666	2495	38.243	15.608	160	200	fill: #ff0000; ...
target_002	POINT (3668 2511)	3668	2511	38.241	15.608	40	50	fill: #ff0000; ...
target_003	POINT (3535 2590)	3535	2590	38.232	15.621	90	100	fill: #ff0000; ...
target_004	POINT (3591 2631)	3591	2631	38.229	15.614	280	280	fill: #ff0000; ...
target_005	POINT (3601 2619)	3601	2619	38.231	15.613	90	40	fill: #ff0000; ...
target_006	POINT (3443 2670)	3443	2670	38.223	15.629	10	40	fill: #ff0000; ...
target_007	POINT (3443 2683)	3443	2683	38.222	15.629	10	70	fill: #ff0000; ...
target_008	POINT (3529 2705)	3529	2705	38.222	15.619	140	140	fill: #ff0000; ...
target_009	POINT (3871 2924)	3871	2924	38.208	15.576	130	80	fill: #ff0000; ...
target_010	POINT (3465 3166)	3465	3166	38.179	15.616	100	200	fill: #ff0000; ...
target_011	POINT (6091 3003)	6091	3003	38.236	15.325	250	230	fill: #ff0000; ...
target_012	POINT (6261 3228)	6261	3228	38.219	15.301	150	180	fill: #ff0000; ...
target_013	POINT (6364 3245)	6364	3245	38.219	15.289	110	250	fill: #ff0000; ...
target_014	POINT (6883 3018)	6883	3018	38.248	15.235	20	60	fill: #ff0000; ...
target_015	POINT (3113 3690)	3113	3690	38.126	15.645	90	130	fill: #ff0000; ...
target_016	POINT (3614 3577)	3614	3577	38.145	15.591	160	140	fill: #ff0000; ...
target_017	POINT (4005 3625)	4005	3625	38.147	15.546	30	40	fill: #ff0000; ...
target_018	POINT (3811 3726)	3811	3726	38.134	15.565	120	280	fill: #ff0000; ...
target_019	POINT (4110 3810)	4110	3810	38.132	15.53	90	80	fill: #ff0000; ...
target_020	POINT (6885 3417)	6885	3417	38.212	15.227	50	90	fill: #ff0000; ...
target_021	POINT (3121 4236)	3121	4236	38.077	15.632	70	20	fill: #ff0000; ...
target_022	POINT (3107 4250)	3107	4250	38.076	15.633	30	60	fill: #ff0000; ...
target_023	POINT (316 5358)	316	5358	37.93	15.922	30	10	fill: #ff0000; ...
target_024	POINT (207 5387)	207	5387	37.925	15.934	80	10	fill: #ff0000; ...
target_025	POINT (215 5387)	215	5387	37.925	15.933	30	10	fill: #ff0000; ...
target_026	POINT (2778 5195)	2778	5195	37.985	15.65	30	20	fill: #ff0000; ...
target_027	POINT (2766 5209)	2766	5209	37.984	15.651	80	100	fill: #ff0000; ...
target_028	POINT (3423 5208)	3423	5208	37.994	15.578	120	280	fill: #ff0000; ...
target_029	POINT (119 5756)	119	5756	37.89	15.936	60	50	fill: #ff0000; ...
target_030	POINT (1731 5734)	1731	5734	37.919	15.756	170	60	fill: #ff0000; ...
target_031	POINT (2076 5642)	2076	5642	37.933	15.72	160	90	fill: #ff0000; ...

Figure 38: detected object file

3 FLOOD DETECTION BY SAR BACKSCATTERING. Flood in Mozambico on 14 March 2019

Now. the Sentinel 1 SAR missions product will be used to perform Flood Detection. In particular, it will be studied a flood occured in Mozambico last March 14 of 2019. This studying requires the utilization of two acquisitions, one before the flood and another after. The In particular, the 2 used products are the one reported below:

- **Pre-event (Master):** S1A_IW_GRDH_1SDV_20190313T161522_20190313T161557_026321_02F156_A8A9.SAFE
- **Post-event (Slave):** S1B_IW_GRDH_1SDV_20190319T161451_20190319T161520_015425_01CE3C_A401.SAFE

In order to accomplish this task, it is necessary to work with the amplitude and intensity of the product, for that reason an upper level product, GRDH (ground range detected), has been used. The workflow is composed by different steps that will be analyzed, one by one, from point 3.1 to 3.5. The Figure below shows the entire pipeline.

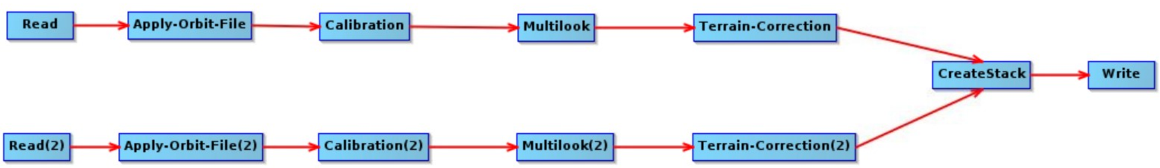


Figure 39: Flood Detection workflow

3.1 Data band exploration and subsetting for ROI

As first thing, it is necessary to take a look at the imported products. Figure 39 and 40 show respectively the Intensity VV polarization for pre and post flood event. As can be immediately noticed, the post event displays a dark region, not present in the pre event acquisition. Most likely this area represents the region hit by the flood. The presence of this darker stain is the consequence of a very low backscatter. This due to the fact that, the water facilitates the reflection of the signal that is transmitted by the instrument. For that reason, only a small part of the signal is backscatterd back to the SAR satellite sensor. so, as can be easily inhered, to the black areas in associated a very low backscatter coefficient.

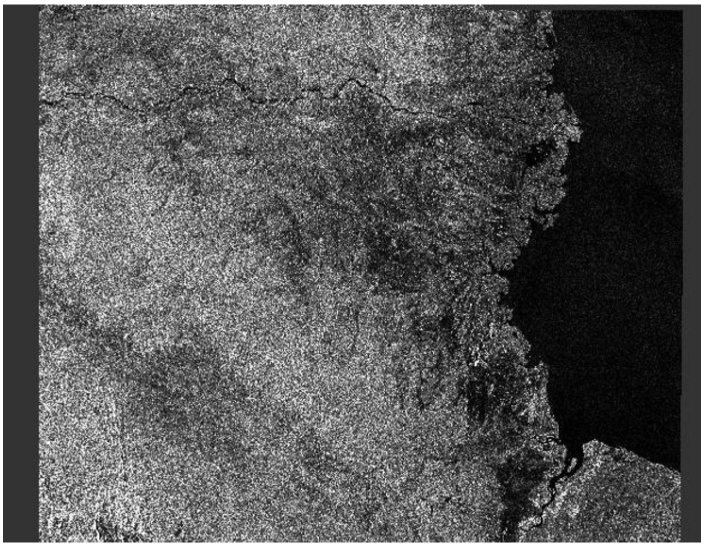


Figure 40: Pre-event acquisition

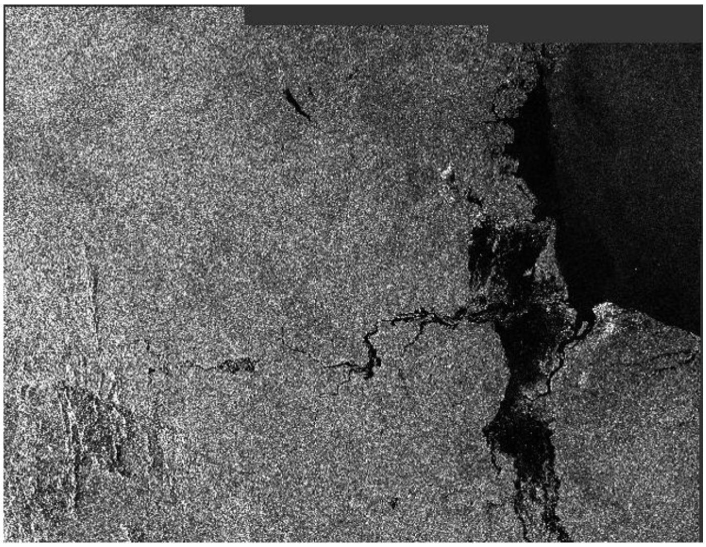


Figure 41: Post-event acquisition

Figure 41, 42 show the subsetted area of interest using

3.2 Orbit precising and projection

As it is possible to remember from the other task, SAR products metadata orbit state vectors are not accurate, so it is necessary also here polish them with the precise orbit files. The Apply Orbit Correction tool provides an accurate satellite position information. Thanks to this information, the orbit state vectors in the product metadata can be update.

3.3 Calibration and multilooking

As second preprocessing step, it is required to do calibration of the product, in order to pass from the amplitude of the signal to a product which is related to the actual backscatter coefficient of the target surface. For this particular problem, it has be chosen an output of $\sigma = 0$ band and the utilization of only VV polarization.

After that, it also necessary perform Multilooking operation, for the same reason described at point (1.7) and summurized as follow: because SAR images appears speckled with inherent speckle noise. So, in order to reduce this inherent speckled appearance, multilooking operation is performed, that consists on combining several images as if they correspond to different looks of the same scene. The multilooked image is produced by space-domain averaging of a single look image with a specific 2D kernels by convolution.
The Multilook parameters has been set as follow. The Mean GR Square pixel is computed based on the number of range looks, the number of azimuth looks and the source image pixel spacings; and it will return, in this case a ground range square pixels of about 90 meters.

- **n° of Range looks**= 9
- **n° of Azimuth Looks**= 9
- **Mean GR Square Pixel**= 90

3.4 Terrain correction

Due to the fact that the images are still on the radar geometry, it is also necessary to perform the terrain correction. Using the Terrain Correction operator is possible to perform the projection. The operator takes in input the original image and for the parameters all the default ones has been maintained and used.
The Figures below show the Multilook and Terrain correction operators and the set parameters.

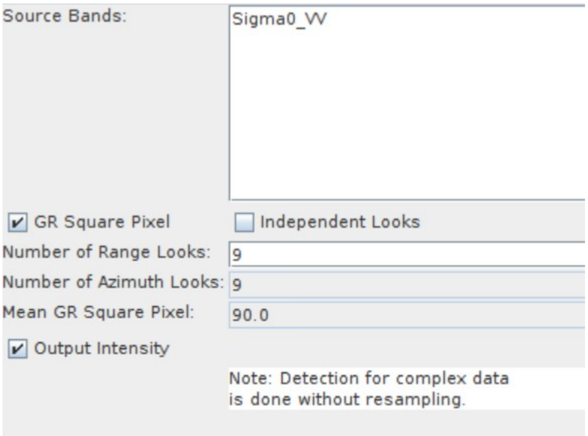


Figure 42: Multilook window

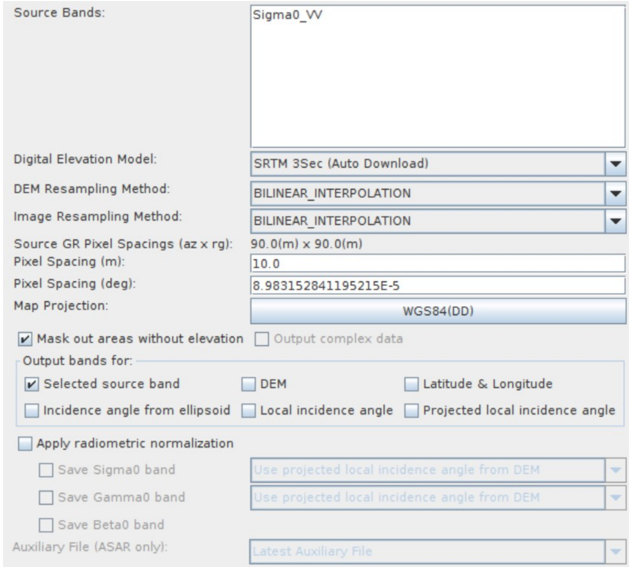


Figure 43: Terrain Correction window

3.5 Image stacking

The last pipeline brick is the the Stacking. It is used to stack the two preprocessed images into one single product. In this way, the band data of the slave product is resampled into the geographical raster of the master product.
Figures below shows the backscatter for both acquistions (masted and slave) already converted from linear scale to logarithmic scale.

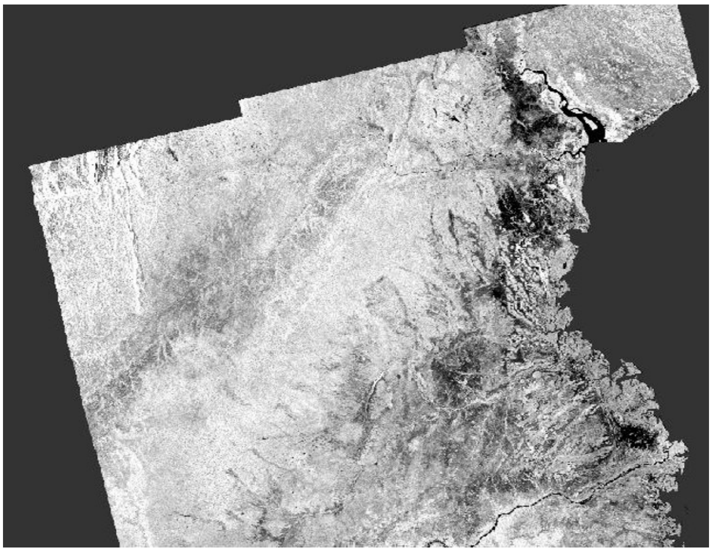


Figure 44: Master backscatter

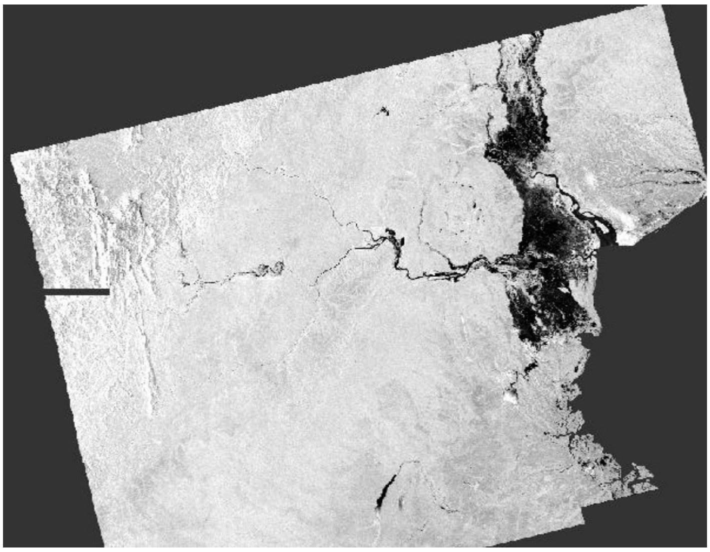


Figure 45: Slave backscatter

3.6 Thresholding, sigma-0-VV RGB combination and flood area detection

As mentioned before, in presence of flood the backscatter acquisition is highly low due to the presence of water that actually increases the reflection of the signal. Thanks to this phenomena, by computing the difference among the backscatter values of the two signals, it is possible to study the changing involved by the flood.
A qualitative approach used to highlight the difference among the signals is to create and RGB composite by combining the values of the master and slave bands.
The RED band contains the values of the Sigma0 Slave band only if the differences in absolute value with

the master are higher than 3dB, otherwise its value is an average between the two. The GREEN band contains the values of the Sigma0 Master band only if the differences in absolute value with the slave are higher than 3dB, otherwise its value is an average between the two.The BLUE band contains the values of the Sigma0 Master band only if the differences in absolute value with the slave are higher than 3dB, otherwise its value is an average between the two.
The 3dB threshold has been chosen in order to discard all the possible smallest differences between the two acquisitions and taking into account only the ones with higher entity.
What is expected in the final out is that: if there are red pixels it means that we are in the presence of a backscatter coefficient higher than 3dB for the slave acquisition respect to the backscatter of master acquistion so these pixels do not represent flooded areas. On the other hand, cian pixels shows the area affected by the flood because this color comes from the sum of the green and blue colors, which identify a very high backscatter coefficient for the master acquisition.
Below are reported the RGB combination expressions used to return the RGB image shown in Figure 46:

- **Red=** (Sigma0_master and Sigma0_slave) then if abs(Sigma0_slave - Sigma0_master) >3 then Sigma0_slave else avg(Sigma0_master, Sigma0_slave) : NaN
- **Green=**(Sigma0_master and Sigma0_slave) then if abs(Sigma0_slave - Sigma0_master) >3 then Sigma0_master else avg(Sigma0_master, Sigma0_slave) : NaN
- **Blue=** Sigma0_master and Sigma0_slave) then if abs(Sigma0_slave - Sigma0_master) >3 then Sigma0_master else avg(Sigma0_master, Sigma0_slave) : NaN

Once the RGB image has been chosen, it is necessary to perform color manipulation in order to set a common scale for all RGB bands.Having a uniform scale for all the channels, gives the certainty of highlighting really present differences.

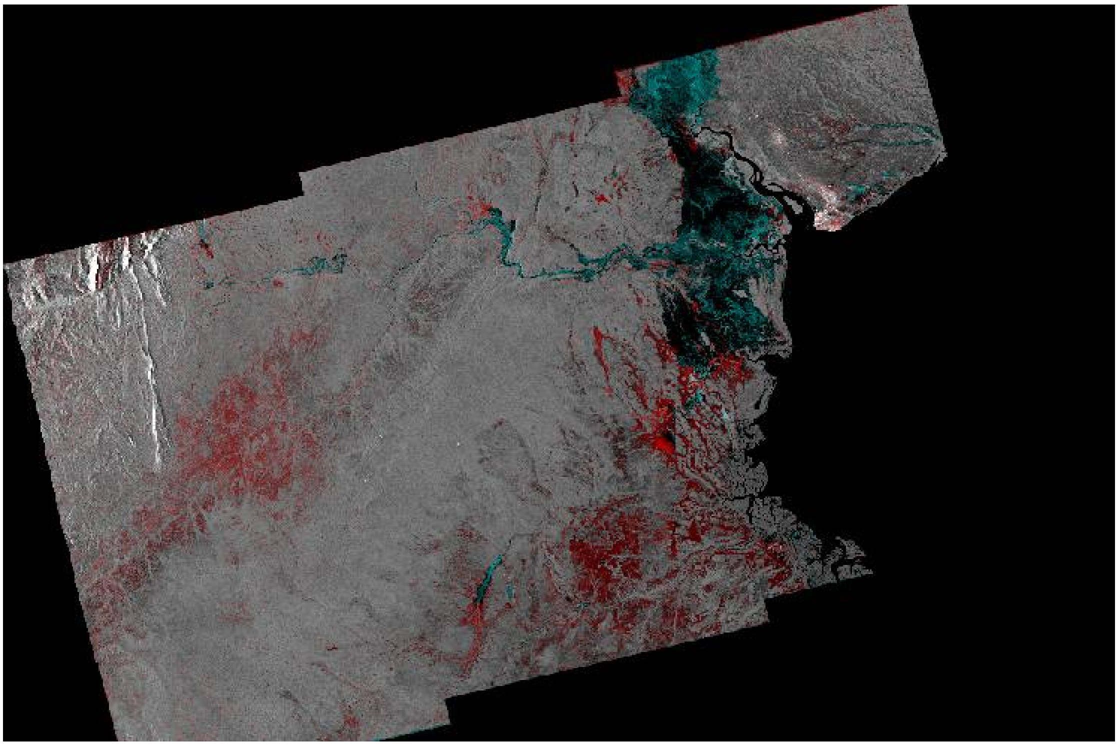


Figure 46: Flood detection image

As said before, red pixels show the condition on which the Slave backscatter acquisition is higher then the MAster backscatter acquisition, showing a phenomenon not related to the flood event. On the other hand, cian pixels show the condition on which the Slave backscatter acquisition is significantly smaller then the Master backscatter acquisition, explaining that there is now the presence of water on this area (i.e. display the areas hit by the flood). Instead, the ares gray, black and white are the parts of the image where the backscatter difference among the Master and Slave acquisition is equal to zero (meaning that the signal is not changed) or is smaller than the 3dB threshold. More precisely, black areas represent a back scatter acquisition for both products very low, meaning that in the considered area, there were already water; white areas instead, could represent urban areas where the back scatter for both acquisition is very high.