SARPolTool-SPT v2.1

User Manual

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1. Overview

SARPolTool–Version 2.1, designed and developed at SAR Data Processing Division, Microwave Data Processing Group, Data Processing Area of National Remote Sensing Centre, is a Multi-Mission SAR Toolbox for supporting SAR data based remote sensing applications. SARPOLTool v2.1 is a Windows Based Application designed as a plug-in for QGIS which would enhance the utilization of PolSAR data for various potential applications and carry out geospatial analysis. It provides adequate support for the end-user in order to carry out multi-sensor SAR data analysis using target scattering mechanisms, radar backscatter signatures , textural variation in data and so on which are the basis for Classification and Segmentation studies. The tool is also designed to carry out Mission Specific data format based SAR data functionalities like Polarimetric Processing, Model-Based Full and Hybrid Polarimetric Target Decompositions, Sigma Naught Backscatter Generation, Oil Slick parameters estimation, Radar Vegetation Index, Pedestal Height Estimation, Water Layer Generation and so on. The in-built EOS-4 Toolset offers support for EOS-04/RISAT 1A data products for visualization and make it analysis ready. Equipped with FCC generation, Sigma0 generation and ship detection, and can thus boost geospatial analysis along with EOS-4 data products.

2. Functionalities

The SAR missions currently supported are RISAT-1, EOS04, RADARSAT-2, L&S Airborne SAR, Sentinel-1A Chandrayaan-1-MiniSAR and Chandrayaan-2 DFSAR. The tool is designed to carry out the following functionalities:

- Full Quad Polarimetric Processing
- Hybrid Polarimetric Processing
- Intuitive Support for EOS-4 products
- Full-Quad and Hybrid Polarimetric Target Decompositions
- Chandrayaan 1 and 2 SAR data polarimeric Processing
- Sigma Naught Backscatter (σ0) Product Generation
- Texture-Based Analysis
- The Radar Vegetation Index (RVI) and Pedestal Height Estimation
- Grey-Level Co-occurence Matrices(GLCM) can be generated for neighbouring distances and in the specific directions
- Processing of oil slick data .In order to distinguish between oil-spill and look -alike signatures using CTLR hybrid & full pol SAR
- False Colour Composite (FCC) Generation
- Mosaicking of Beamwise SLC products for EOS04
- Customized filters for enhancing the Image Quality
- CFAR based integrated Ship Extraction on EOS-4 Products with Ship positions saved as shape file.

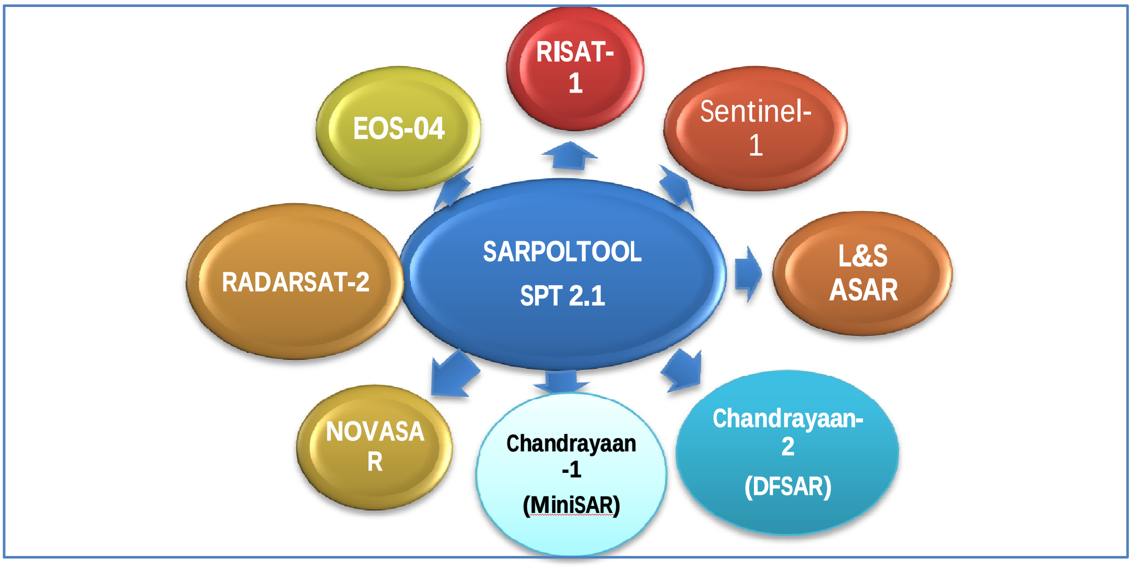


Figure 1: SAR Data Supported by SARPOLTool v2.1

The detailed processing based on the various functionalities performed for Full and Hybrid Pol Data is given as follows:

- Derivation of Polarimetric Coherency and Covariance matrices from the target Scattering Matrix (SM) for Fine Quad SLC dataset.
- Implementation of polarimetric speckle filtering- Boxcar and Refined -Lee.
- Implementation of coherent and incoherent polarimetric decomposition techniques like Pauli Decomposition , Krogagaer Decomposition , Three-Component Freeman-Durden , Four Component Yamaguchi Decomposition , General Four Component Decomposition ,Model Based Seven Component Decomposition Method
- Implementation of Correction Algorithm to minimize the negative power components if any.
- Extraction of Stokes child parameters.
- Implementation of hybrid pol decomposition techniques based on Raney Modelling- m-delta, m-chi and m-alpha decompositions.
- Chandrayaan-1 Mini-SAR L1-CDR data processing.
- Chandrayaan-2 DFSAR Polarimetric Processing.
- Implementation of GLCM based texture –features extraction.
- Implementation of Eigen-Value based methods for generating Radar Vegetation Index and Pedestal Height Products.
- The tool also helps in the generation of Sigma Naught Backscatter Images of EOS-04,RISAT-1 ,Sentinel-1, Radarsat-2 ,L&S Airborne SAR.

The software can read the Single Look Complex data in CEOS and GeoTIFF formats according to the corresponding SAR data structure for the corresponding mission. It can also handle Chandrayaan-1 Planetary

Data System format (PDS) data processing and has been extended for the Chandrayaan-2 Dual Frequency SAR–PDS4 polarimetric data processing as well.

For supporting application potential and analysis, the tool is also designed to generate Textural Features using Grey Level Co-occurrence matrix (GLCM) , Radar Vegetation Index –RVI , Pedestal Height using Eigen Value Modeling for selected SAR datasets. Modules are also available for Oil Slick and Look-alike signatures extraction over the water bodies using polarization data.

The output files are generated in the Tiff format with geo-referencing, as applicable.

3. Installation Guidelines

3.1. SARPolTool v2.1 is made available on the Bhoonidhi *"Resources"* panel as a zip directory.

3.2. SARPolTool v2.1 is designed as Software plug-in in the QGIS Environment (Tested for Version 3.14 onwards). The QGIS installer is provided along with the application.

3.3. The User may first install the QGIS download the SARPOLTool v2.1 from Bhoonidhi and install the Plug-in from zip as shown in Figure 1.

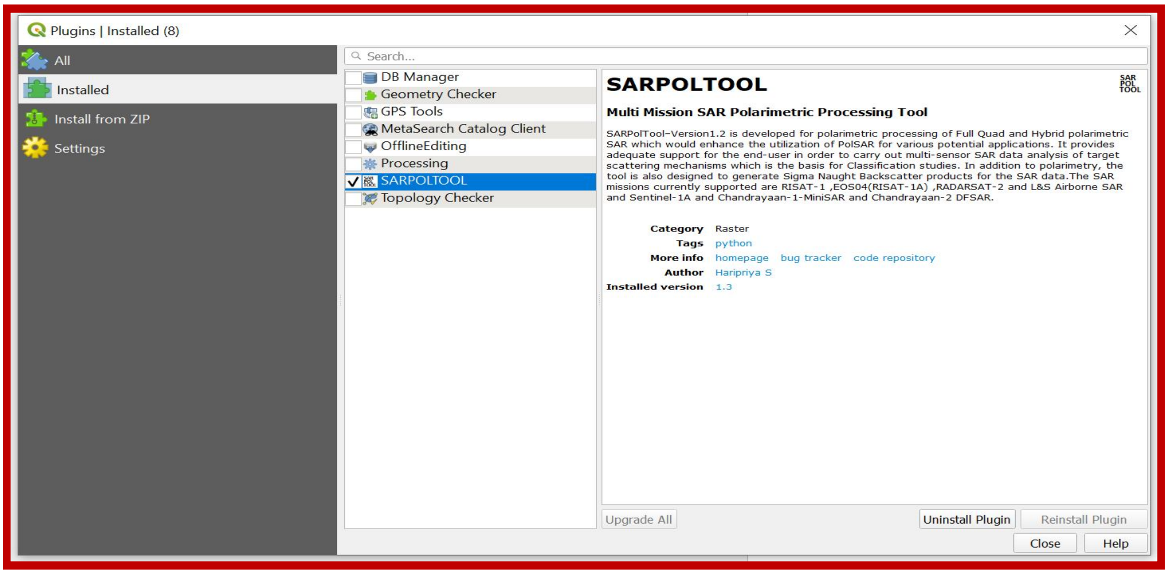


Figure 2 : SARPOLTOOL installed in QGIS plug-in Successfully

3.4. After Successful Installation, the SARPOLTOOL Icon shall be seen in the Functionalities Panel of QGIS as in Figure 2.

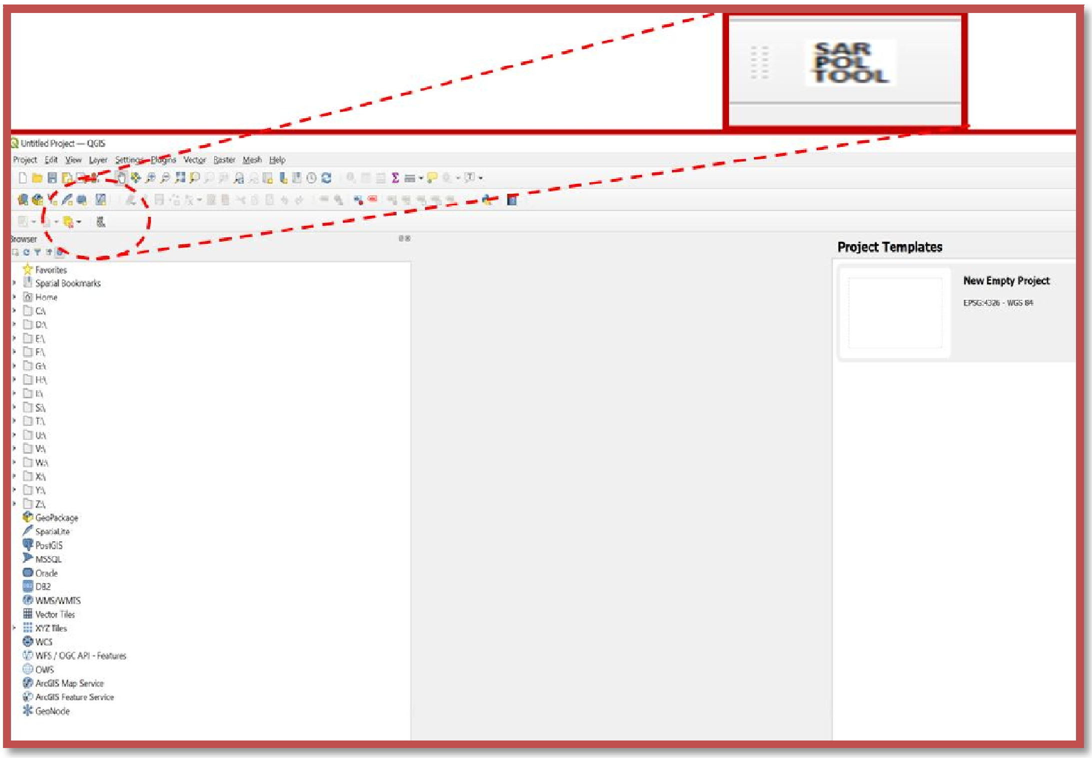


Figure 3: SARPOLTool Icon Tagged In Quick Tool Bar In The Ribbon View

3.5. The User may click on the SARPOLTool Icon which would open up the SARPOLTool Functionalities and EOS 4 Toolset Functionalities as shown in Figure 3.

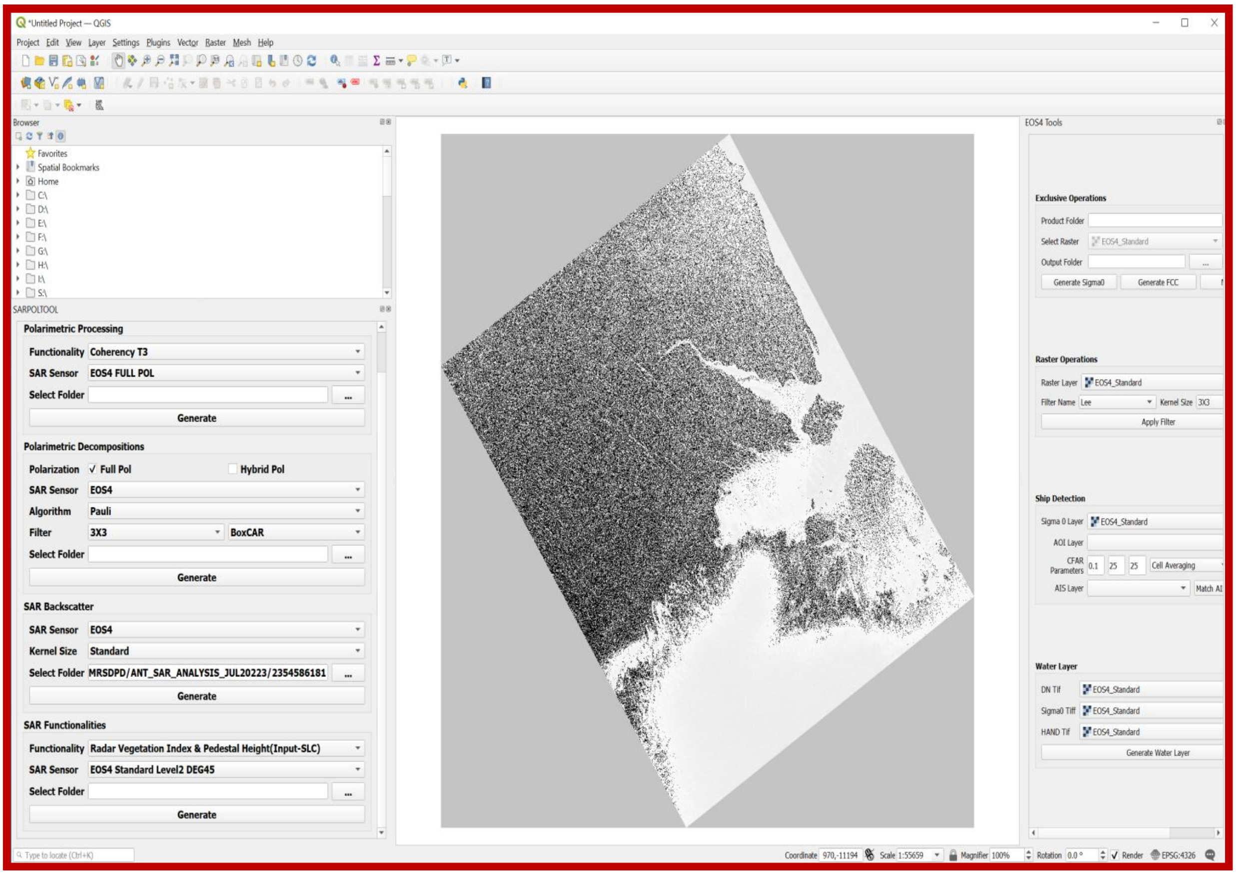


Figure 4 : SARPOLTOOL working in QGIS successfully

3.6. The User may then select the appropriate SAR functionality and choose the input data folder appropriately.

<u>4. Tool Functionalities</u>

4. a. Sigma Naught Module

This module generates the sigma naught backscatter values in the ground plane for each pixel based on the incidence angles and calibration co-efficient for various receive polarizations, while taking into consideration, the masking of pixels if applicable. Selective filtering is applied as per the user requirement. The output data is scaled in logarithmic domain for the sake of universal understanding.

For a given SAR and depending on the Noise Equivalent Sigma Naught value, the valid range is between -40dB to and +30dB.

For the invalid or masked pixels, the tool assigns a nominal value of -60dB in order to maintain the image contrast. These low values may be ignored by the user while doing the statistical analysis.

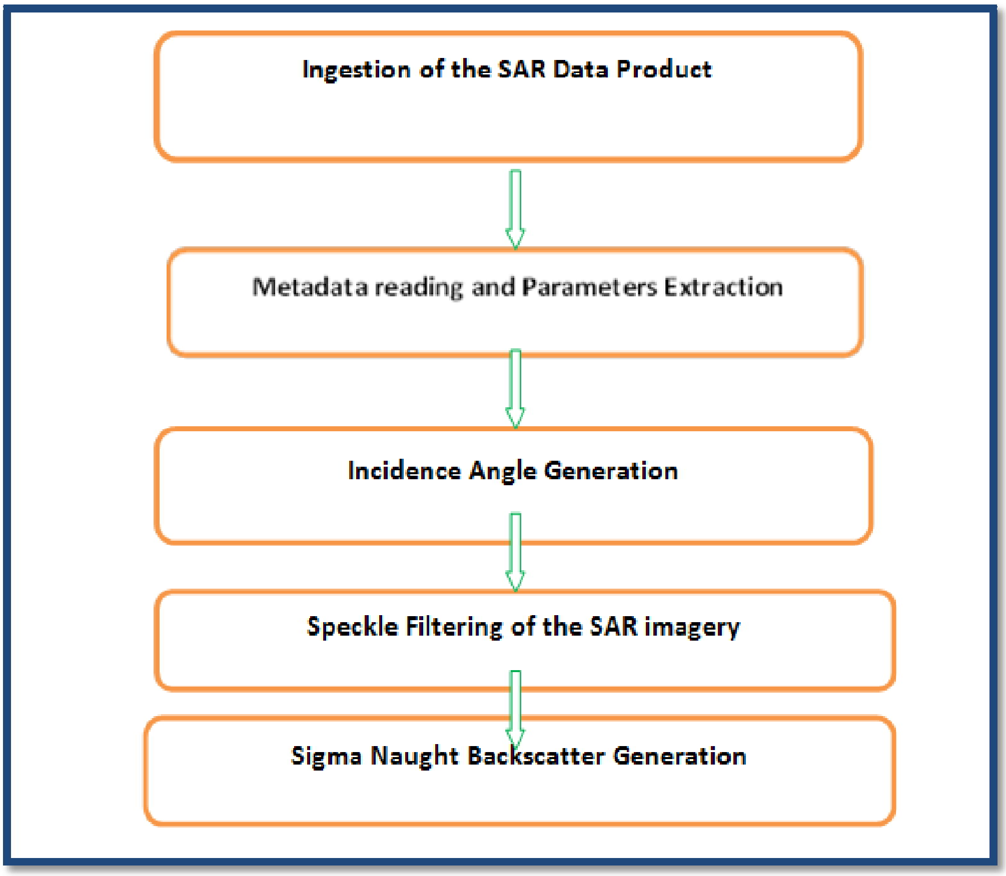


Figure 5: Process Flow for Sigma Naught Backscatter Layer Generation

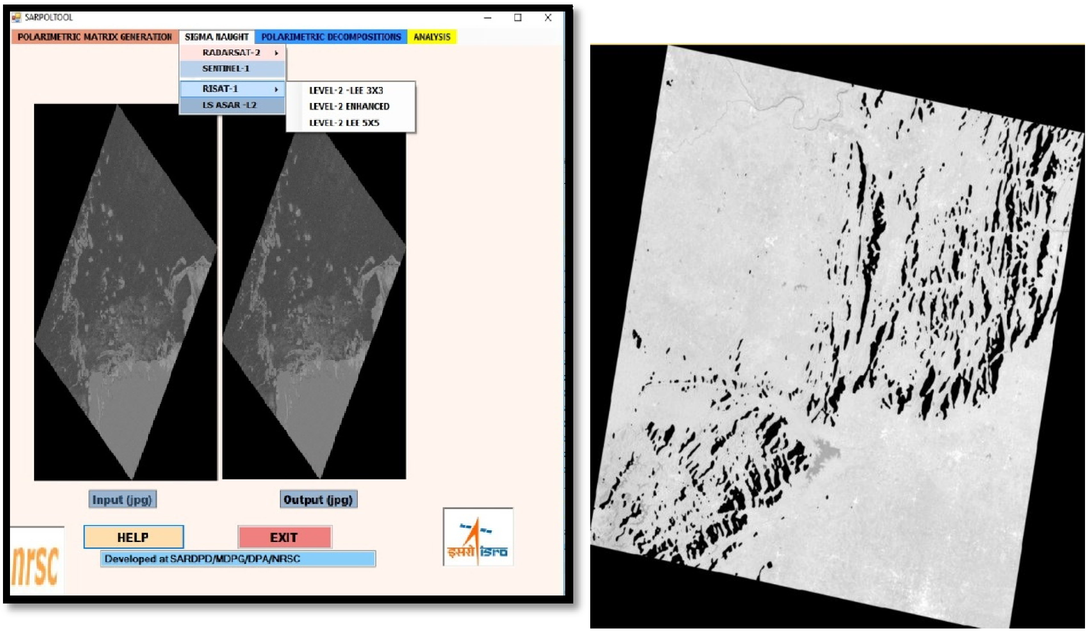


Figure 6: RISAT-1 Sigma Naught generation Left :-Level-2 LEE 3X3 Mode:FRS-1Right: L2 Enhanced along with Masked Pixels (Mode:MRS)

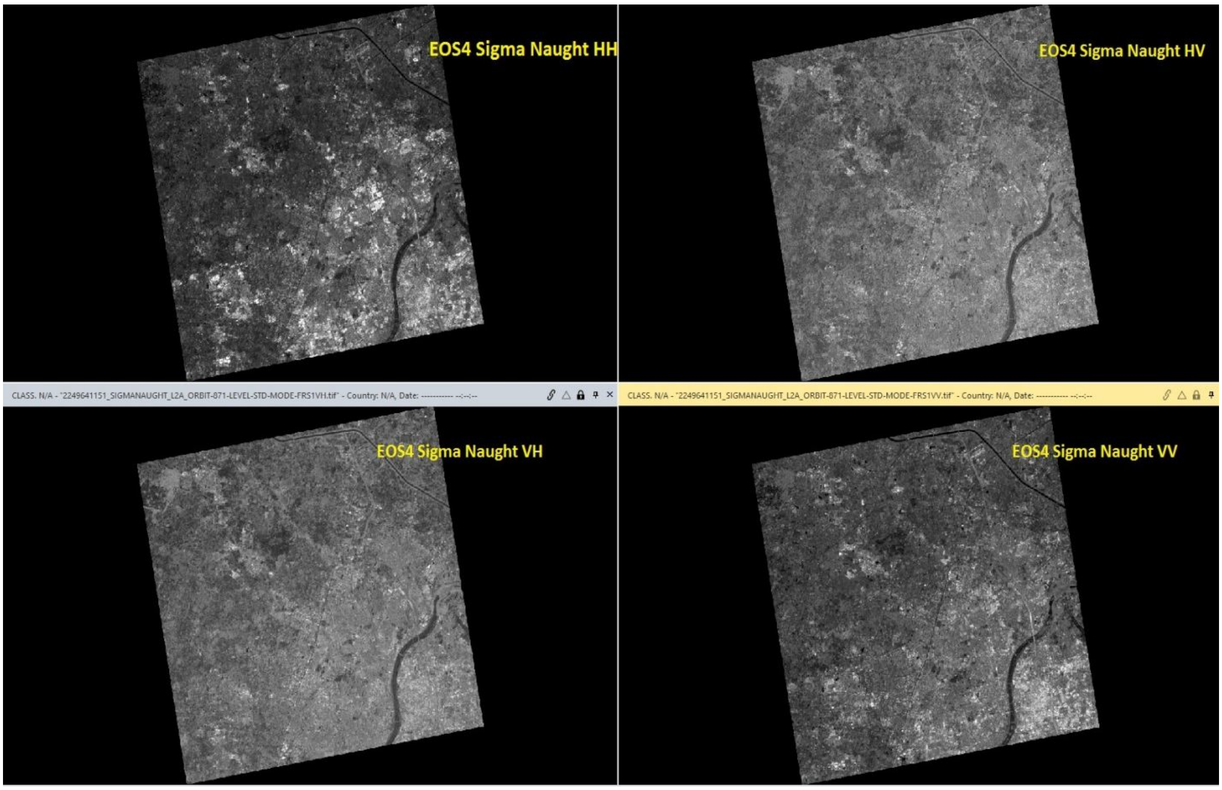
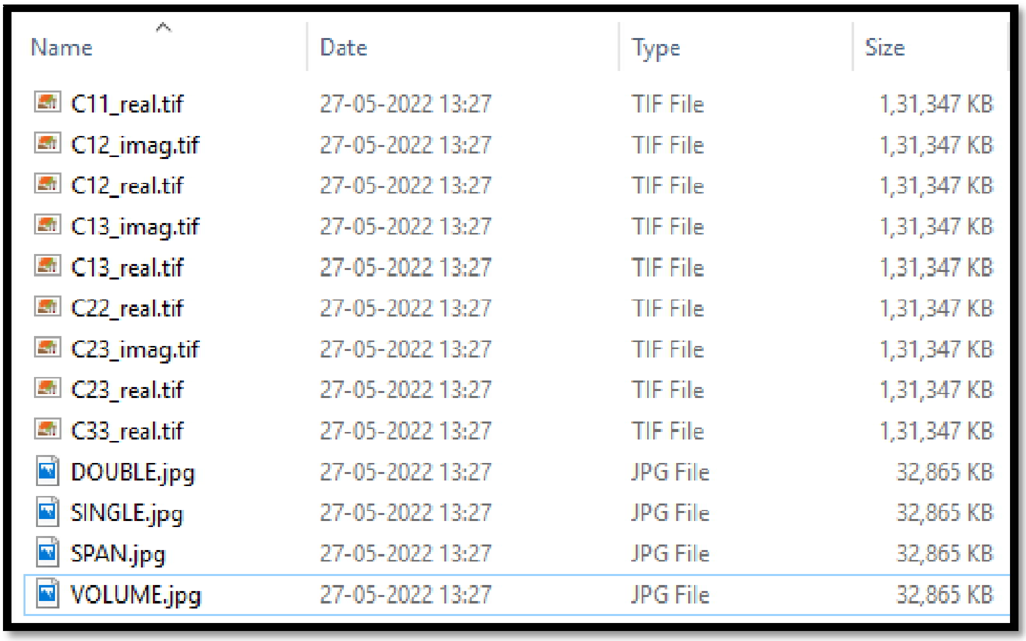


Figure 7: EOS-04 Sigma Naught Mode: FRS-1 Quad pol Level-2 Enhanced

4. b.Polarimetric Processing

In order to carry put polarimetric target classification and decompositions, the Tool is designed to generate the coherency T3 and Covariance C3 matrix elements for Full Quad polarimetric data and the Stokes Vector layers for the Hybrid polarimetric data. The main diagonal elements comprise the tiff layers of real components and the off-diagonal elements comprise .tiff layers of real and imaginary components .A few jpegs are generated to support the static viewer embedded in the tool. The output data type is float.



Name	Date	Type	Size
C11_real.tif	27-05-2022 13:27	TIF File	1,31,347 KB
C12_imag.tif	27-05-2022 13:27	TIF File	1,31,347 KB
C12_real.tif	27-05-2022 13:27	TIF File	1,31,347 KB
C13_imag.tif	27-05-2022 13:27	TIF File	1,31,347 KB
C13_real.tif	27-05-2022 13:27	TIF File	1,31,347 KB
C22_real.tif	27-05-2022 13:27	TIF File	1,31,347 KB
C23_imag.tif	27-05-2022 13:27	TIF File	1,31,347 KB
C23_real.tif	27-05-2022 13:27	TIF File	1,31,347 KB
C33_real.tif	27-05-2022 13:27	TIF File	1,31,347 KB
DOUBLE.jpg	27-05-2022 13:27	JPG File	32,865 KB
SINGLE.jpg	27-05-2022 13:27	JPG File	32,865 KB
SPAN.jpg	27-05-2022 13:27	JPG File	32,865 KB
VOLUME.jpg	27-05-2022 13:27	JPG File	32,865 KB

Figure 8:Coherence Matrix Generation Input Full Pol SLC

4. c Polarimetric Decompositions

Polarimetric Target Decomposition layers can be generated for carrying out further analysis at the user end. The single, volume , helical and surface bounce layers are generated with respect to the scattering model as chosen by the user. The three-layered RGB tiff is also generated by stacking the appropriate layers. The user can apply the relevant models on these images for further analysis.

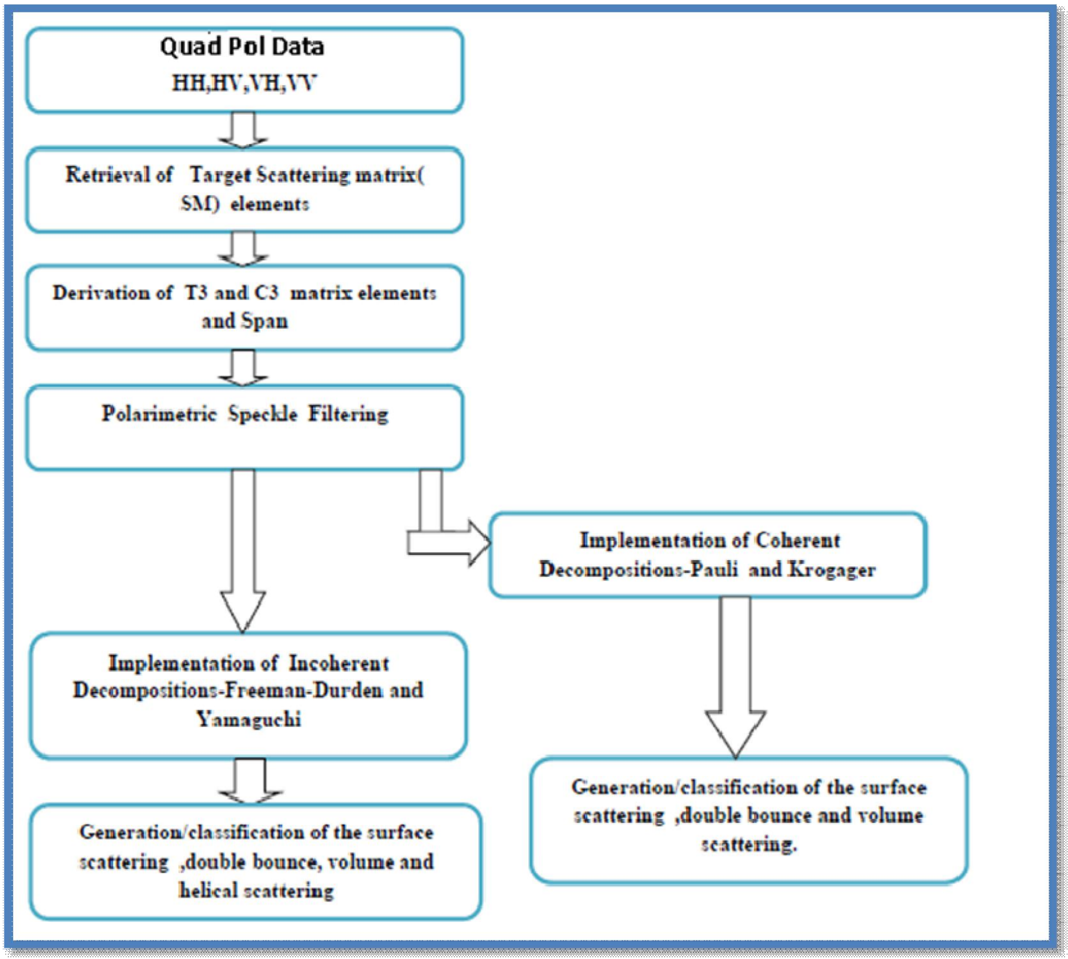


Figure 9: Process Flow for Full Polarimetric Data Polarimetric Processing and Decomposition

Currently, in the present version, for full polarimetric data , Model Based coherent decomposition models like Pauli, Krogagaer and Incoherent decomposition models like Freeman Durden, Yamaguchi , General Four Component (GFU) and Seven Component Decomposition - 7SD are supported.

For Hybrid Polarimetric Data, the primary polarimetric parameters like Degree of Polarization(m), the relative phase (delta), the ellipticity (chi), the circular polarimetric ratio(CPR) are generated as tiff layers . Using Raney's modeling algorithm, m-chi and m-delta RGB layers are also generated in .tif format.

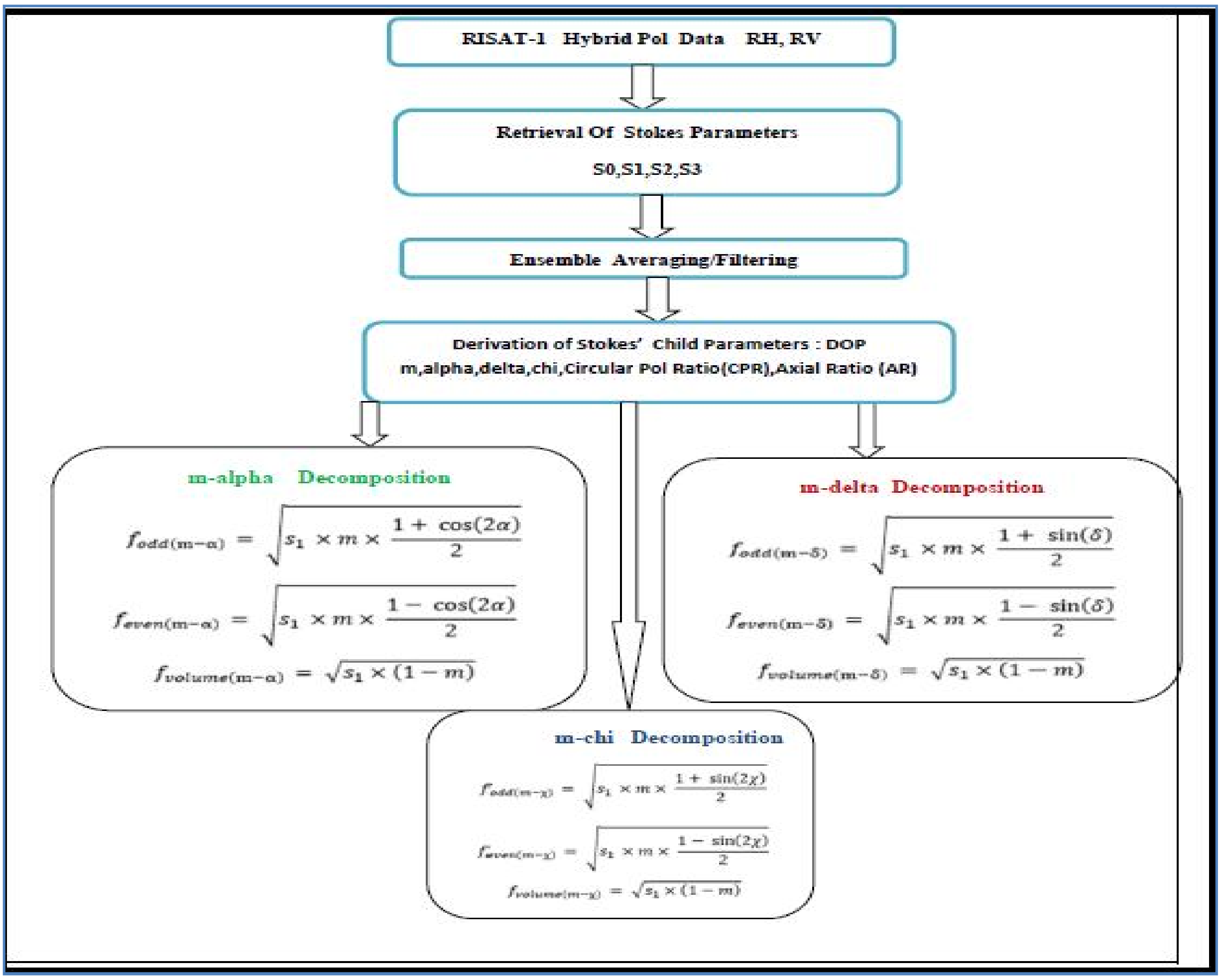


Figure 10: Process Flow for Hybrid Polarimetric Data Polarimetric Processing and Decomposition

A few jpegs are generated to support the static viewer embedded in the tool. The output data type is float.

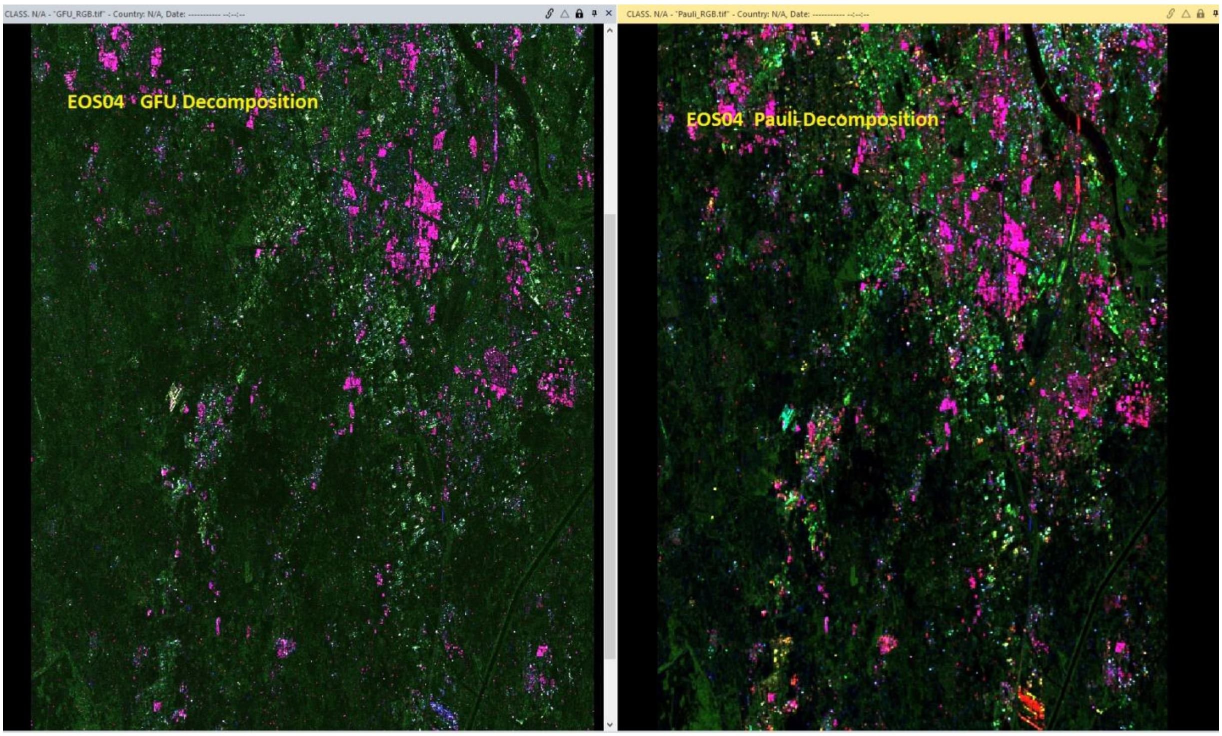


Figure 11:EOS04 Polarimetric Decompositions Mode:FRS-1 Full Quad Pol Left :GFU Decomposition Right :Pauli Decomposition

4. d Oil Slick Parameters

Using polarimetric data, Oil slick parameters can be estimated using the target model based on the Bragg and non-Bragg type of scattering .This helps in differentiating between oil slick and look-alike signatures. The tool generates the Oil slick related tiff files using Full Quad Pol and Hybrid Pol parameters.

Name	Date	Type	Size
Conformity.tif	26-08-2022 12:49	TIF File	3,63,524 KB
CorrCoefficient.tif	26-08-2022 12:49	TIF File	3,63,524 KB
CPRATIO.tif	26-08-2022 12:49	TIF File	3,63,524 KB
DegOfPol.tif	26-08-2022 12:49	TIF File	3,63,524 KB
Delta.tif	26-08-2022 12:49	TIF File	3,63,524 KB
Ellipticity.tif	26-08-2022 12:49	TIF File	3,63,524 KB
Entropy.tif	26-08-2022 12:49	TIF File	3,63,524 KB
RGB.jpg	26-08-2022 12:49	JPG File	90,963 KB
SPAN.jpg	26-08-2022 12:49	JPG File	90,963 KB

Figure 12: Oil slick parameters using Hybrid Pol Parameters

Name	Date	Type	Size	Tags
CHANNEL1.jpg	26-07-2022 16:16	JPG File	32,865 KB	
CHANNEL2.jpg	26-07-2022 16:16	JPG File	32,865 KB	
CHANNEL3.jpg	26-07-2022 16:16	JPG File	32,865 KB	
CONFORMITY.tif	26-07-2022 16:16	TIF File	1,31,330 KB	
CPD.tif	26-07-2022 16:16	TIF File	1,31,330 KB	
ENTROPY.tif	26-07-2022 16:16	TIF File	1,31,330 KB	
RGB.jpg	26-07-2022 16:16	JPG File	98,508 KB	
SPAN.tif	26-07-2022 16:16	TIF File	1,31,330 KB	

Figure 13: Oil Slick Parameters using Full Pol parameters

4.e. Radar Vegetation Index and Pedestal Height Parameters

RVI parameter was introduced by Van Zyl. The average radar return of a distributed target is, in general, partially polarized. The natural target randomness can be measured by the range of the eigen values of the associated averaged coherency T3 or covariance C3 matrix. Another way of measuring randomness in the scattering process is to measure the pedestal height (PH) in polarization signatures.

SARPolTool can generate the RVI and Pedestal Height parameters using the Eigen Value Based scattering models for full polarimetric data.

CHANNEL1.jpg	14-07-2022 14:32	JPG File	16,209 KB
CHANNEL2.jpg	14-07-2022 14:32	JPG File	16,209 KB
PedestalHeight.tif	14-07-2022 14:32	TIF File	64,797 KB
RadarVegetationIndex.tif	14-07-2022 14:32	TIF File	64,797 KB

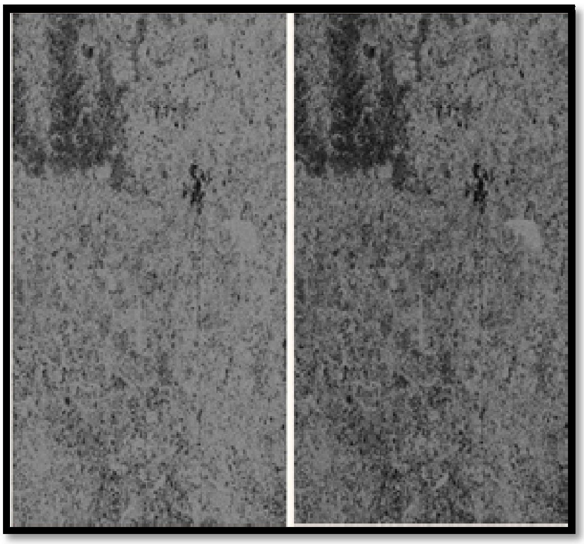
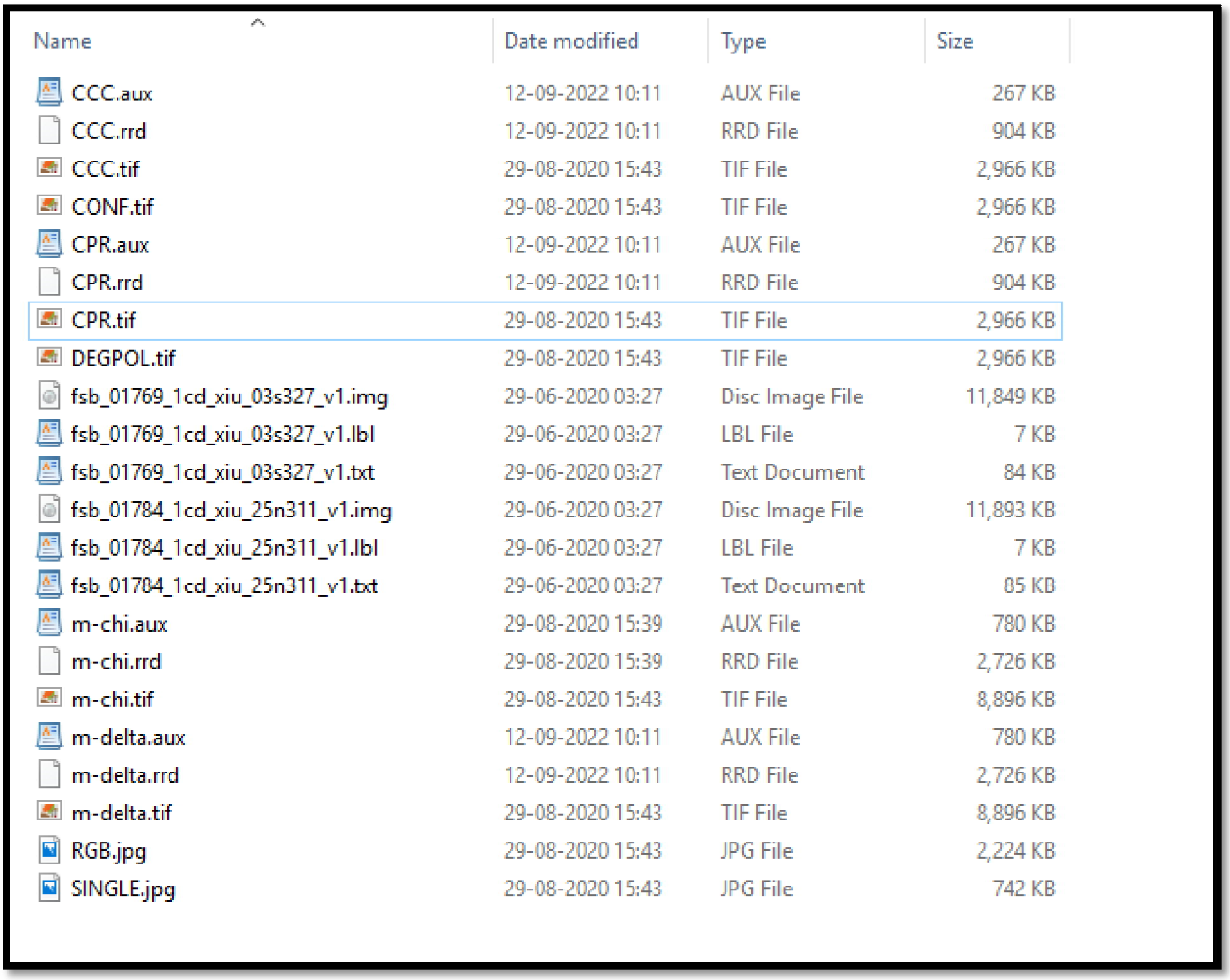


Figure 14: Radarsat-2 Mode :Full Fine Quad
Radar Vegetation Index and Pedestal Height Imagery

4. f. Chandrayaan Data Processing

The Chandrayaan data is in the PDS (Planetary Data Systems 3 &4) format and the level-1 data structure comprises label files and imagery files corresponding to different sensed areas under one primary folder.SARPolTool is designed to process the Level-1 PDS data format for carrying out the Full and Hybrid polarimetric processing of Chandrayaan SAR data and generate the various tiff layers for further processing. The Correlation, Circular Pol Ratio, Conformity tiff layers along with m-delta and m-chi values are generated.



Name	Date modified	Type	Size
CCC.aux	12-09-2022 10:11	AUX File	267 KB
CCC.rrd	12-09-2022 10:11	RRD File	904 KB
CCC.tif	29-08-2020 15:43	TIF File	2,966 KB
CONF.tif	29-08-2020 15:43	TIF File	2,966 KB
CPR.aux	12-09-2022 10:11	AUX File	267 KB
CPR.rrd	12-09-2022 10:11	RRD File	904 KB
CPR.tif	29-08-2020 15:43	TIF File	2,966 KB
DEGPOL.tif	29-08-2020 15:43	TIF File	2,966 KB
fsb_01769_1cd_xiu_03s327_v1.img	29-06-2020 03:27	Disc Image File	11,849 KB
fsb_01769_1cd_xiu_03s327_v1.lbl	29-06-2020 03:27	LBL File	7 KB
fsb_01769_1cd_xiu_03s327_v1.txt	29-06-2020 03:27	Text Document	84 KB
fsb_01784_1cd_xiu_25n311_v1.img	29-06-2020 03:27	Disc Image File	11,893 KB
fsb_01784_1cd_xiu_25n311_v1.lbl	29-06-2020 03:27	LBL File	7 KB
fsb_01784_1cd_xiu_25n311_v1.txt	29-06-2020 03:27	Text Document	85 KB
m-chi.aux	29-08-2020 15:39	AUX File	780 KB
m-chi.rrd	29-08-2020 15:39	RRD File	2,726 KB
m-chi.tif	29-08-2020 15:43	TIF File	8,896 KB
m-delta.aux	12-09-2022 10:11	AUX File	780 KB
m-delta.rrd	12-09-2022 10:11	RRD File	2,726 KB
m-delta.tif	29-08-2020 15:43	TIF File	8,896 KB
RGB.jpg	29-08-2020 15:43	JPG File	2,224 KB
SINGLE.jpg	29-08-2020 15:43	JPG File	742 KB

Figure 15: Chandrayaan Level-1 Data Input folder structure and the polarimetric parameters generated

4. g. Textural Features

Using the Intensity based imagery, Gray Level Co-occurrence matrices help in extracting the underlying textural features .SARPolTool is designed to generate the Harelick textural Features which are deterministic of the homogeneity, entropy, energy and correlation between the neighboring pixels at different directions like 0 deg, 45 deg, 90 deg and 135 deg . The Primary GLCM based texture –features extraction is carried out and the output files are written in Tiff format for further analysis.

Autocorrelation.tif	19-07-2022 17:00	TIF File	3,70,310 KB
Channel1.jpg	19-07-2022 17:00	JPG File	92,635 KB
Channel2.jpg	19-07-2022 17:00	JPG File	92,635 KB
Contrast.tif	19-07-2022 17:00	TIF File	3,70,310 KB
Correlation.tif	19-07-2022 17:00	TIF File	3,70,310 KB
Energy.tif	19-07-2022 17:00	TIF File	3,70,310 KB
Entropy.tif	19-07-2022 17:00	TIF File	3,70,310 KB
Homogeneity.tif	19-07-2022 17:00	TIF File	3,70,310 KB

Figure 16: GLCM Features Generated using NovaSAR GRD data for d=1 deg=0

4.h Ship Extraction Module

Constant false alarm rate (CFAR) is a common algorithm used in radar systems to detect target returns against a background of noise, clutter, and interference. In ship detection, CFAR can be used to identify ships in synthetic aperture radar (SAR) images. The CFAR algorithm works by first calculating the average backscatter power of a region of pixels in the SAR image. This region is called the clutter cell. The threshold for detecting a ship is then set to a multiple of the average backscatter power of the clutter cell. If the backscatter power of a pixel is greater than the threshold, then it is considered to be a possible ship target.To improve the performance of CFAR, it is often used in conjunction with other algorithms, such as adaptive thresholding and morphological filtering.

- The CFAR algorithm can be used to detect ships of different sizes by adjusting the threshold value.
- CFAR can also be used to detect ships in different sea conditions by adjusting the clutter cell size.

- CFAR is a relatively simple algorithm to implement, but it can be computationally expensive for large SAR images.

CFAR is implemented in the python backend of QGIS, having customizable interface for Guard Window, Threshold and choice of mode. Three modes are available for the user to choose from Cell Averaging, Ordered Statistics & Line Ordered Statistics. The output is generated in form of a shape file containing collection of points which are detected as ships in CFAR. The shape file is created in the Output Folder on the right hand panel of SARPOLTOOL.

The following are the required inputs to be configured before running the algorithm.

- Load the EOS-4 scene which is to be analyzed as shown in the image on the right. The scene is denoted as “imagery_HH” in the Layers tab on the left side of the screen.
- Select the Product Folder or Check the Auto Detect box and select the raster layer.
- Select the Output Folder or Check the Save in I/P to save the produced files in the Selected folder or Input Directory respectively.
- Click on Generate Sigma0 to generate the Sigma0 from the BandMeta and product metadata for further Analysis.
- Select the generated Sigma0 layer which is generated in the previous step as “Sigma0_HH” as shown in the layer menu, of Raster Operations.
- Select a filter to be used, for this example we have used the Median Filter, and after selecting kernel the “Apply Filter” button is clicked.
- The output is generated after completion of processing and a smoothened image layer is added to QGIS in form of “Median_5x5”.
- The Ship Detection operation can be either performed on the entire image or a region which is in ocean. A new shapefile layer is created using the

"Create New Shapefile Layer" and the region is shown in orange in the image on the left.

- The Sigma0 Layer in the Ship Detection toolbox is then set to the Median Filtered layer, the AOI Layer is set to "Region" which corresponds to the created region in the previous step.
- The CFAR parameters are set to default values in the Ship Detection toolbox of SARPOLTOOL. If you wish to change the value of Threshold, Guard Box-Horizontal window size, Guard Box- Vertical window size & CFAR method (listed left to right in the image on left), you can modify the values and click on Detect Ships.
- The output of the step is shown as "Subsetted_AOI" in the Layers menu. The "Detected Ships" vector layer shown corresponds to the detected ships. The file is stored in "Output Folder".

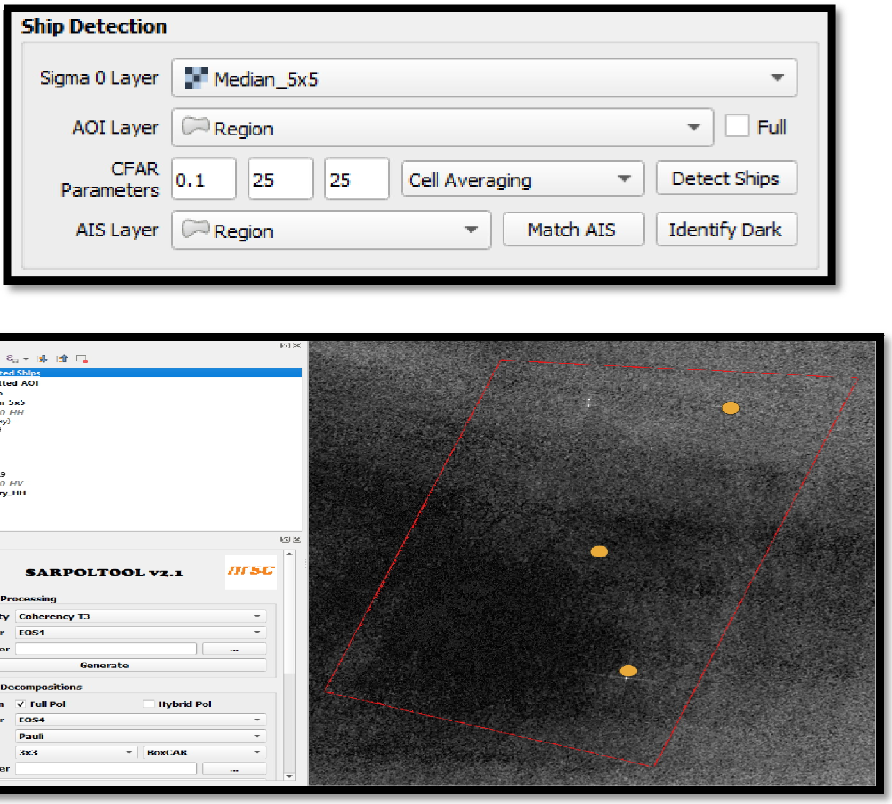
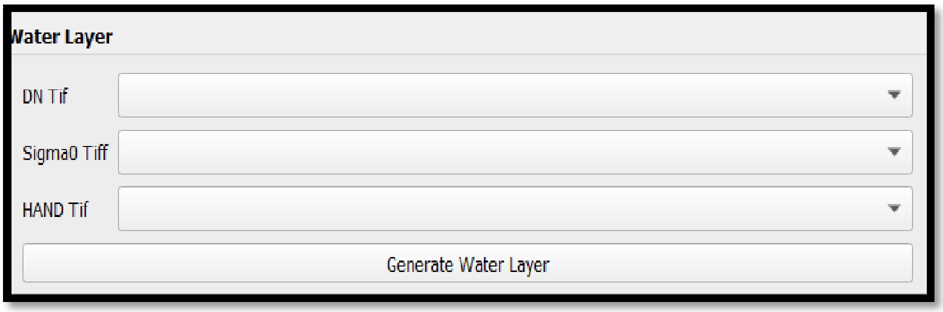


Figure 17: Ship Detection Parameters Selection and Output

4.i. Surface Water Layer Extraction using HAND

Synthetic Aperture Radar (SAR) images can be used to generate water layer information by exploiting the fact that water bodies have a lower backscatter signal than other land cover types. However, SAR images can also be affected by speckle noise, which can make it difficult to identify water bodies.One way to address this problem is to use Height Above Nearest Drainage (HAND) information. HAND is a measure of the elevation of a pixel relative to the nearest drainage feature. Water bodies typically have a higher HAND value than other land cover types, so this information can be used to filter out noise and improve the accuracy of water detection.

In a fuzzy logic-based water layer generation algorithm, the HAND information for each pixel is used to calculate a fuzzy membership value. This value represents the degree to which the pixel is likely to be water. The fuzzy membership values for all pixels are then combined using a fuzzy rule base to generate a water layer map. The use of HAND information and fuzzy logic can significantly improve the accuracy of water layer generation from SAR images. This information can be used to generate water layer maps with high spatial resolution and accuracy, which can be used for a variety of applications, such as flood mapping, water resource management, and environmental monitoring. The Height Above Nearest Drainage (HAND) layer for the given region that is available or pre-processed is available here.



Loadthe DN product/Sigma Naught of the polarization for which Water Layer has to be generated.

Figure 18: Surface Water Layer Extraction Using HAND

5. SPT-2.1 Salient Features

- SARPOLTool v2.1 is a GUI based application designed and developed in Visual C++ and Python using QT Interface. It serves as a Plug-in for the QGIS Geo-Spatial Analysis Software.
- The QGIS Installer and sarpoltool is available on the Bhoonidhi *Resources t*ab and is available on ***www.bhoonidhi.nrsc.gov.in***
- ***W***hen the data folder is given as the input, the software fetches further files for processing.
- The output datasets are written in TIFF format which can be ingested easily for all practical applications.
- The tool contains a Menu Strip and Button/Tab Clicks can be used for carrying out various SAR data functionalities and parameter extraction.
- Mission Specific functionalities are carried out using the input data folder. The ancillary files and imagery files are ingested and the processing is carried out. Post completion, the output imagery is written in generic GeoTIFF format which can be opened using QGIS or any COTS Image Analysis software.
- The tool also supports generation of sigma naught backscatter images for EOS-4, RISAT-1, Sentinel-1 Interferometric Wide (IW) mode, Radarsat-2 and L&S Airborne SAR data.
- In addition to TIFF output imagery, a few relevant jpegs are also generated which can be displayed in QGIS.

Care must be taken to select the right input data folder as the data structure and data packaging is different for different supported SAR missions.

The background console application may throw a few Error and Warning Messages regarding TIFF format writing which may be ignored.

The application may throw exceptions if the input work order folder does not contain all the required files as presented in the Data structure. Care must be taken to ensure that there are no spaces in the input folder path.

SARPOLTool- SPT V2.1has been developed using C/C++ and python controls and is provided with the required libraries and executables. No additional libraries are required in the present format.

Newer models/functionalities shall be inducted in the SARPOLTool V2.2 version onwards based on user requirements and mission specific demands.
NRSC reserves the right to modify and enhance the software as and when requirements arise. This is Beta Version and continual improvements would be incorporated in the application.

All user queries will be answered by the designer and suggestions and feedback are welcome for further enhancement of the Application.
For queries and feedback please contact haripriya_s@nrsc.gov.in, samvram@nrsc.gov.in,ushasundari_hsv@nrsc.gov.in