Processing And Interpretation of Sentinel-1 Synthetic Aperture Radar Data for Scattering Behavior of Earth Surfaces

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Abstract: Microwave remote sensing is used to gather information about the Earth's surface and atmosphere. It can detect changes in land surfaces, even in adverse weather conditions or darkness. The Sentinel- 1 satellite utilizes Synthetic Aperture Radar (SAR) to capture high- resolution microwave imagery for various Earth observation applications. The present work focuses on the processing of Sentinel- 1A SAR data to generate backscattering (σ^0) images and discuss the interpretation of scattering mechanisms. Based on the interpretation of this data, the identification and assessment of Earth's surfaces is an objective of this work. The data is processed using the Sentinel Application Platform (SNAP) toolbox provided by the European Space Agency. To obtain (σ^0) images, the data must undergo various processing corrections, including Apply Orbit File, Radiometric Calibration, Multi looking, Speckle Filtering (Lee Sigma), Geometric Range-Doppler Terrain Correction, Data Conversion (Linear to dB), and σ0 in dB images (VV & VH polarization) for selected study sites. This work is significant for the identification and monitoring of different land covers.

Keywords: Sentinel- 1, σ^0, Microwave, SNAP

I. Introduction

Remote sensing is a method of obtaining useful information about the Earth’s surfaces including soil and vegetation which uses microwave frequencies. In remote sensing, the interpretation of satellite data depends on the backscattering phenomenon [3]. The backscattering coefficient (σ^0) represents the electromagnetic radiation that is scattered back from the Earth’s surface.

The σ0 value depends on factors such as wavelength, polarization, moisture, and surface roughness. Since water surfaces produce specular reflection, microwave remote sensing is useful for flood assessment [1]. Soil moisture measurement using this data is also beneficial for agriculture.

To use Synthetic Aperture Radar (SAR) data effectively, raw data must undergo processing steps such as calibration, multi-looking, speckle filtering, terrain correction, and conversion to a σ^0 image in decibels (dB).

This study processes SAR level-1 data from the Sentinel-1 satellite, which is available for free from the Copernicus website. The study focuses on a coastal region in Panaji, Goa, as limited research is available for this area. The European Space Agency’s (ESA) SNAP Toolbox is used to process the data and generate σ^0 images.

II. Literature Review and Need for Study.

Remote sensing plays a crucial role in environmental monitoring, change detection, and disaster management. Sentinel-1 SAR data is widely used for applications such as flood mapping, land classification, and urban change detection [1] . Various processing techniques, including speckle filtering and data fusion, have been explored to enhance its accuracy [2] [3] . However, challenges like noise and complex backscatter effects remain.

Despite its extensive use, very little research focuses on coastal areas like Panaji, Goa. Coastal regions are dynamic, influenced by tides, erosion, and human activities, making them critical for study. Understanding how SAR data interacts with these surfaces is essential for shoreline monitoring, vegetation analysis, and water detection. Proper processing of SAR data enhances accuracy and usability for such applications.

This study aims to refine SAR processing methods using the ESA SNAP Toolbox to generate clear backscatter (σ0) images. The results will contribute to better coastal management, assisting researchers, urban planners, and policymakers in making informed decisions.

III. Objectives.

1. Process Sentinel-1 SAR data using the ESA SNAP Toolbox.
2. Study backscattering patterns in Panaji's coastal region.
3. Improve SAR data processing with calibration and filtering.
4. Use SAR data for coastal monitoring, like shoreline changes.
5. Help in better coastal management with useful insights.

IV. About Study Area.

The figure 4.1 shows about the study area located in **Panaji, Goa**, the capital city of Goa, a small but significant state on the western coast of India. Goa is bordered by Maharashtra to the north and Karnataka to the south and east. It has a coastline of approximately 160 kilometers along the Arabian Sea and experiences a tropical climate.

Panaji is situated in the Konkan region, which lies between the Western Ghats and the Arabian Sea. This coastal lowland is characterized by an elevation below 200 meters and a width of around 50 kilometers. The Konkan region extends through the states of Goa, Maharashtra, and Karnataka, forming a unique geographical landscape.

figure 4.1(study area)

V. Dataset and Sources.

The Sentinel-1A dataset used in this study was obtained from the [4], which provides free and open access to Sentinel satellite data. The data is acquired at Level-1 Ground Range Detected (GRD) processing level. Sentinel-1A is operated by the European Space Agency

Access Hub enables the study of any region of the world, making it a valuable resource for global environmental monitoring.

(ESA), provides high-resolution Synthetic Aperture Radar (SAR) data useful for earth observation applications. Copernicus Open

VI. Methodology.

Although the **Copernicus Open Access Hub** provides open access to any data of the region in which the user is interested in, the dataset has many distortions which include speckle noise, thermal noise, radiometric distortions and geometric distortions. These types of distortions or pollution's can be removed with the help of free SNAP toolbox software. It includes various steps such as filtering.

The steps to follow are as follows:

Step 1: Importing the dataset in the form of zip file into the software.

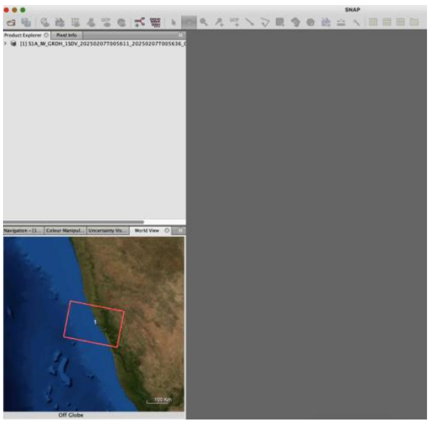


figure 6.1(step 1)

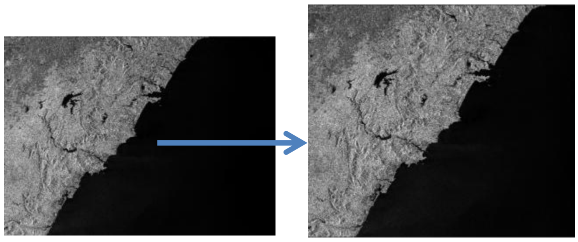
Step 2: Applying file orbit to the VV and VH bands.

Applying the orbit file is an essential preprocessing step in Sentinel-1 SAR data processing. It improves the geolocation accuracy of the SAR image by correcting the satellite's position and velocity errors using precise orbital information. This step is to be done before radiometric calibration, speckle filtering, and terrain correction to ensure the best results for further processing.

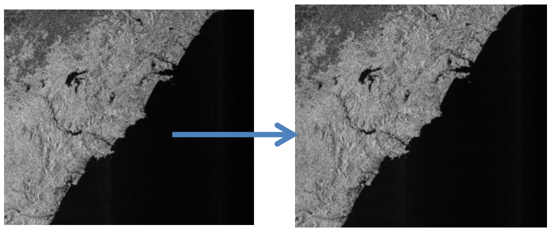
Step 3: Applying Radiometric Calibration filter to the VV and VH bands.

Radiometric calibration corrects the intensity values in SAR images so they accurately represent the radar backscatter (σ^0) of the Earth's surface. Sentinel-1 SAR data, in its raw form, contains sensor-specific distortions that must be corrected to compare different images and extract meaningful physical properties.

Figure 6.2 shows the before and after results of this step for **VV** and **VH** bands:



VV Band



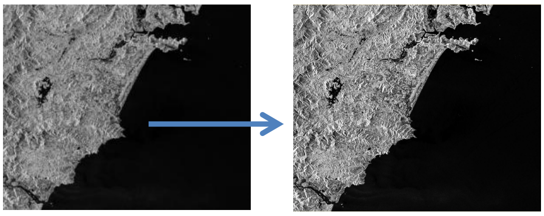
VH Band

figure 6.2(step 3)

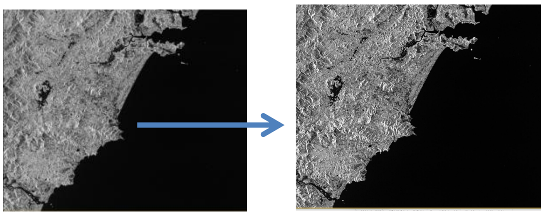
Step 4: Applying Speckle Filter (Lee Sigma) to the VV and VH bands.

Speckle is a type of grainy noise that appears in SAR images due to the interference of radar signals reflected from different scatterers. It reduces image quality and makes interpretation difficult. Applying a speckle filter is crucial for improving SAR image quality, making the data more useful for scientific and practical applications.

Figure 6.3 shows the before and after results of this step for **VV** and **VH** bands:



VV Band



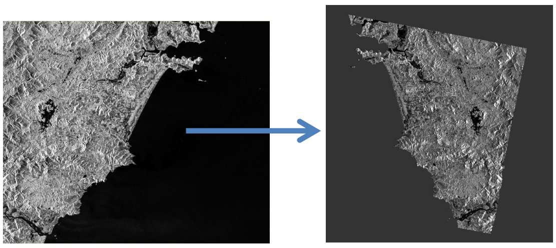
VH Band

figure 6.3(step 4)

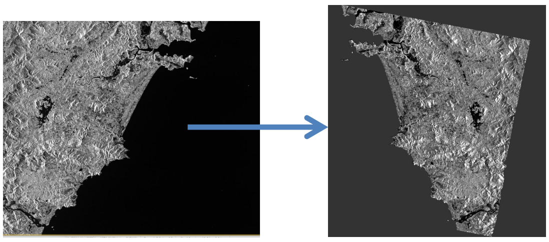
Step 5: Applying Geometric- Range Doppler Terrain Correction to the VV and VH Bands.

Sentinel-1 SAR images are captured at an angle (side-looking radar), which causes distortions like Foreshortening, Layover and Shadowing. To correct these distortions, we apply Range Doppler Terrain Correction. This step is crucial for accurate geospatial analysis using Sentinel-1 SAR data.

Figure 6.4 shows the before and after results of this step for **VV** and **VH** bands:



VV Band



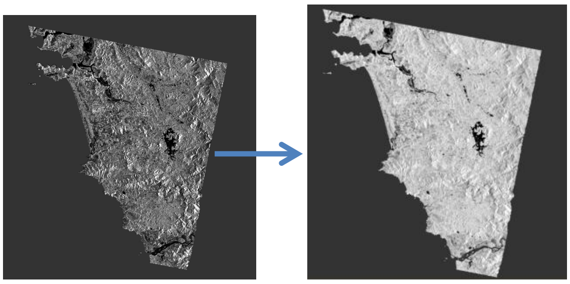
VH Band

figure 6.4(step 5)

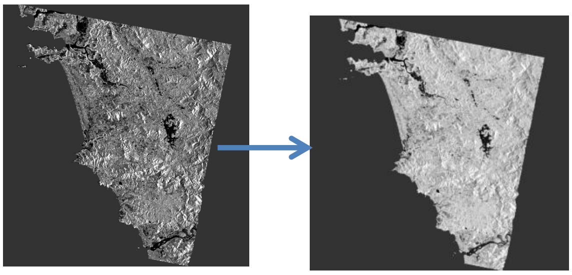
Step 6: Data Conversion (Linear to dB).

SAR data is converted to decibels (dB) because it enhances image contrast, it is easier for interpretation and standard in remote sensing. The image is now easier to interpret and use in analysis (e.g., flood mapping, land classification).

Figure 6.5 shows the before and after results of this step for **VV** and **VH** bands:



VV Band



VH Band

figure 6.5(step 6)

Step 7: To Generate RGB Composite.

An RGB Composite allows you to combine multiple SAR bands into a color-enhanced image for better visualization. For Sentinel-1 SAR, using VV and VH polarizations, you can create an RGB image to distinguish different surface features like water, vegetation, and urban areas.

Figure 6.6 shows image after all the filters:

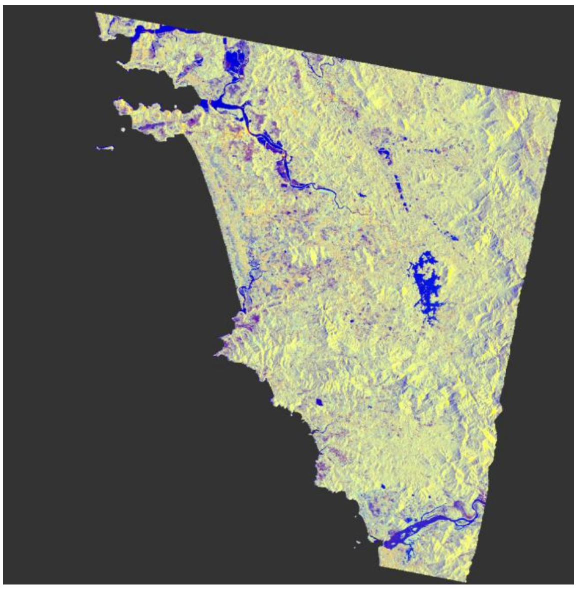


figure 6.6(step 7)

VII. Results and Discussion:

The processed Sentinel-1A SAR data of Panaji, Goa, using the ESA SNAP Toolbox, effectively distinguishes water bodies, urban areas, and vegetation based on backscatter values.

→ Water bodies appear as dark regions due to low backscatter.

→ Urban areas show high backscatter due to strong radar returns.

→Vegetation displays moderate backscatter, varying with canopy density and moisture.

VIII. Conclusion.

This study shows that Sentinel-1A SAR data is effective for coastal monitoring in Panaji, Goa. Using the ESA SNAP Toolbox, we identified shoreline changes, vegetation health, and land cover variations. Despite minor challenges like speckle noise, SAR proves useful for all -weather monitoring. Future improvements with AI and optical data fusion can enhance accuracy, supporting better coastal management and planning.

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IX. References.

[1] Ashish B. Itolikar, V. M. Arole "Processing of Sentinel-1 Synthetic Aperture Radar Satellite Data," Extraction of Backscattering Coefficient (σ0) in Maharashtra Region, India., p. 8, 13 Februbary 2020. [Ref]

[2] Jamal Ezzahr, Nadia Ouaadi, Mehrez Zribi, Jamal Elfarkh. "Evaluation of backscattering models and support vector machine for the retrieval of bare soil moisture from sentinel-1 data," Remote Sensing, vol. 12, no. 1, p. 20, 2020. [Ref]

[3] Rayan Nas, Fusun Balik Sanil, Saygin Abdikan, Ziyadin Cakir. "Sensitivity analysis of multi-temporal Sentinel-1 SAR parameters to crop height and canopy coverage," Applied Sciences (Switzerland), vol. 9, no. 4, p. 19, 2019. [Ref]

[4] Conventional Data Access Hubs [Ref]