SAR Image Processing Progress Report

Subject: Progress and Challenges in SAR Image Preprocessing for Multi-Vessel Detection

1. Introduction

This document provides a concise summary of the progress made in preprocessing Sentinel-1 Synthetic Aperture Radar (SAR) images for a project focused on **multi-vessel detection, classification, segmentation, dimension calculation, and precise direction prediction.** It also highlights key challenges encountered during the preprocessing phase and the solutions implemented to overcome them.

2. Initial Preprocessing Steps Completed

Prior to this report, the following standard preprocessing steps were successfully applied using ESA SNAP:
1.Apply Orbit File: Correction of geometric distortions using precise orbit information.
2.Radiometric Calibration: Conversion of raw digital numbers to radiometrically calibrated backscatter values.
3.SAR - Top Deburst: Merging of individual bursts in TOPSAR mode data.
4.Thermal Noise Removal: Reduction of noise introduced by the SAR system's thermal components.
5.Polarimetric Matrix Building (C11 and C22 images): Generation of the coherency matrix, essential for polarimetric analysis.
6.Polarimetric Speckle Filtering: Initial reduction of speckle noise, inherent in SAR imagery.
7. **Polarimetric Decomposition**
8.Range Doppler Terrain Correction: Geocoding of the SAR data to a map projection.
9.Multi-Looking: Averaging of pixels to reduce speckle and create approximately square pixels.

3. Key Struggles Encountered

Despite the initial successful steps, significant challenges arose when attempting to leverage the full polarimetric information from Sentinel-1 Single Look Complex (SLC) data for advanced analysis. The primary struggles revolved around correctly configuring the processing chain in **ESA SNAP** to produce a usable polarimetric product.

Struggle 3.1: Incorrect Polarimetric Decomposition Output (Noisy,

Even though building the pipeline looks smooth and feels like reaching the perfectly preprocessed image at some stage the entire processing is getting wasted which we felt as lack of order for operations to be performed in order to achieve the end image with finest details. So seeking a solution for a procedural pipeline.

Struggle 3.2: Sub-optimal Image Resolution

Noise filtering has become a huge challenge where the more effort we put in to reduce the speckle the higher the loss of details in the image.
Still searching for better filters and lack of awareness of what to use is causing the trouble. Seeking what parameters might outperform regular techniques.

Struggle 3.3: Interpreting and Visualizing Polarimetric Data

Even after successfully processing the data and generating the H, A, and Alpha bands, the initial RGB composite visualization (H=Red, A=Blue, Alpha=Green) appeared noisy and difficult to interpret, with vessels not clearly distinguishable from the sea clutter. This led to a perception that the polarimetric data was not visually useful.

Struggle 3.4: RGB Channeled Polarimetric Data

Even though it seems like gray scale intensity based SAR pre-processed images are looking promising and outperforming the RGB Channeled Polarimetric Data keeping the end goal in mind LLM's , AI models are suggesting to use RGB Channeled Polarimetric Data for better results. We are stuck here to make a decision whether to stick with gray scaled polarimetric image or RGB channeled polarimetric image.

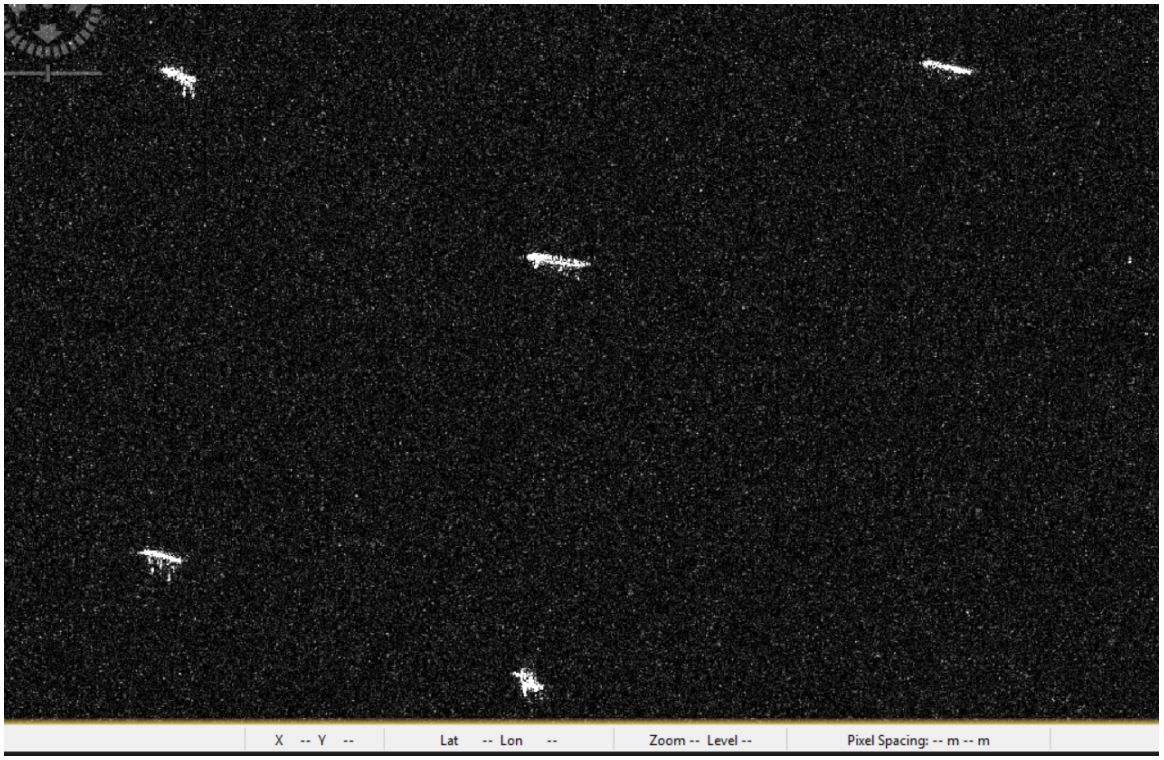
4. Current Status and Next Steps

As of this report, a robust and validated preprocessing pipeline for Sentinel-1 IW SLC data has not been established. This pipeline correctly handles polarimetric processing, speckle reduction, and geocoding , multi-band polarimetric product (H, A, Alpha, and potentially Sigma0 VV/VH) but still producing a low-medium resolution that is not optimal for advanced vessel analysis.

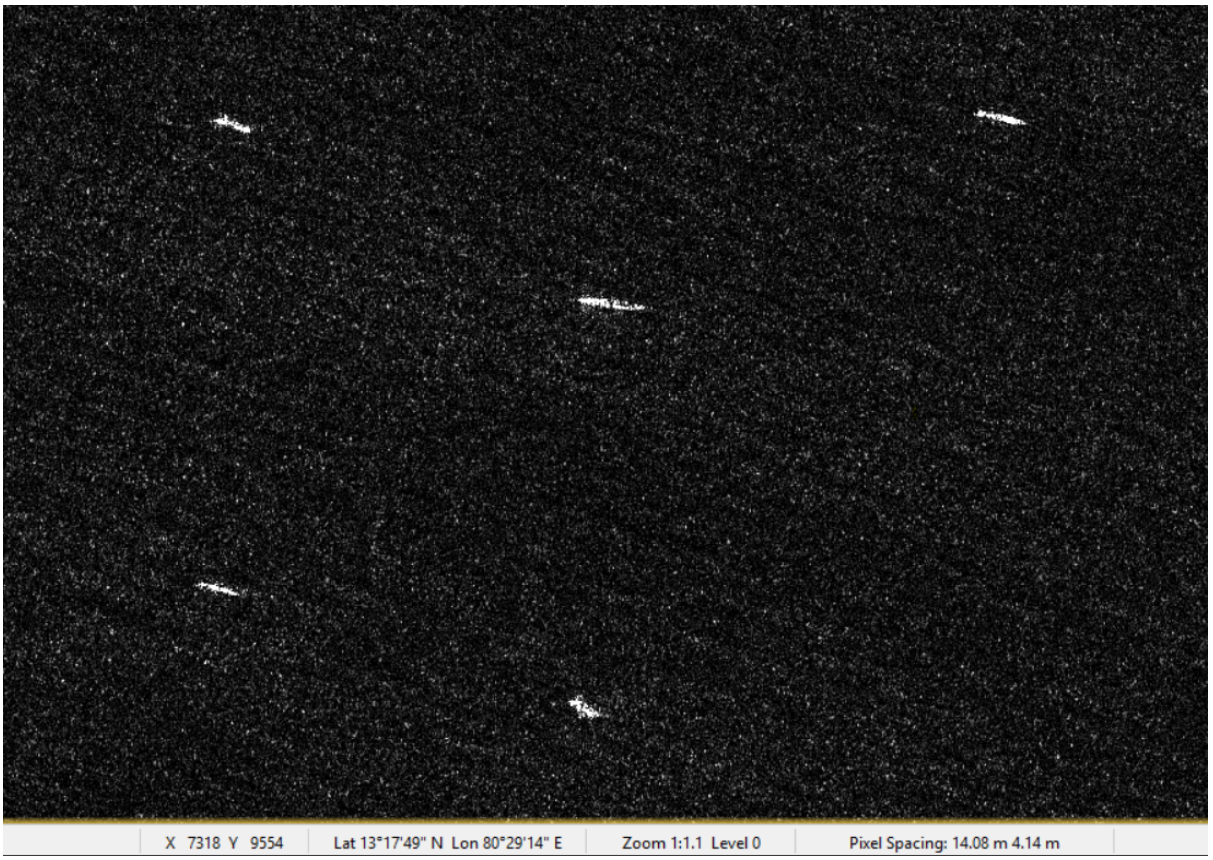
•Leveraging Polarimetric Information in AI: How to ensure the AI models effectively utilize the rich polarimetric scattering information (H, A, Alpha) for superior performance compared to traditional intensity-based approaches, especially for classification and precise segmentation.
We are now at a critical juncture where guidance on best practices for integrating this advanced SAR data into a robust AI framework would be highly beneficial to ensure the project progresses efficiently towards its ambitious goals.

Here are the resultant Preprocessed images that are built using the pipeline that is mentioned above.

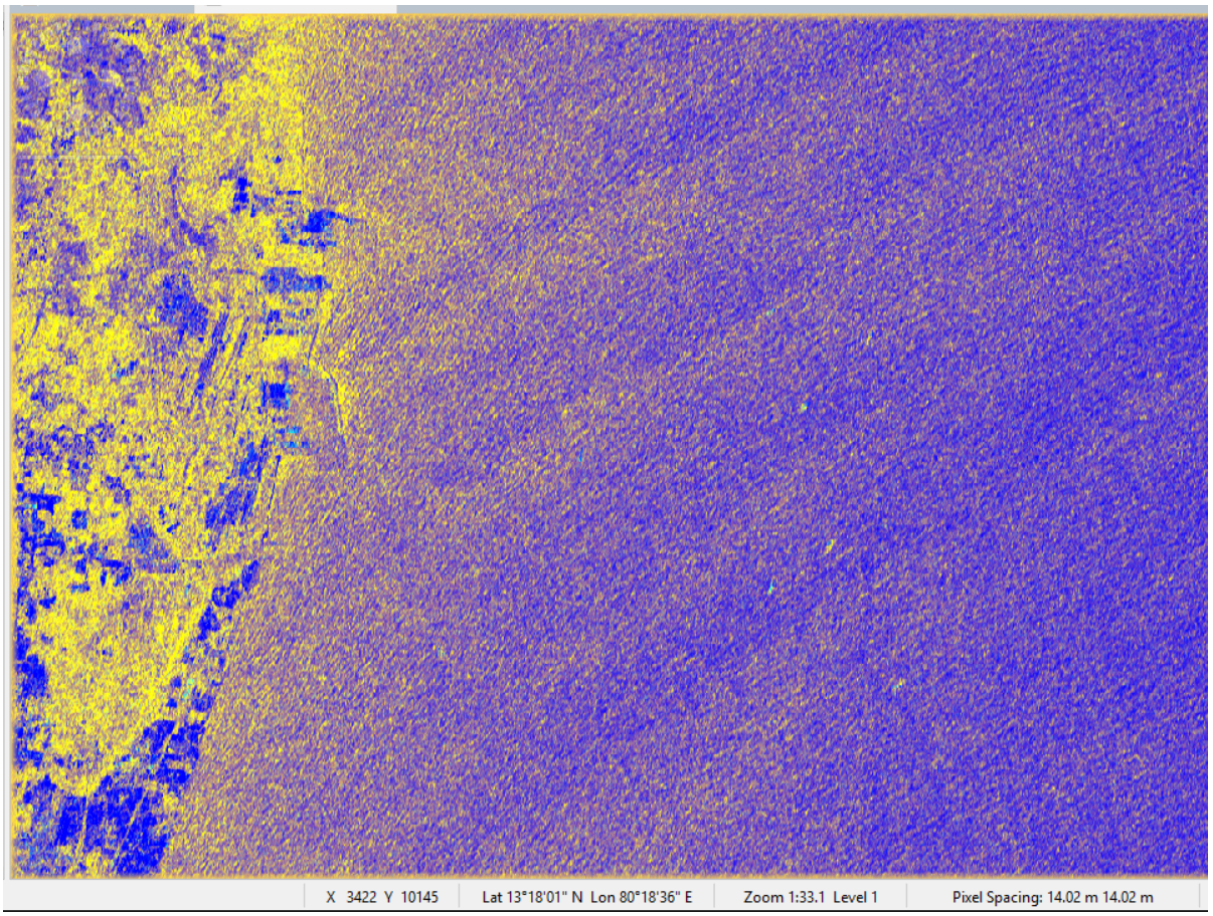
C22 Image



Non Polarimetric Image with VH Polarization



Non Polarimetric Image with VV Polarization



RGB Channelled Polarimetric Image
Red (Entropy)
Green (Anisotrophy)
Blue (Alpha)