Polarimetric Analysis Of Permanently Shadowed Regions On The Moon Using Dual-Frequency Full-Pol Data From Chandrayaan-2 DFSAR

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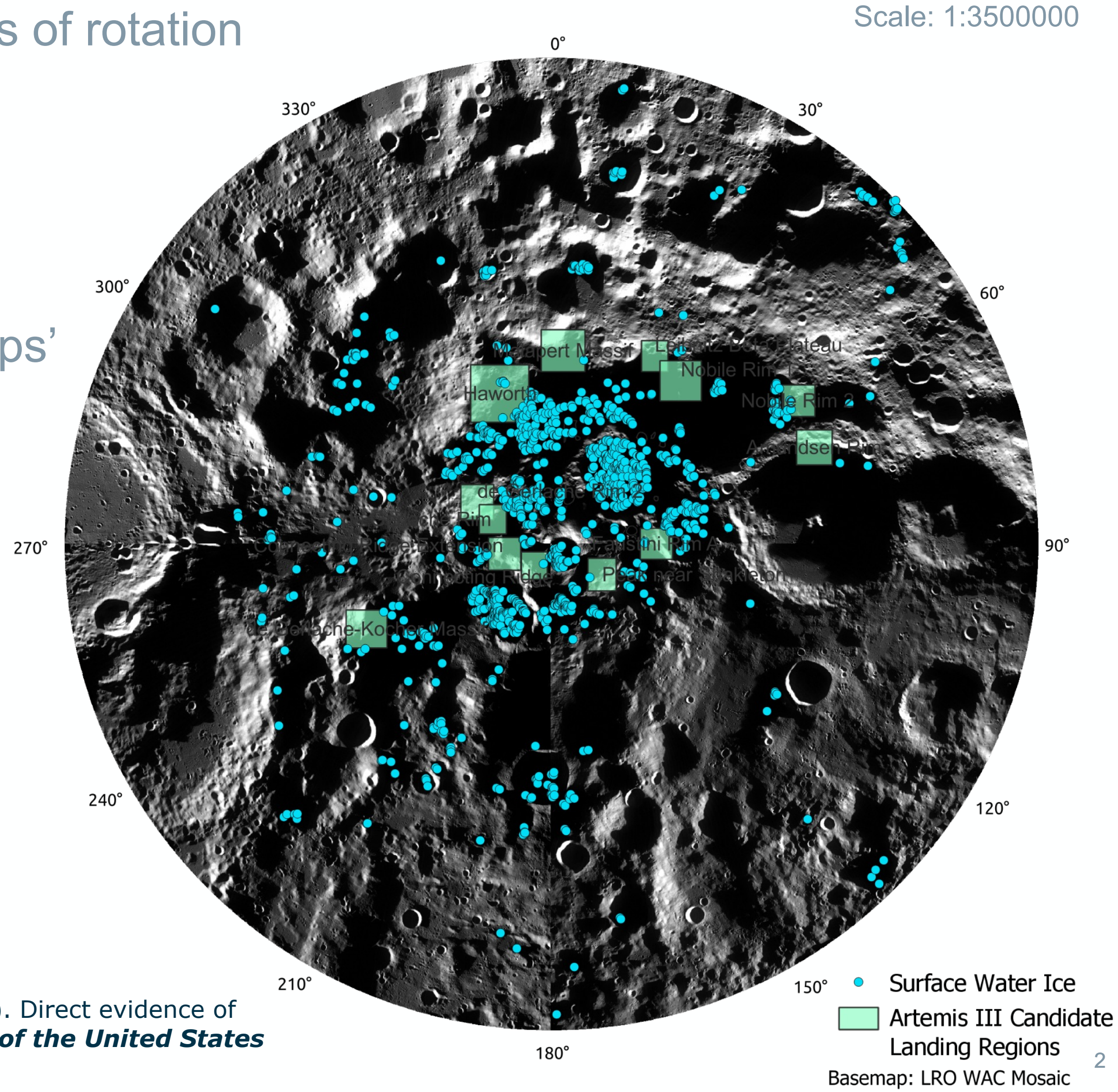
South Pole of the Moon

- Peculiar illumination conditions due to 1.54° tilt of Moon’s axis of rotation
- Topographic highs always have the Sun at/near the horizon
- Topographic lows lie in darkness, some in Permanently Shadowed Regions (PSRs)
- These PSRs have very low temperatures and act as ‘cold traps’ for volatiles and water-ice
- Water ice exists as crystals mixed with lunar regolith
- Resulting in higher dielectric constant and volume scattering



Source:
Li, S., P. G. Lucey, R. E. Milliken, P. O. Hayne, E. Fisher, J. P. Williams, D. M. Hurley, and R. C. Elphic (2018). Direct evidence of surface exposed water ice in the lunar polar regions. ***Proceedings of the National Academy of Sciences of the United States of America (PNAS)***, 115(36), 8907-8912.

Chandrayaan-2 DFSAR

Data

•India's second mission to the Moon

• Launched on 22 July 2019

• Dual Frequency Synthetic Aperture Radar

• Operates in L and S bands

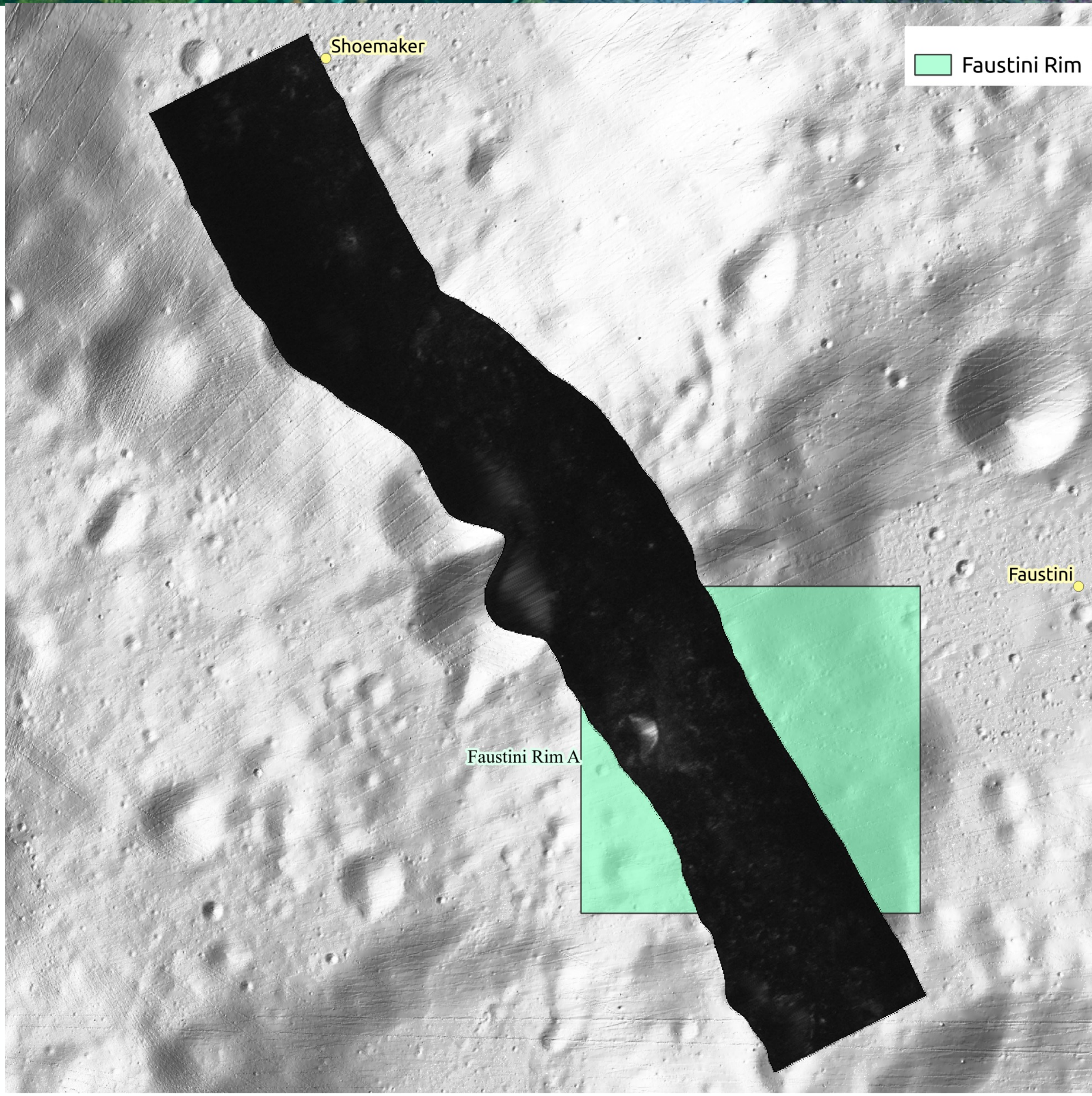
• Operates in Fully polarimetric mode

• Launched with an objective to characterize the lunar poles

• Aims to quantify lunar water

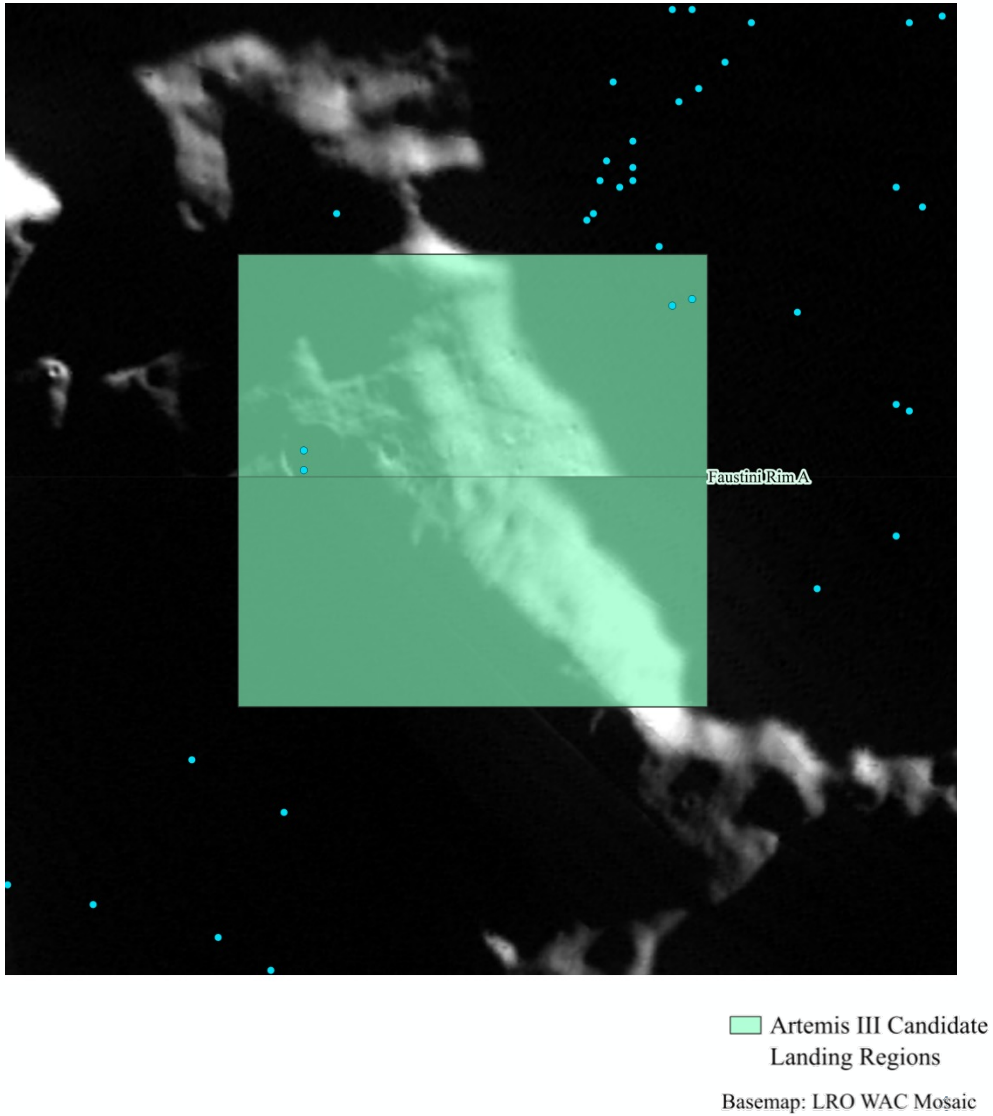
Dataset Used

- ch2_sar_ncls_20200913t042439405_d_fp_d18
- Both L and S bands
- Captured on 13-Sep-2020



Rim of Faustini Crater

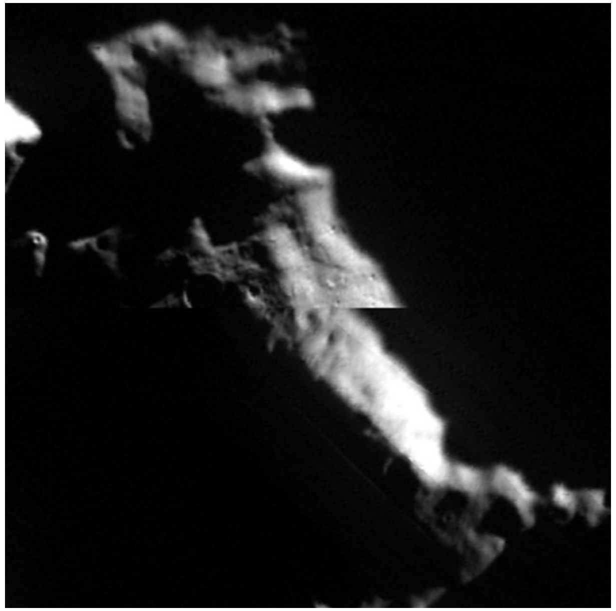
- Proximity to regions of
  - Persistent Solar illumination - to set up solar power plants
  - Persistent Earth visibility - for communication
  - Potential locations of lunar volatiles and water ice
- One of the Candidate Landing Sites of Artemis III
- Limited visibility in optical data since the craters lie in Permanently Shadowed Region



Rim of Faustini Crater

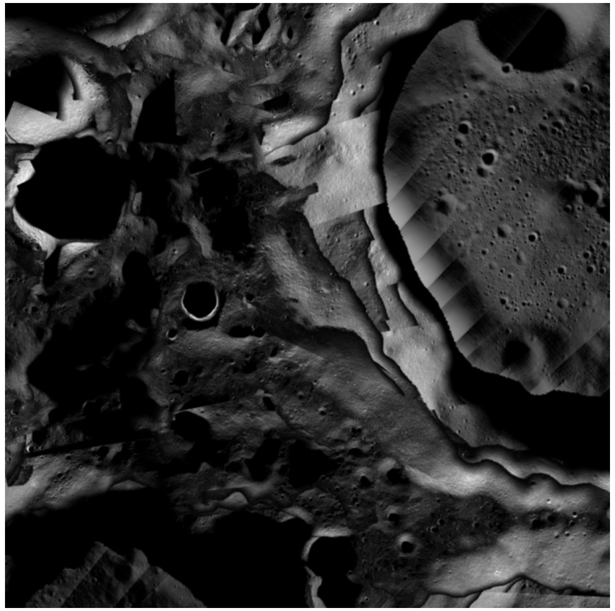
Clementine UVVIS (1994)

- UltraViolet-Visible Camera
- Only the rim visible
- Due to saturation of albedo, features not distinguishable



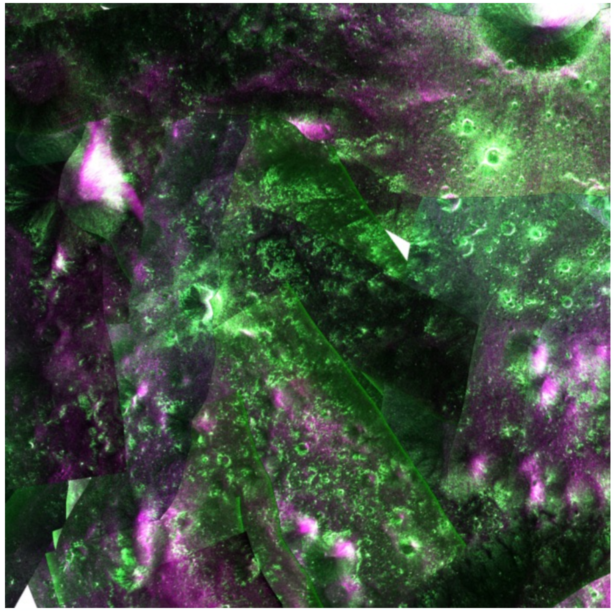
LRO WAC (2009)

- Lunar Reconnaissance Orbiter Wide Angle Camera
- Better tonal contrast
- Some features on rim visible



LRO NAC (2009)

- LRO Narrow Angle Camera
- Longer exposure time
- Records faint light reflected from surrounding
- High noise
- Base of walls still hidden

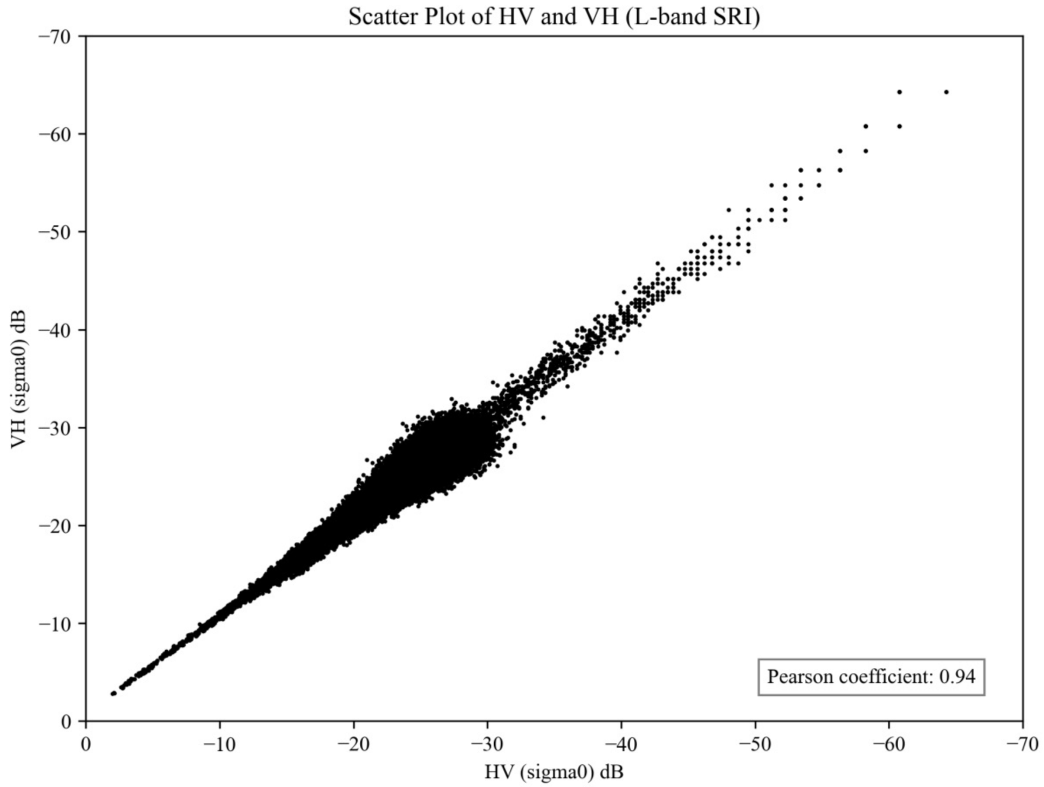


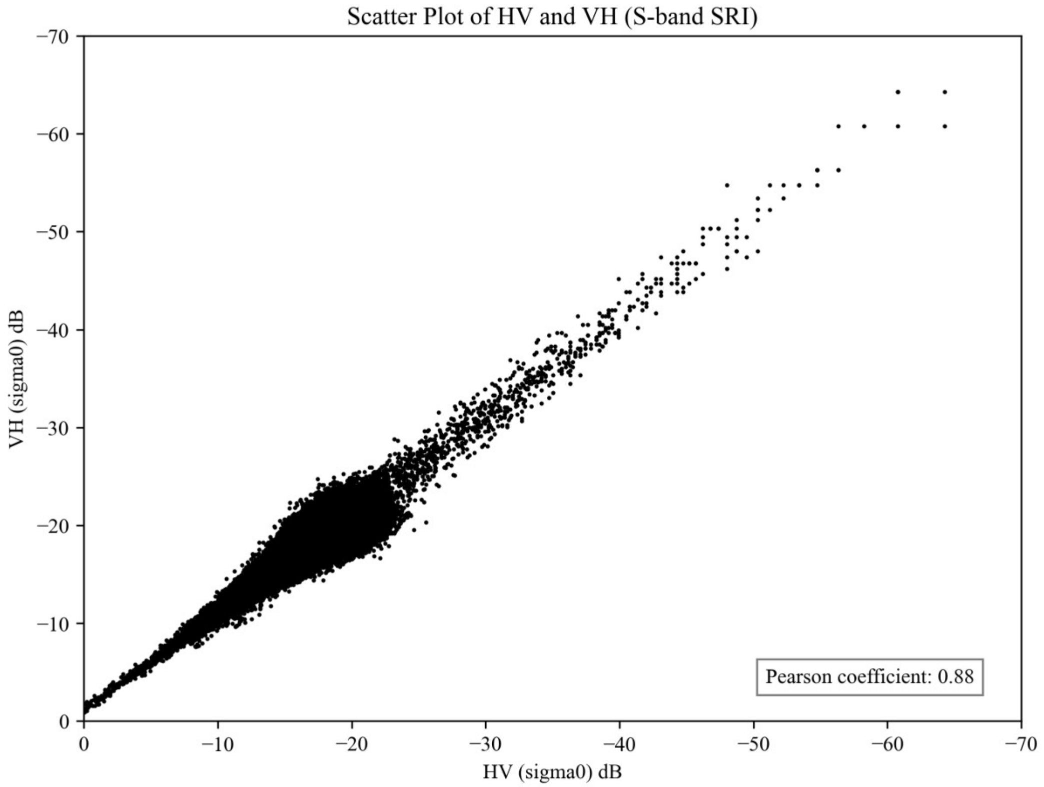
Chandrayaan-2 DFSAR (2019)
RGB:HH,HV,VV

- First L band Full pol SAR
- Able to visualize entire surface
- Fresh craters within the larger crater visible

Scale: 1:200000

Correlation between cross-pol channels





- High correlation between sigma0 (dB) backscatter values in calibrated Seleno Referenced Images
- Correlation lesser in S-band

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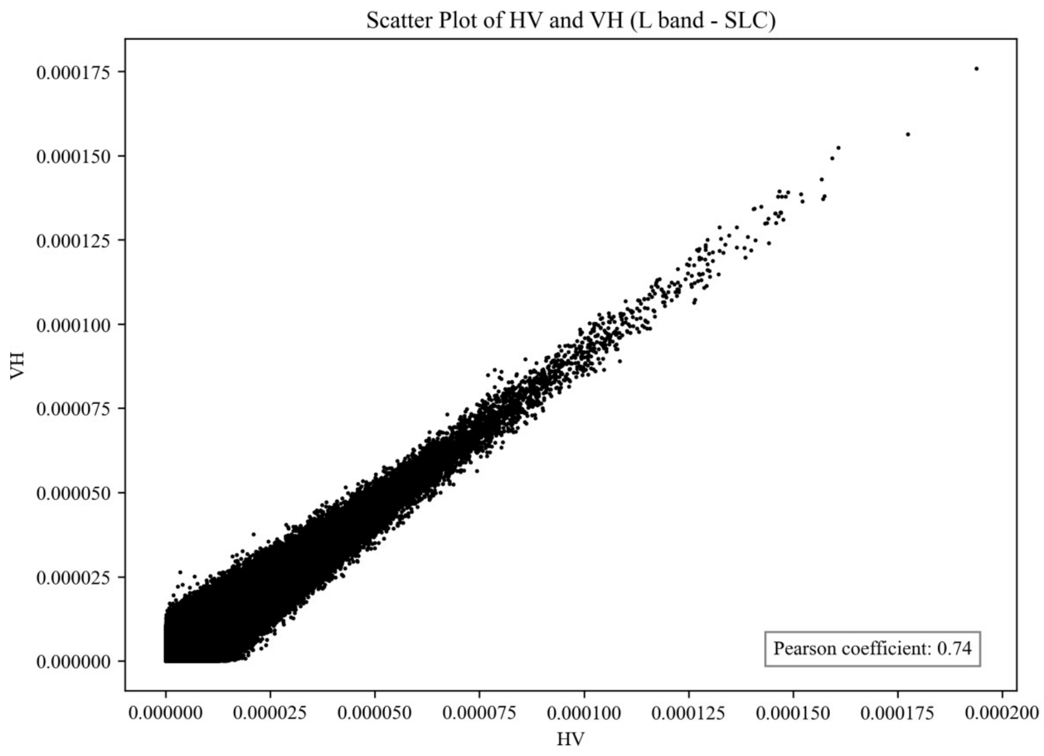
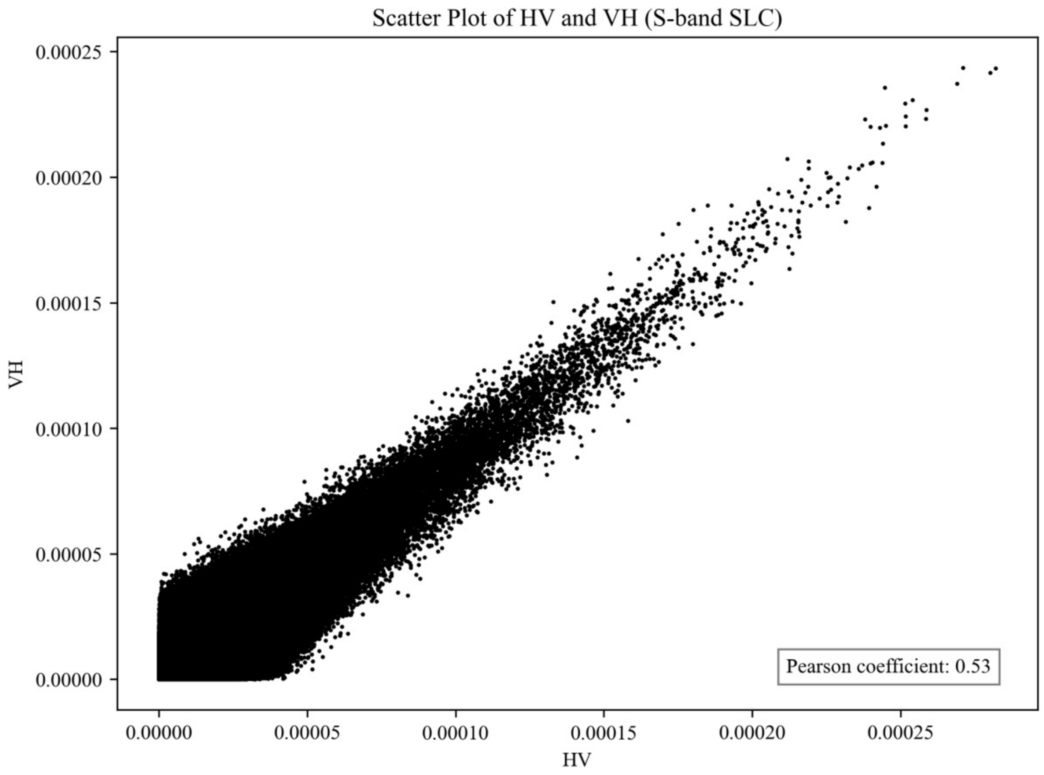
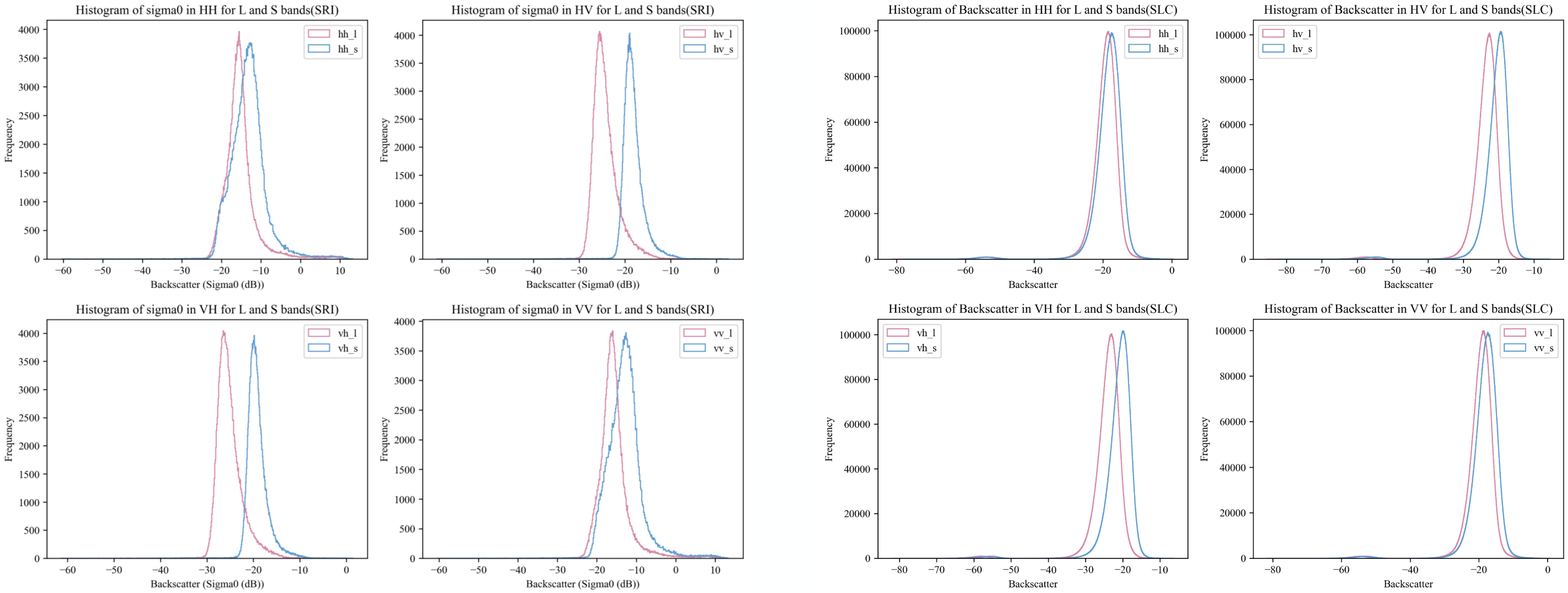
Correlation between cross-pol channels





- Lower correlation between backscatter values in calibrated Single Look Complex images
- Correlation very less in S-band
- Due to absence of corner reflectors on the Moon, calibration is difficult

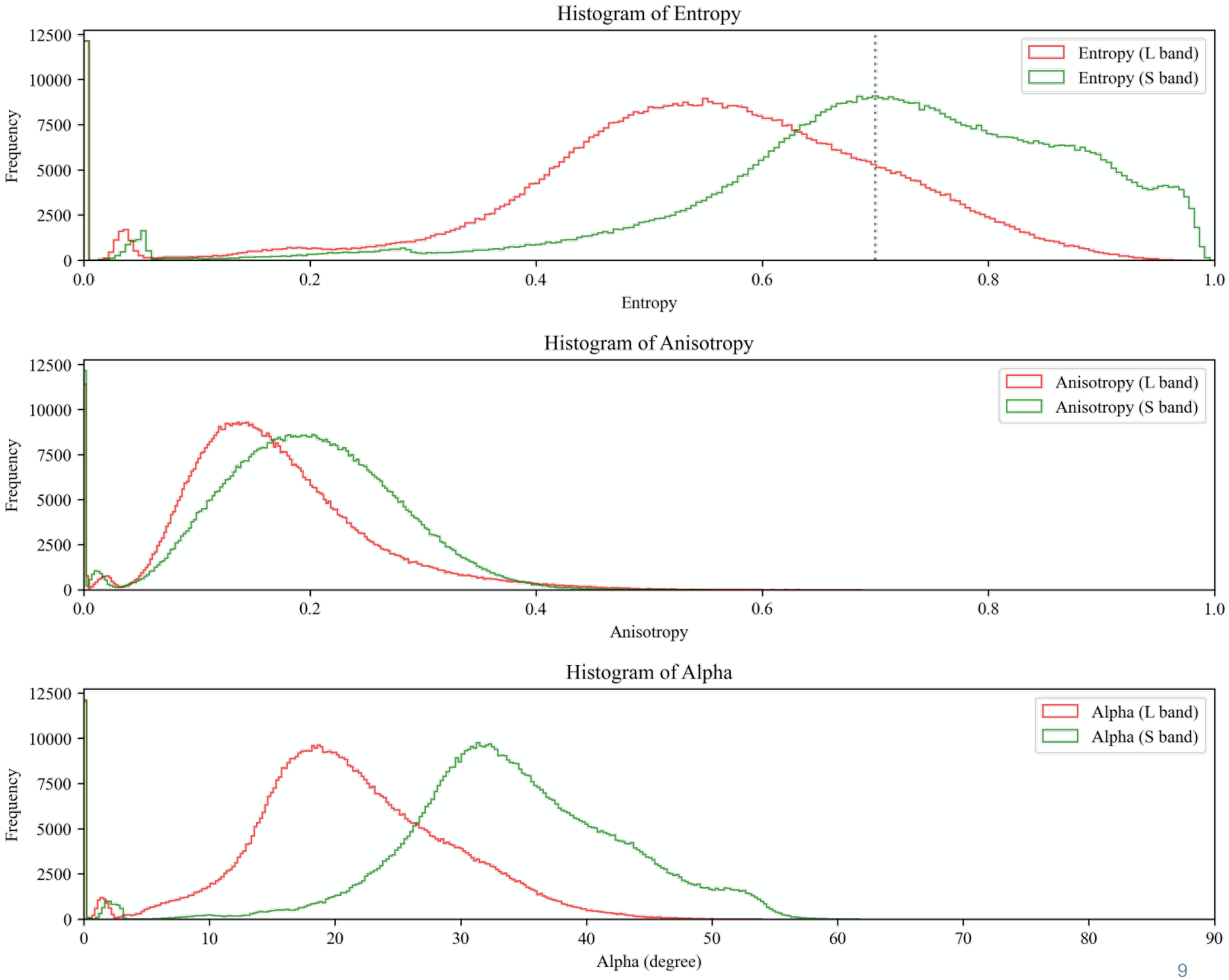
Backscatter in all channels (SRI product)



- Gaussian distribution of values in all 4 channels
- In all 4 channels, S band has higher backscatter than L band
- Difference between ranges of values more pronounced in cross pol channels

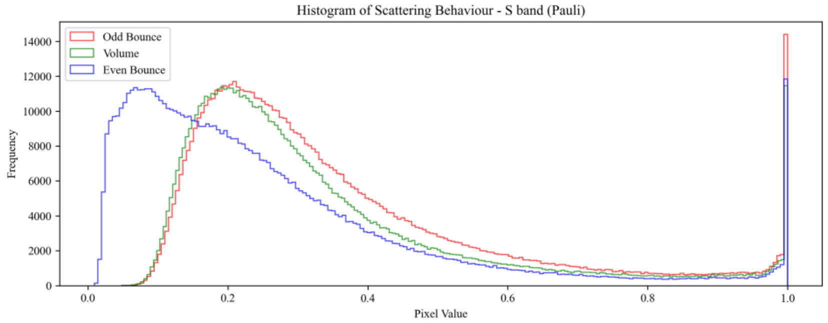
Polarimetric Decomposition – H/A/Alpha

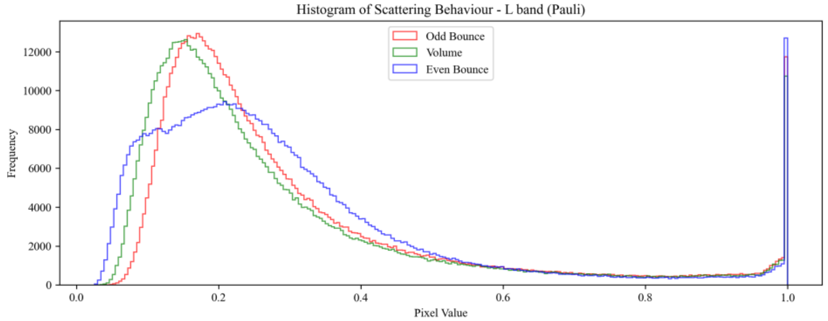
- In S-band, entropy is saturated above 0.7 for most regions
- For anisotropy, values for L band are lesser than 0.3 but in S band some values exist more than 0.3
- Since most values of alpha lie below 45, it denotes a dominance of surface and volume scattering



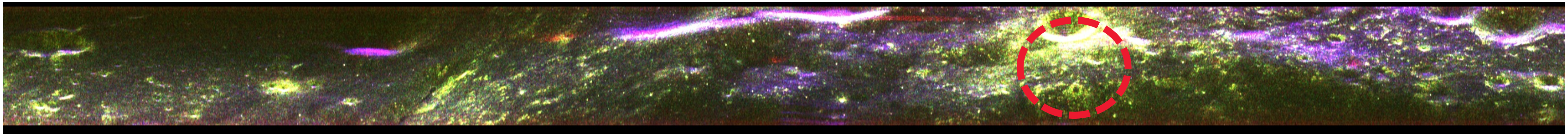
Polarimetric Decomposition – Pauli

- In S band, most pixels have lesser contributions from double bounce scattering
- In L band the number of pixels with contributions to double bounce scattering reduces
- The rim and ejecta of the crater shows high volume scattering in S band but odd bounce scattering in L band
- This could be due to L band waves penetrating through the upper layers of the ejecta and interacting with a dense surface below

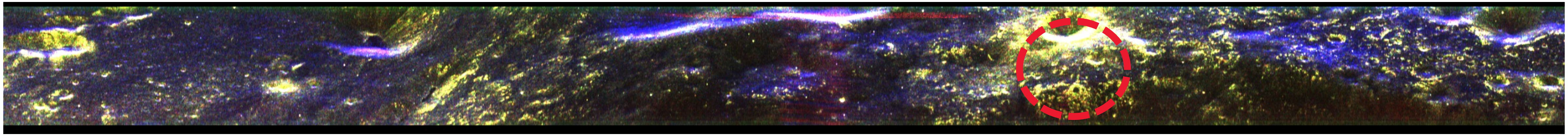




S

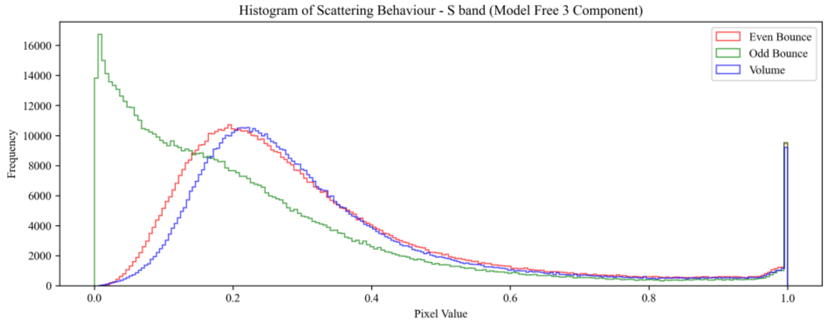


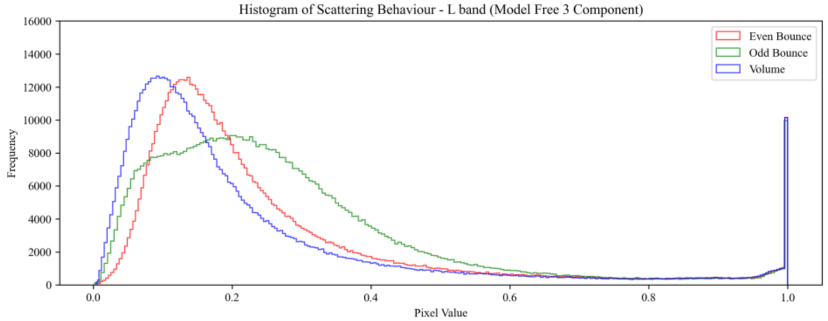
L

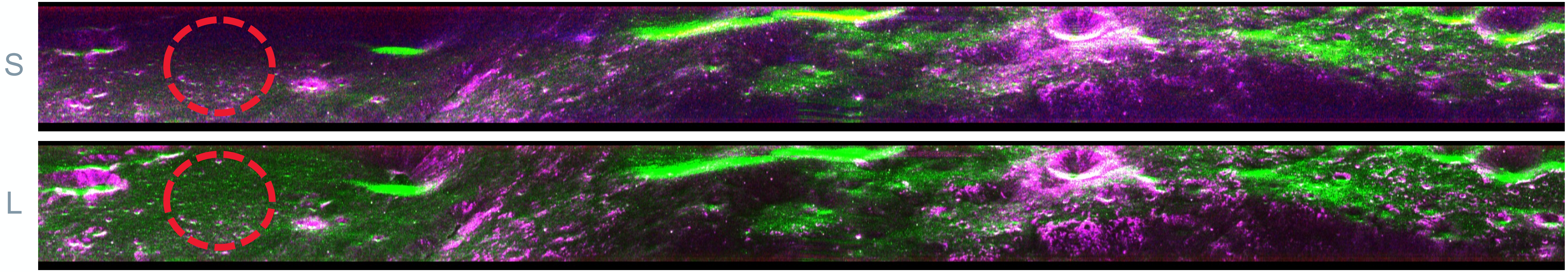


Polarimetric Decomposition – Model Free 3 Component

- Regions that show dominance of volume scattering in S band, shows dominance of odd bounce scattering in L band
- L band is able to penetrate through the upper layer to bounce off the dense layer beneath the regolith

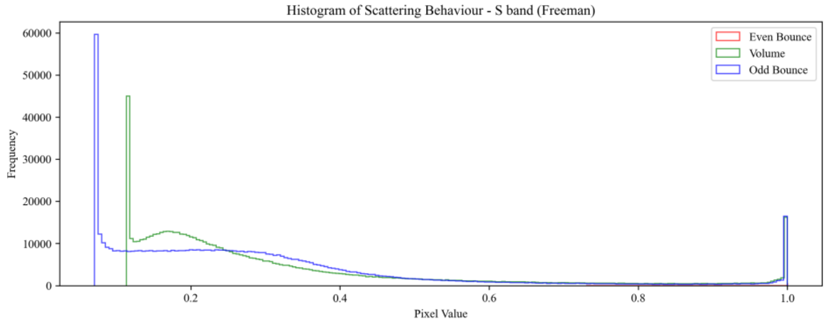


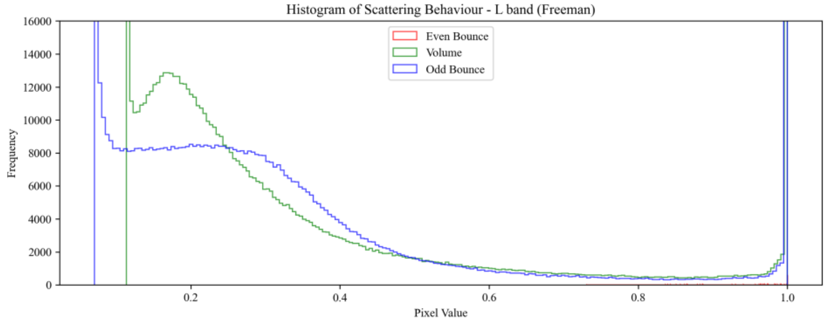




Polarimetric Decomposition – Freeman

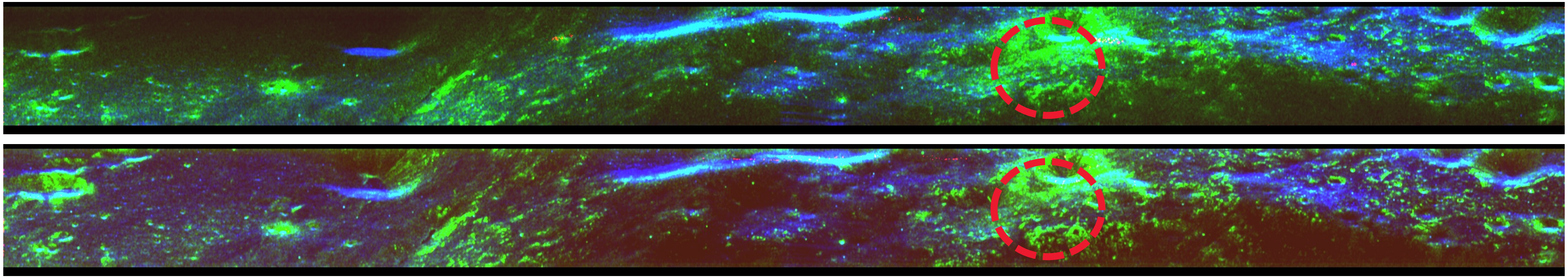
- Does not show contribution of double bounce scattering
- Dominance of contribution of volume scattering in both S and L bands
- Rim of crater shows high backscatter with higher contribution from volume scattering
- High distinct backscatter from the rim of the craters
- Loose ejecta shows volume scattering in S band and surface scattering in L band





S

L



Conclusion

- Chandrayaan-2 DFSAR is a viable alternative to optical remote sensing for geologic mapping of PSRs on the Moon
- High volume scattering observed from the ejecta of younger craters
- Some regions showing volume scattering in S band show surface scattering in L band showing the ability of L band to penetrate through the upper layer of the regolith
- Further analysis using hyperspectral and thermal data could add more context to the observations
- The study was limited due to unavailability of seleno-referenced SLC products, availability of orthorectified seleno referenced complex products can give further insights into the polarimetric analysis of this data