A SOFTWARE TOOL TO PROCESS & ANALYSE CHANDRAYAAN-2 POLARIMETRIC DUAL-FREQUENCY SAR (DFSAR) DATA. Tarun M., Tathagata Chakraborty, Sanid C., Deepak Putrevu and Arundhati Misra, Space Applications Centre, ISRO, Ahmedabad, India *(tarunm@sac.isro.gov.in)

Introduction: Dual-Frequency Synthetic Aperture Radar (DFSAR) onboard Chandrayaan-2 orbiter is state-of-the-art SAR sensor for planetary mission. The architecture of this radar instrument is capable to acquire data in L- & S-bands in both full- and hybrid-polarimetric modes, with varying resolution maximum upto 2m/pixel[1]. Hence, DFSAR observations can contribute significantly towards mapping and characterization of various geomorphological features on Moon[2-4]. Presently, worldwide no software tool is available to analyse DFSAR data. Hence, we made an effort to use the features of our indigenously developed software tool MIDAS (MIcrowave Data Analysis Software) to carry-out the polarimetric and radiometric analysis of the DFSAR data. The software is free to users and easy to use in both Windows and LINUX platforms. The software has a GUI, which makes it easy to use for the users.

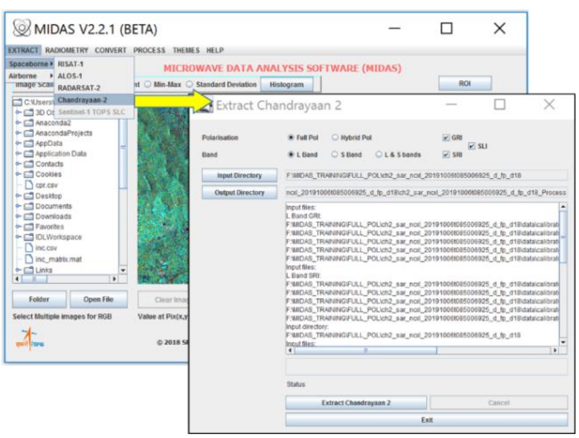

Figure 1: The GUI of MIDAS software, with support towards Chandrayaan-2 DFSAR data analysis.

Software Functionalities: MIDAS has been developed to carry out analysis of different microwave data using advanced algorithms, including polarimetric and radiometric analysis of SAR data, including that of DFSAR (Figure 1). We incorporated majority of the commonly used functionalities for polarimetric analysis of SAR data. In addition to DFSAR, the software supports other Microwave spaceborne and airborne sensors data. The modules catering to the polarimetric data analysis in the software are as follows:

1. Radiometric Processing: The level-2 co- and cross-polarized backscattering elements (both full-pol or dual-pol) can be processed to derive the calibrated backscatter coefficients (σ^0).

2. Covariance/Coherence Matrices: The distributed targets can be analyzed by considering a varying space and time stochastic processes, so that the target can be analyzed through second order moments. The covariance and coherence matrices can be obtained by outer product of target vector and its transpose, where target vector (in complex) is defined in terms of Lexicographic or Pauli basis, respectively. Thus, the complex co-polarized (HH and VV) and cross-polarized (HV and VH) backscattering elements can be used to generate covariance and coherency matrices.

3. Filtering: To reduce the inherent speckle noise of the SAR data while keeping the polarimetric characteristics intact, polarimetric filtering of the data is required. MIDAS contains various amplitude and polarimetric filters. To preserve the edges, while sufficiently filtering the homogeneous regions, Refined Lee polarimetric filter is recommended.

4. Stokes Parameters and CPR: Characterization of a wave in terms of power (real only) values is quite useful and can be done using Stokes parameters. MIDAS supports calculating Stokes parameters and Circular Polarization Ratio (CPR) for both hybrid-polarization and full-polarization SAR data. In particular, for full-polarization data, the covariance matrix (C3) matrix is converted to a C2 matrix corresponding to Hybrid-Pol (CP) scattering elements[5] and are used for computation of Stokes parameters and CPR[6]. As DFSAR provides the first opportunity of full-polarimetric observations of the Moon, this feature of MIDAS enables CPR analysis using this data.

5. Polarimetric Decomposition: MIDAS has the functionalities to carry out various polarimetric decompositions for both full-polarimetric data and hybrid-polarimetric data. The major decomposition methods are as follows:

i. Polarimetric Entropy, Anisotropy and Alpha: The three eigenvalues of coherence matrix are used to derive three major polarimetric parameters named Entropy (H), Anisotropy (A) and Mean Alpha angle ($\bar{\alpha}$)[7]. Entropy (H) indicates degree of randomness in the scatterer and depolarization of the microwave energy. $H < 0.3$ implies scatterers are coherent and strongly polarized[8]. High entropy can be produced by distributed targets. Anisotropy is a measure of relative importance of second and third eigenvalues, generally used as a discriminating parameter in $H > 0.7$ cases. The mean alpha angle ($\bar{\alpha}$) describes the nature of scatterer along with the type of scattering triggered by the target. $\bar{\alpha} \leq 40°$ represents surface scattering, $40° < \bar{\alpha} \leq 60°$ is for volume scattering and $60° < \bar{\alpha} \leq 90°$ represents double bounce scattering from the target[7].

ii. Physical scattering model Decomposition: MIDAS has provision for Freeman-Durden (FD) and Yamaguchi decomposition methods (Y4O, Y4R and G4U). FD describes Bragg's scattering, orthogonal surfaces with different dielectric constants and randomly oriented dipoles to generate three components (odd, even and volume). Yamaguchi adds additional component (helix) by introducing the non-symmetrical cases for SAR observations. Y4R has orientation angle correction to its predecessor Y4O[9], [10] and hence, preferred.

iii. m-Delta and m-Chi (Raney): This feature of MIDAS is used to decompose Hybrid-pol data into odd, even and volume scattering using "degree of polarization" (m), δ (orientation) and χ (ellipticity) descriptors of Stokes parameters on Poincaré sphere[6].

iv. Geocoding and Ortho-rectification: The module for geocoding and ortho-rectification of DFSAR data using LOLA DEM is under development, and will be incorporated in a subsequent version of the MIDAS.

Results: The above mentioned modules are used to analyse L-band full-polarimetric Chandrayaan-2 DFSAR data acquired over Peary crater, North pole of the Moon. The fully-polarimetric data is first converted to coherency matrix (T3). Using *H-A-Alpha* module, the Entropy, Alpha and Anisotropy parameters are derived. Further, using *Yamaguchi Y4R* decomposition module the fully-polarimetric data is decomposed into odd, even, volumetric and helix scattering components. Using *CPR(FP)* module, the fully-polarimetric data is converted to hybrid-pol data and further CPR is calculated (Fig. 2). Similarly, the hybrid-pol data can be analysed using *m-Delta/m-Chi (CP)* module to derive child parameters such as Stokes parameters and scattering components from Raney decomposition.

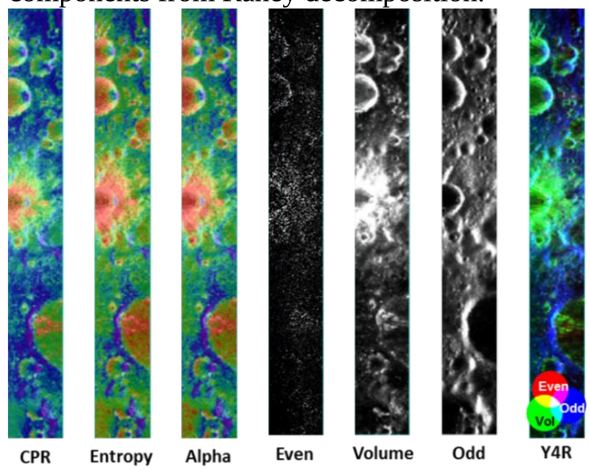

Figure 2: Polarimetric analysis of Chandrayaan-2 full-pol DFSAR data and derived products.

Comparison with other Software: The DFSAR results obtained from MIDAS software are compared with that obtained from ESA PolSARPro software, and successfully validated. For example, a comparison between CPR value derived from MIDAS and PolSARPro for L-band full-polarimetric DFSAR data is shown in Figure 3. The distribution of CPR in both the outputs from MIDAS and PolSARPro are same.

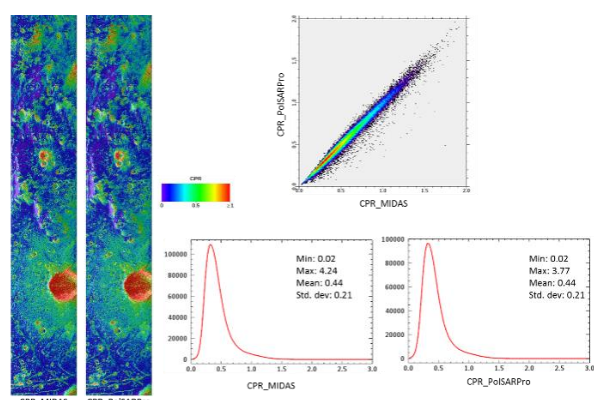

Figure 3: Comparison between distribution of CPR data derived using MIDAS and ESA PolSARPro.

References: [1] Putrevu, D. et al. (2016) *Adv. Space Res*., 57, 627-646. [2] Putrevu, D. et al., (2020), 51st LPSC, Abstract#1420. [3] Chakraborty T. et al., (2021), 52nd LPSC, Abstract#1447. [4] Bhiravarasu et al., (2021), PSJ, 2, 134, DOI: 10.3847/PSJ/abfdbf. [5] Raney, R.K. (2016) *IEEE GRSL*, 13 (6), 861-864. [6] Raney, R.K. et al. (2012) *JGR*, 117, E00H21. [7] Cloude, S.R., and Pottier, E. (1997) IEEE TGRS, 35(1), 68-78. [8] Singh, G. et al. (2013) *IEEE TGRS*, 52(2), 1177-1196. [9] Lee, J.S., and Ainsworth, T.L. (2010) *IEEE TGRS*, 49(1), 53-64. [10] Yamaguchi, Y. et al. (2010) *IEEE TGRS*, 49(6), 2251-2258.