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Short communication

Analysis of SCATSAT-1 Gamma-0 and Sigma-0 products for agricultural land use applications

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Satellite data has become an important aspect in modern agricultural studies due to its potential in assessing plant conditions over large areas and enabling site-specific crop management. SCATSAT-1, a satellite equipped with a Ku-band scatterometer primarily intended for monitoring wind patterns over ocean surfaces, its multifunctional capabilities has been extended to terrestrial applications, encompassing areas such as agriculture, land use and land cover classification (Singh *et al.,* 2020). This research investigates the utility of SCATSAT-1's backscatter coefficients, specifically gamma-0 and sigma-0, in the context of crop monitoring by assessing their performance across different surface types, including agricultural land, water bodies, barren areas, and urban settlements. Notably, gamma-0, which adjusts backscatter values according to the local incidence angle, shows significant promise for multi-temporal analyses due to its diminished sensitivity to angular fluctuations when compared to sigma-0. The findings provide valuable technical insights into the potential use of these products for crop monitoring and wider environmental research.

The study was conducted in southern Andhra Pradesh, India, within latitudes 16°25′61″ N to 18°90′5″ N and longitudes 80°21′39″ E to 82°21′48″ E. The region encompasses diverse surface types, including agricultural fields, barren land, water bodies, and settlements. SCATSAT-1 scatterometer data acquired in February 2022 were used for this analysis. Data pre-processing involved several critical steps, including radiometric calibration to address errors introduced by the system, geometric corrections to account for the satellite's viewing geometry and the curvature of the Earth, and the normalization of backscatter values to compute gamma-0. This computation utilized the formula $\Gamma = \sigma 0/\cos\theta$, where $\sigma 0$ signifies the backscatter coefficient and θ represents the local incidence angle (Adamala *et al.,* 2020). The backscatter coefficients for both HH and VV polarizations were calculated and examined to gain insights into the scattering characteristics of various surfaces.

Backscatter coefficients for different surfaces

SCATSAT-1's backscatter coefficients, sigma-0 and gamma-0, showed distinct responses across the four analysed surface types (Table 1).

***Rice fields (Agriculture)**:* Increased backscatter values were recorded for higher HH levels (-10.04 dB for sigma-0 and -8.28 dB for gamma-0), attributed to the irregular surface characteristics induced by dense vegetation and moisture presence (Lopez-sanchez *et al.,* 2012). The application of gamma-0 corrections, which mitigate the effects of angular discrepancies, yielded consistently elevated values in comparison to sigma-0. Conversely, VV polarization demonstrated reduced backscatter values (-12.47 dB for sigma-0 and -9.70 dB for gamma-0), indicative of interactions with canopy structure and sensitivity to moisture variations. These results highlight the efficacy of gamma-0 in the assessment of crop health and biomass.

***Barren land**:* Moderate backscatter values were observed, specifically -9.25 dB for HH sigma-0 and -7.40 dB (Table 1) for HH gamma-0, attributed to the rough texture of the surface and its low moisture levels. The observed difference of approximately -0.85 dB between HH and VV polarization suggests that the texture of the surface significantly influences the variability in backscatter. The normalization of gamma-0 enhanced the stability against angular distortions, thereby increasing its reliability for monitoring barren land (Parekh *et al.,* 2016).

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Table 1: SCATSAT-1 Backscatter coefficients of various surfaces

Surface	HH Sigma-0 (Avg)	HH Gamma-0 (Avg)	VV Sigma-0 (Avg)	VV Gamma-0 (Avg)
Rice	-10.04 dB	-8.28 dB	-12.47 dB	-9.70 dB
Barren land	-9.25 dB	-7.40 dB	-10.27 dB	-7.56 dB
Water	-12.21 dB	-10.16 dB	-13.15 dB	-10.39 dB
Settlements	-8.49 dB	-6.67 dB	-10.34 dB	-7.60 dB

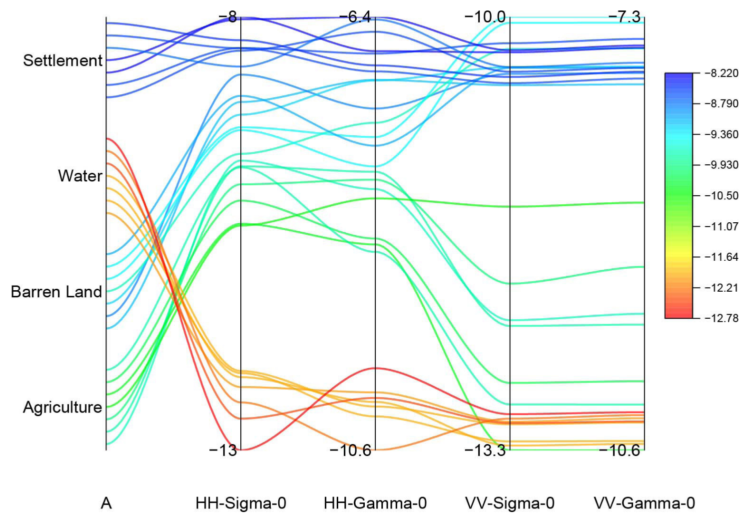

Fig. 1: Response of various surfaces at VV and HH polarisations

Water bodies: The characteristics of smooth surfaces led to the lowest recorded backscatter values, specifically -12.21 dB for HH sigma-0 and -10.16 dB for HH gamma-0, attributed to specular reflection. The slight variation of approximately 2 dB between sigma-0 and gamma-0 for water suggests a low level of angular sensitivity, highlighting their effectiveness in detecting water bodies and monitoring flood occurrences (Palakuru *et al.,* 2021).

Settlements*:* The maximum backscatter values recorded were -8.49 dB for HH sigma-0 and -6.67 dB for HH gamma-0, attributed to double-bounce scattering phenomena occurring from buildings and urban structures. The adjustments applied to gamma-0 significantly improved the distinction of urban characteristics, thereby proving to be advantageous for urban mapping and the analysis of infrastructure (Gamba and Dell'Acqua, 2009).

Gamma-0 vs. Sigma-0 comparison

The variation in gamma-0 and sigma-0 values across all surfaces consistently fell within the range of -1 to -3 dB (Fig. 1). This pattern underscores the effectiveness of gamma-0 in normalizing the incidence angle, which in turn mitigates angular distortions. These attributes are crucial for extensive, multi-temporal monitoring of agricultural landscapes. In the context of vegetation, gamma-0 exhibited greater stability across different incidence angles, thereby affirming its dependability for evaluating crop conditions.

Polarization insights

HH polarization consistently demonstrated elevated backscatter values compared to VV polarization across all examined surfaces. This phenomenon can be explained by the fact that horizontally polarized radar waves engage more effectively with vertically oriented structures, including plant stems and artificial edifices (Choudhury and Chakraborty, 2006; Palakuru *et al.,* 2020a). In the case of vegetation, the increased HH backscatter indicated surface roughness associated with healthy crops, whereas the reduced VV values represented the smoother characteristics of the canopy. The disparities in polarization between HH and VV further elucidated the density and roughness of vegetation canopies and various surface attributes (Rucha *et al.,* 2023).

Temporal and spatial relevance

The frequent revisit capability of SCATSAT-1 facilitates consistent temporal observations, which are essential for tracking dynamic phenomena, including vegetation phenology, stages of crop growth, and seasonal variations in soil moisture (Murugesan *et al.,* 2023; Palakuru *et al*., 2020b). Smooth surfaces, such as bodies of water, demonstrated stable backscatter characteristics over time, whereas urban and barren areas showed greater variability attributed to surface roughness and double-bounce scattering effects. These temporal observations highlight the satellite's efficacy in monitoring alterations (Palakuru and Yarrakula, 2019)

Surface-specific observations

Vegetation (rice)*:* Gamma-0 values ranging from -8 to -9 dB exhibited a strong correlation with both canopy density and biomass, establishing them as dependable metrics for monitoring crop health. The normalization procedure effectively minimized variability caused by angular distortions, thereby improving the precision of multi-temporal analyses (Fig. 1).

Water: The lowest gamma-0 values (-10 to -16 dB) confirmed smooth surface properties, aiding in flood monitoring and delineation of water bodies.

Barren land: Moderate gamma-0 values (-7 to -9 dB) reflected dry, rough conditions, providing insights into soil texture and aridity.

Settlements: High gamma-0 values (-6 to -7 dB) highlighted urban infrastructure and double-bounce scattering, making them suitable for urban mapping and infrastructure analysis.

The research highlights the effectiveness of SCATSAT-1 in delivering critical information for agricultural and environmental monitoring through its sigma-0 and gamma-0 backscatter data. The gamma-0 product exhibits diminished sensitivity to angular variations, which enhances its reliability for multi-temporal studies, especially in assessing crop health, estimating biomass, and examining vegetation phenology. The findings reveal a notable capacity for differentiating surface types: elevated gamma-0 values corresponded to dense vegetation and thriving crops, whereas lower values were indicative of water bodies and smooth terrains. Sigma-0 further enriched the analysis by measuring surface moisture and roughness, thus offering a more holistic evaluation of soil and crop conditions.

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