GAMMA-0 over Amazon Rainforest Calibration Site in Multifrequency Space-borne SAR

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ABSTRACT

Over the past decade, ISRO has launched a series of Synthetic Aperture Radar (SAR) missions to monitor Earth from space, covering a wide spectrum of SAR frequencies to support various scientific and environmental applications. Noteworthy missions include RISAT-1 and EOS-04, RISAT-2B and the upcoming **NASA-ISRO SAR (NISAR)** mission scheduled for launch in early 2025. Accurate calibration and stringent data quality standards are essential for ensuring that SAR data across these frequencies meet the high demands of scientific research and applications. The Amazon Rainforest serves as a critical site for radiometric calibration due to its natural homogeneity, isotropy, and stability, making it an invaluable target for antenna characterization and long-term data quality monitoring. This study examines the radar backscattering coefficient, Gamma-0 (γ^o), across multiple SAR frequencies to validate its invariability concerning incidence angles and swath regions. Focusing on C-band data from EOS-04 and X-band data from the RISAT-2B series, this analysis provides Gamma-0 values and standard deviations to assess calibration accuracy. Future work will extend this methodology to NISAR's L- and S-bands, aiming to establish a standardized, generic radiometric calibration tool for multifrequency SAR data across missions.

INTRODUCTION

ISRO has made substantial advancements in SAR technology, launching several SAR-enabled EO missions to support a diverse range of applications such as environmental monitoring, agriculture, disaster management, urban planning, and scientific research. These missions utilize various SAR frequency bands, each providing unique observational capabilities due to differences in frequency penetration and surface interaction characteristics. Key ISRO SAR missions include:

- **RISAT-1** & **EOS-04** in C-band for applications such as agricultural monitoring, soil moisture analysis, flood mapping etc.
- **RISAT-2B** in X-band, provides high-resolution data for defense purpose.
- **NISAR (NASA-ISRO SAR)**: An upcoming mission covering both L & S-band, expected to launch in 2025. NISAR is designed to enhance understanding of global environmental changes, contributing to studies in forestry, land cover changes, and ice dynamics.

The SAR frequency spectrum (X, C, S, L) covered by these missions serves as a foundation for a variety of scientific applications, which requires accurate and reliable calibration resulting into high-quality imaging. Radiometric calibration is particularly important to minimize measurement errors and to enable direct comparisons between data acquired at different times, incidence angles, and swath positions.

One of the most effective sites for SAR calibration is the **Amazon Rainforest**, a naturally homogeneous and isotropic extended target that has long been used by SAR missions globally for radiometric calibration, antenna characterization, and long-term data quality assessment. Here we investigate the invariability of γ^o backscattering coefficient over defined Amazon Rainforest area, using EOS-04 & RISAT-2B data.

METHODOLOGY

To assess the invariable nature of γ^o across SAR bands, a study window over the Amazon Rainforest is utilized (5^0 to 9^0 South & 65^0 to 69^0 West. The data is in both strip map & ScanSAR modes in Ascending/Descending passes (EOS-04) from April 2022 to July 2024 and all beam modes of RISAT-2B series is studied. The γ^o and its standard deviations, for all polarization (co-pol and cross-pol) are computed. The γ^o coefficient is expected to be stable, irrespective of incidence angle and swath, allowing for standardized monitoring across varied SAR systems. This analysis methodology includes:

Data acquisition and preprocessing; Calculation of Gamma-0 and standard deviation values over the defined Amazon window; Comparative analysis of co- and cross-polarization. Long-term time series generation for EOS-04 data to analyze any temporal shifts.

These steps aim to validate the stability and applicability of Amazon Rainforest as a radiometric calibration site across various SAR bands. This systematic methodology ensures a rigorous assessment of Gamma-0 stability and provides valuable benchmarks for calibrating SAR data in different frequency bands.

RESULTS

- ✓ Backscattered values (γ^0) along with Standard Deviation for 'X' and 'C' band are given in Table-1.
- ✓ Time series is generated for the C-band using EOS-04 (strip Map & Scan-SAR mode) since April 2022 till July 2024 shown in Figure 1.
- ✓ Gamma-0 is within specifications for both polarizations.
- ✓ The expected Gamma-0 values over the Amazon Rainforest is nearly -6.6dB/ 12.6dB ±1dB for co-pol/Cross pol.

Table-1 Results of Gamma-0 Backscatter for multi-frequency SAR data

Polarization	*X Band		C Band	
	Gamma-0	Std. dev.	Gamma-0	Std. dev.
HH	-6.03	0.6	-6.07	0.22
HV	NA	NA	-12.02	0.23
VV	-6.02	0.7	-6.89	0.12
VH	NA	NA	-11.76	0.22

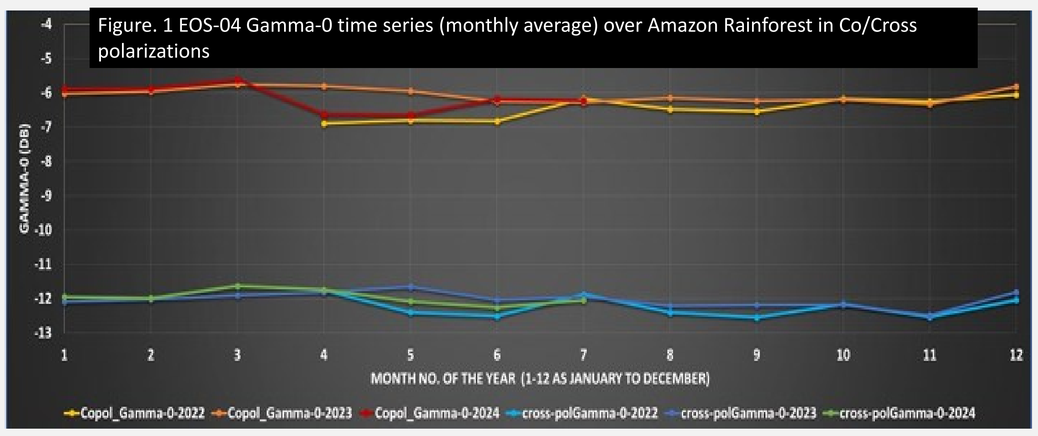
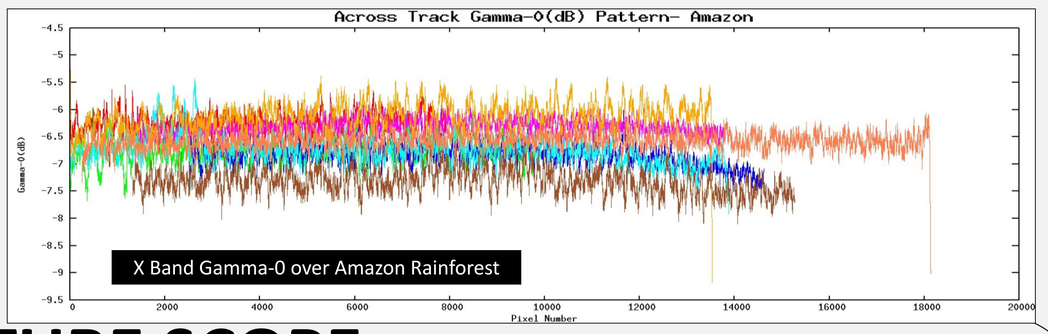


Figure. 1 EOS-04 Gamma-0 time series (monthly average) over Amazon Rainforest in Co/Cross polarizations



CONCLUSION AND FUTURE SCOPE

- This study reinforces the Amazon Rainforest's critical role in SAR radiometric calibration and long-term data quality monitoring.
- By validating the Gamma-0 stability across X-band and C-band data from RISAT-2B and EOS-04, this research confirms the rainforest's suitability as a benchmark site.
- The consistent backscatter values across various incidence angles and swath positions support the assumption that Gamma-0 remains invariable over homogeneous targets, underscoring its reliability for calibration purposes.
- Future work will extend this analysis to the L- and S-band data from the upcoming NISAR mission, which is anticipated to significantly broaden our understanding of radiometric calibration across a wider SAR frequency spectrum.
- This study also introduces a novel approach to developing a standardized the Software tool that can support multifrequency SAR missions across various agencies, ensuring data is compliant with international standards. Tool will facilitate cross-mission comparisons, foster collaboration, and contribute to a global framework for SAR data calibration and analysis.
- This contribution to the calibration field promises to enhance the scientific utility of SAR data, paving the way for more accurate and reliable Earth observation data across diverse applications, from climate change studies and environmental monitoring to disaster management and infrastructure planning.