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Integrating Ergodic Sampling in Gamma-Ray Spectrometry: A Case Study from Brazil's Carajás Province

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Introduction

The Carajás Mineral Province in northern Brazil is among the most prominent mineral belts worldwide, hosting extensive Cu–Au and iron ore deposits. Airborne gamma-ray spectrometry (AGRS) has been used extensively for regional geological mapping and mineral exploration. However, AGRS data acquisition can be costly especially when ensuring high data quality, which is often affected by survey overlaps, irregular flight paths, and radiometric noise, especially in areas with rugged topography and thick lateritic covers. In this study, we apply the ergodic sampling approach to optimize the processing of AGRS data from the Aquiri and Cinzento regions of Carajás. This method is designed to preserve spatial and spectral information of the original data while reducing sampling redundancy and improving interpretability in areas where survey boundaries intersect.

Method and/or Theory

This study presents an application of ergodic sampling, following the methodology developed by Zhang and Li (2023a), to airborne gamma-ray spectrometry (AGRS) data from the Aquiri and Cinzento regions. The ergodic approach identifies irregular and non-redundant sampling masks that retain the spectral and spatial integrity of the original dataset while reducing acquisition effort. AGRS grids for potassium, equivalent uranium, and equivalent thorium were subsampled using ergodic masks and subsequently reconstructed. For comparison, the same datasets were processed using standard interpolation and constrained inversion (Weihermann et al., 2021). To evaluate performance, we adopted the Information Sampling Ability (ISA) framework, which assesses spatial resolution, angular coverage, sampling density, and spectral fidelity. Benchmark comparisons were made against full-resolution datasets and conventional gridded approaches.

Results and Conclusions

Ergodic sampling produced reconstructed AGRS maps with high spatial fidelity, even when sampling density was significantly reduced. The method effectively preserved key geological patterns, suppressed line noise and interpolation artifacts, and improved the continuity of anomalies across overlapping survey zones. Notably, the denoising effect observed in the reconstructed AGRS data aligns with findings by Zhang and Li (2023b), who demonstrated that compressive sensing-based reconstructions can enhance data quality by attenuating incoherent noise during the signal recovery process. The approach was particularly effective in revealing subtle features associated with hydrothermal alteration and Cu–Au mineralization, demonstrating strong potential for optimizing airborne geophysical surveys in weathered tropical terrains. In regions such as Carajás, where acquisition conditions are often challenging due to dense vegetation and uneven topography, the enhanced performance of ergodic sampling highlights its practical value for improving data quality and survey efficiency.