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Study of Seismic Anisotropy in the Intraplate Provinces of South America using the Receiver Function

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Abstract

Observations of seismic anisotropy provide crucial constraints on dynamic processes in the crust and upper mantle, which are essential for understanding tectonic evolution. Receiver functions show the relative response of the structure beneath the receiver, allowing, for example, the study of anisotropy, particularly for the crust and upper mantle through waves converted at the Moho interface, along with methodologies such as Harmonic Decomposition and the Joint Objective Function. Preliminary results from 39 stations of the Brazilian Seismographic Network (RSBR) were analyzed, revealing a fast polarization direction predominantly aligned with local geological structures and with certain boundaries of South American tectonic provinces. Anisotropy magnitudes ranged from 0.1 to 1.0.

Introduction

Since the implementation of the Brazilian Seismographic Network (RSBR) in 2013, seismological studies in Brazil have significantly increased (Bianchi et al., 2018), driven by the expansion of monitoring stations. This progress enabled the use of methodologies like Receiver Functions (RFs), which analyze the geological structure beneath seismic stations through the conversion of P-waves to SV and SH waves. These analyses reveal discontinuities and anisotropy patterns in the crust and mantle, crucial for understanding tectonic processes. The study focuses on seismic anisotropy—the variation in wave velocity depending on propagation direction—using Harmonic Decomposition (HD) and Joint Objective Function (JOF) techniques. The geological context covers the formation of the South American platform, emphasizing the three geological provinces: Sedimentary Basins, Cratons, and Fold-Thrust Belts.

Method and/or Theory

This study implemented two complementary techniques using Seispy (Xu & He, 2023) to analyze seismic anisotropy across three distinct geological provinces. First, HD (Bianchi et al., 2010) (Figure 1) was applied to analyze RFs, breaking them down into harmonic components (k=0, k=1, k=2) representing isotropic and anisotropic variations. This approach visualized RF amplitude as a function of backazimuth, identifying anisotropy patterns linked to geological interfaces. Next, JOF (Liu e Niu, 2011) (Figure 2) method estimated Fast Velocity Direction (FVD) and τ (Delay Time), quantifying wave propagation direction and anisotropy-induced delay. The JOF combined maximizing radial (R) energy and minimizing transverse (T) energy, ensuring a robust analysis of shear-wave splitting.

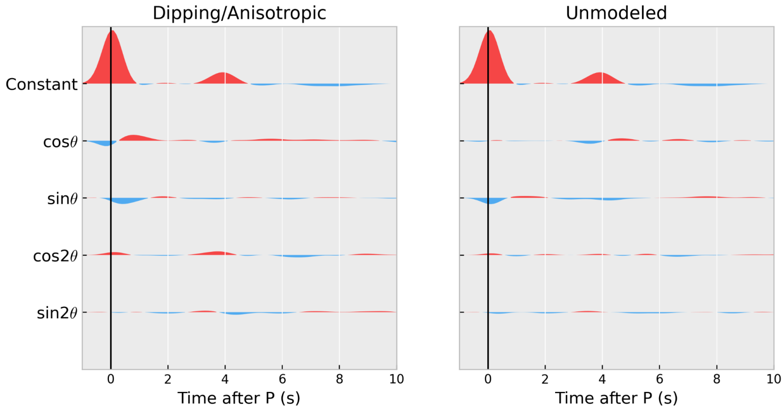

Figure 1: Application of Harmonic Decomposition. Results from the decomposition of receiver functions into harmonics on ARAG, highlighting anisotropy patterns in the subsurface structure.

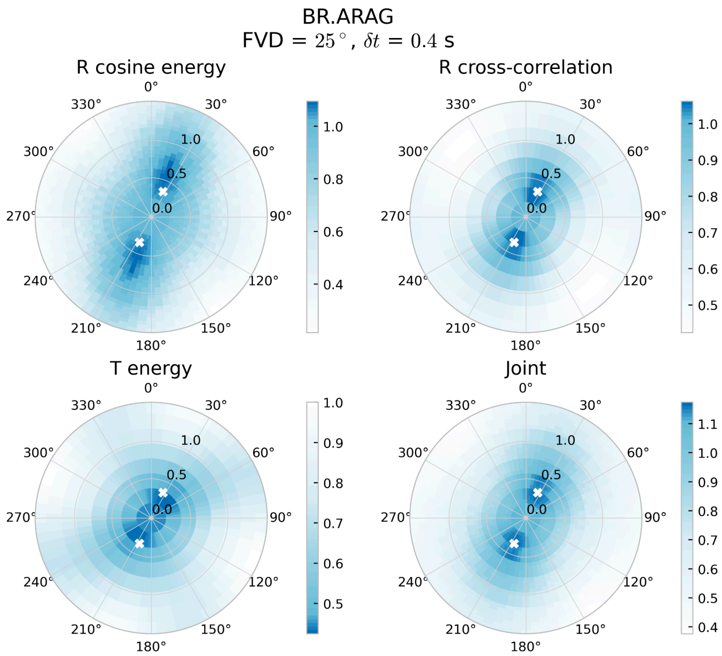

Figure 2: Application of the Joint Objective Function (JOF) method. Results showing: (a) Fast Velocity Direction (FVD) and Delay Time (τ) parameters; (b) cosine energy of the R-component; (c) cross-correlation of the R-component; (d) energy of the T-component; and (e) joint objective function analysis.

Results and Conclusions

Preliminary results showed significant variations in anisotropy parameters across stations. FVD ranged between 0° (North) and 330° (Northwest) and τ (Splitting Time) values were 0.1–1.0s. Valid event counts varied per station (147 to 515), reflecting data availability and quality control. Figure 3 displays the Fast Velocity Direction and Splitting Times across the study area. The directional patterns show strong alignment with major geological structures (e.g., Transbrasiliano Lineament). Additionally, we observe evidence linking anisotropy patterns to geological province boundaries, as exemplified by the western margin of the Paraná Basin.

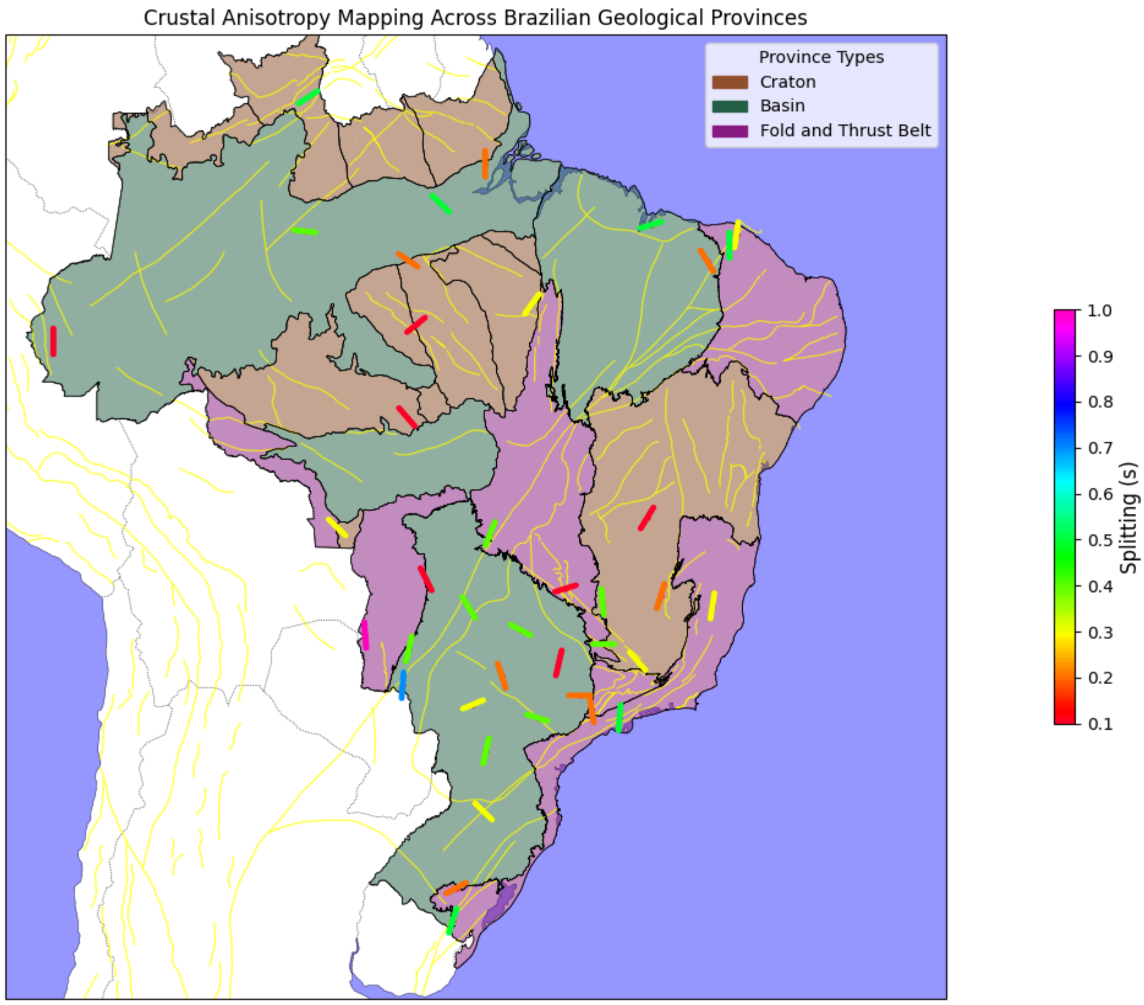

Figure 3: Figure 3: Regional map of Brazil showing (a) geological provinces (Cordani et al., 2016) (sedimentary basins: green; fold-thrust belts: purple; cratons: brown), (b) tectonic structures (Gómez et al., 2018) (yellow), and (c) seismic anisotropy measurements (FVD = bar azimuth; τ = color-coded values).

Conclusions

This study utilizes harmonic decomposition and joint objective function analysis of RSBR data to reveal that seismic anisotropy patterns across Brazil's intraplate provinces consistently align the fast velocity direction (FVD) with major tectonic structures (e.g., the Transbrasiliano Lineament) and provincial boundaries (e.g., western margins of the Paraná Basin). Measured delay times (τ = 0.1–1.0 s, mean = 0.4 s) show systematic spatial variations, with elevated values particularly evident at belt-basin transition zones, such as along the Paraná Basin margins.

Acknowledgments

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