Rayleigh Wave Tomography of the South American Platform: Preliminary Results of the BLSP02 Project

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Abstract

Rayleigh waves from teleseisms recorded by BLSP portable stations and GSN permanent stations in South America are used to estimate lithospheric structure of the major geological provinces of the Brazilian platform. A 2D tomographic inversion is applied to Rayleigh wave group velocities to determine local velocities inside blocks of 3°×5°. With the regionalized dispersion curves, 1D S-wave velocity inversions were carried out for each block, giving a final 3D S-wave velocity model. Both the 2D Rayleigh wave group velocity and the 3D S-wave velocity maps show low velocities in the Andean region and high velocities in the Amazon craton. Waveform modeling, another technique with better resolution than group velocity inversion, is being applied to the teleseismic records to get the average 1D S-wave velocity profile for each event-station pair. Preliminary results of the 1D waveform modeling confirm the low velocities in the upper mantle beneath the Chaco basin.

Introduction

The upper mantle of the stable South American platform has not yet been imaged adequately by previous tomographic studies due to the insufficiency of seismological stations, especially in Northern and Northeastern Brazil. For the same reason, there are relatively few studies of surface waves in this stable platform. New portable broadband stations have been installed recently in Northern and Northeastern Brazil to improve the path-coverage in these regions in a joint project between IAG-USP and the Institute of Geophysics of the Federal Technology Institute, Zurique, Switzerland (ETH-Z), named Brazilian Lithosphere Seismic Project 2002 - BLSP02. We want to map the lithospheric/ asthenospheric structure of the mainly Archean and Proterozoic platform of Brazil. Records from all BLSP portable stations and the permanent GSN stations in South America are collected with emphasis on purely continental paths. Using this data set, the upper mantle of the South American platform is studied using both the group velocity inversion of fundamental mode Rayleigh waves and the waveform inversion of the fundamental and higher mode Rayleigh waves. Preliminary results of the group velocity inversion will be shown here.

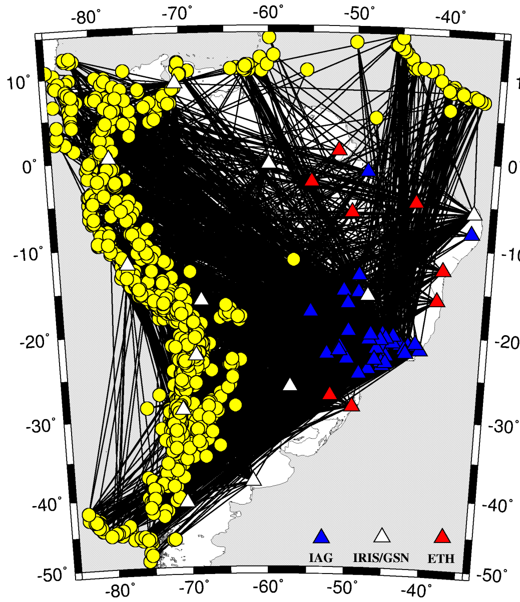

Fig. 1. Epicenters (yellow circle), stations (triangle) and paths (black lines) used in the Rayleigh wave group velocity tomography for the period of 50 second.

Rayleigh wave group velocities

2D Rayleigh wave tomography

Rayleigh wave group velocities, in the period range of 10~150s, were determined by multiple filtering techniques (Dziewonski et al., 1969) for about 1000 records of GSN stations and about 1500 records of BLSP stations. Fig. 1 shows the epicenters, stations and paths used in the tomographic inversion for the period of 50s. More detailed path coverage for NE and northern Brazil is now possible, compared with the more regional, larger scale previous tomographic studies of South America (Vdovin et al., 1999, Heintz et al., 2001). 2D tomographic inversion is applied to the Rayleigh group velocities to get the local dispersion inside blocks of 3°×5°. Smoothness constraint is applied to regularize the inversion giving smoother velocity distribution in the poorly covered regions. The Rayleigh wave group velocities and their uncertainties for the period of 50s are shown in Figs.2a,b. The Andean region showed the lowest group velocities; high velocities are observed in the Guyana shield, in the NE Brazil fold belt and the southern part of São Francisco craton, similar to the previous group velocity map of Vdovin et al.(2001). In addition, a low velocity anomaly was found to extend through the whole Chaco Basin, to the west of the Paraná Basin. Along the Amazon River basin, the group velocities are generally lower than in the shield, which had not been revealed by previously. Comparing with the results of Vdovin et al. (2001) whose resolution ranges between 6° and 8°, our results indicates a resolution of about 5°. On the other hand, Vdovin et al. used many mixed paths with both oceanic and continental parts while we mostly purely continental paths reducing errors caused by lateral refraction effects. The average group velocity uncertainty (Fig. 2b) is about 0.1 km/s for the 50s period, with well covered regions having smaller uncertainties, as expected.

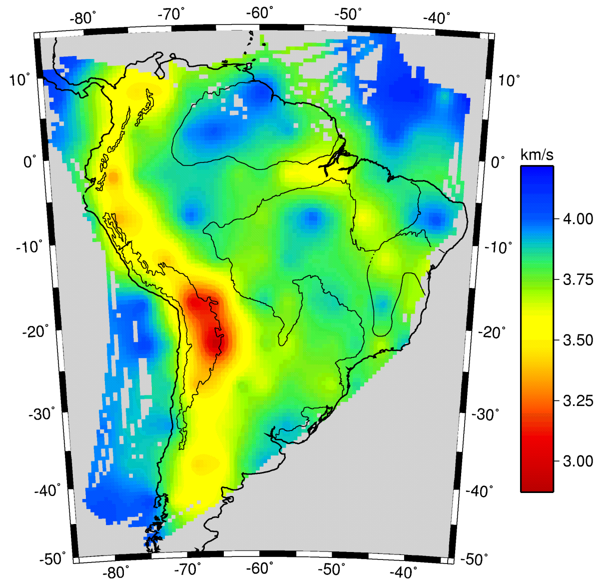

Fig. 2a). Rayleigh wave group velocities for 50s.

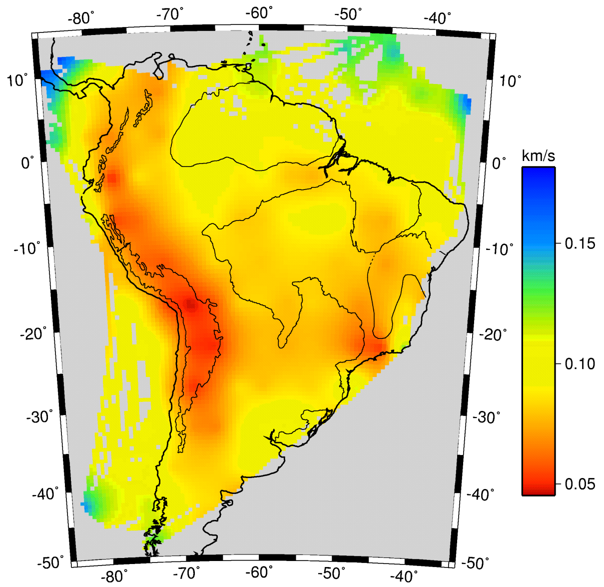

Fig. 2b). Uncertainties of Rayleigh wave group velocities for 50s.

3D S-wave model

The 2D group velocity tomography resulted in a local Rayleigh wave dispersion curve for each block. 1D S-wave velocity inversions were carried out for each block providing a final 3D S-wave velocity model. The 1D velocity-depth profiles were determined with a linearized inversion (*surf96* package of Herrmann et al., 2002) by iteratively perturbing an initial IASP91 model, with fixed layer thicknesses. Smoothness constraint was applied to prevent large velocity contrasts between adjacent layers in depth but not laterally across the blocks, as each block was inverted independently. Fig. 3 shows the relative Vs perturbation with respect to the IASP91 model at 100km depth. The highest velocity anomalies were found in the Amazon craton. Relatively high velocities are seen in the southern part of the São Francisco craton and beneath the NE part of the Paraná basin. The Andean region has generally low velocities, except near Peru (about 5°S 78°W) and central Chile (32°S, 68°W), as found previously by Van der Lee et al.(2001) and Heintz et al.(2001), due to the flat subduction of the Nazca plate. Low velocities seem to extend from the Andean region to the Chaco and Pantanal basins. In addition to general agreement with previous works, our 3D S-wave model shows two low velocity anomalies in the equatorial margin: a strong anomaly in the Ceará margin (3°S, 40°W) and a weaker near the Amazon cone, an area not covered by Van der Lee et al(2001). Heintz's model shows the same pattern in this margin, although with different amplitudes.

Group velocities do not have the same resolving power for upper mantle structure as waveform modeling. However, the similarities with previous models do show that a large dataset with purely continental paths can add important information for upper mantle studies and encourage us to do further analysis with more data.

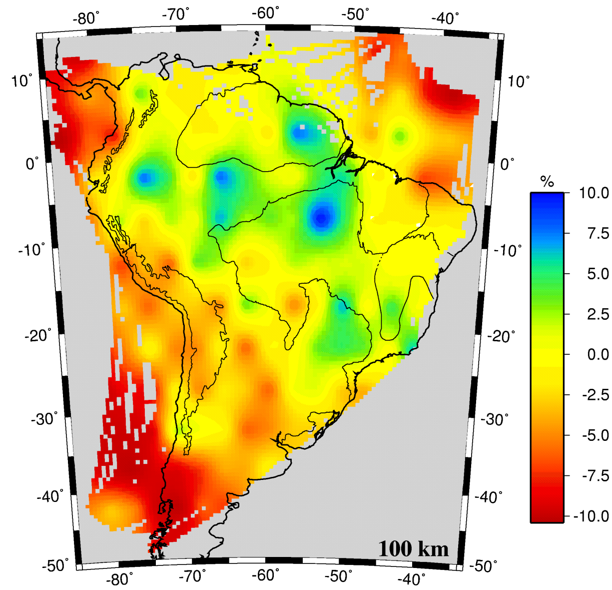

Fig. 3. S velocity perturbations relative to the IASP91 model at 100km depth (reference velocity of 4.49 km/s).

Waveform modeling

Waveform modeling makes use of the full information contained in the train of surface waves (fundamental and higher modes) and body waves, resulting in better resolution than methods that only use discrete data like arrival times and group velocities. However, waveform modeling requires well-determined focal mechanism for each event, which implies that only large events can be used. In this project, the Partitioned Waveform Inversion method (Nolet, 1990) is utilized to realize our 1D waveform fittings. For each event-station pair, an initial 1D S velocity model is iteratively perturbed until a good match is found between synthetic and observed seismograms. Fig. 4a shows four examples of paths crossing different geological provinces for which 1D waveform fittings were carried out. The initial IASP model was used for all four paths. The waveform fitting and the 1D S velocity model for the path to the station BAMB are shown in Fig. 4b. The synthetic waveform (dashed line in the left part of Fig. 4b) fits very well the observed waveform (solid line in the left part of Fig. 4b) which implies that our inverted model is reliable. The inverted 1D S velocity model (dashed line in the right part of Fig. 4b) presents a low velocity anomaly (asthenosphere) with respect to the initial IASP model (solid line in the right part of Fig. 4b). The model for the path to station DAEB (Fig. 4c) presents the same low velocity anomaly as BAMB at 200km depth. Both paths include a large proportion of the Andean region and the Chaco Basin where the group velocity results in the previous part of this paper also showed low velocities. The model for the paths to PDCB (Fig. 4d) which is a long mixed path crossing different geological units shows little difference with the IASP model. The path to PORB, predominated by the Brazilian shield, shows high velocities in the upper mantle. The presence of a strong asthenosphere only in the paths to BAMB and DAEB is consistent with the upper mantle low velocity anomaly observed beneath the Chaco basin by Van der Lee et al.(2001) and Heintz et al.(2001).

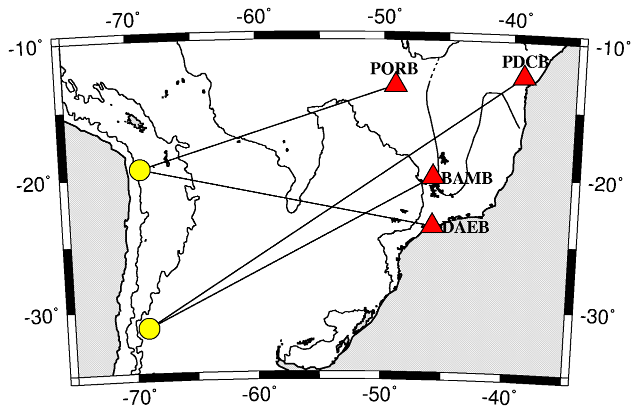

Fig. 4a Examples of four paths crossing different geological units used in the 1D waveform inversion.

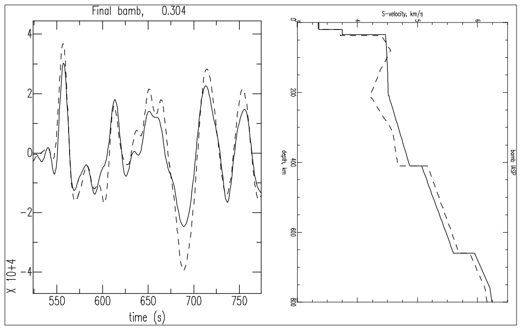

Fig. 4b) Waveform fitting and 1D Vs model for the path to the station BAMB. The left part shows the synthetic (dashed line) and the observed (solid line) waveforms. The right part is the final inverted Vs model (dashed line) and the initial IASP model (solid line).

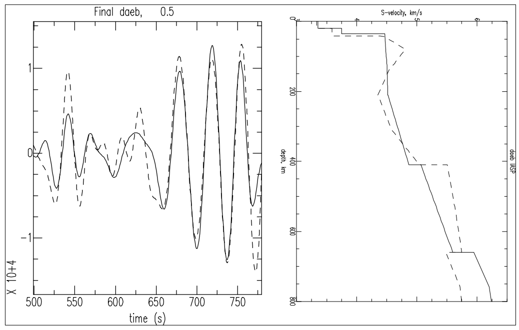

Fig. 4c) Waveform fitting and 1D Vs model for the path to DAEB.

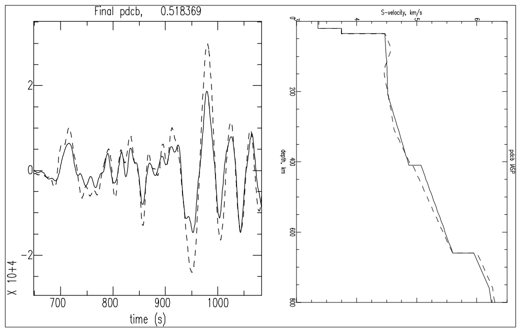

Fig. 4d) Waveform fitting and 1D Vs model for the path to PDCB.

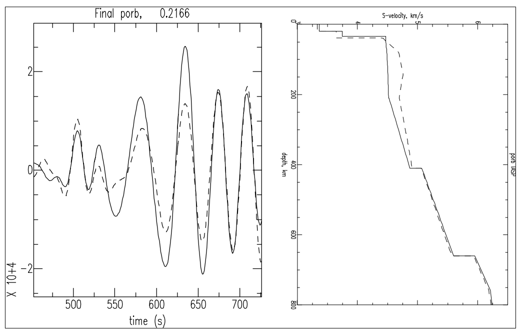

Fig. 4e) Waveform fitting and 1D Vs model for the path to PORB.

Conclusions

Though this work is still in progress, the preliminary results of group velocity inversion and the waveform modelings not only showed good compatibility with results of previous works but also revealed new anomalies in the South American platform. Our study will improve the surface wave coverage in northern and northeastern Brazil and provide important information about the lithospheric structure in those regions. The good quality and the compatibility between the results of the group velocity and the waveform inversions encourage a simultaneous inversion with both group velocity and waveform data to get a 3D S-wave velocity model.

Acknowledgements

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