# Preliminary estimates of Upper crustal thickness using Reciever Function for stations of the Seismic Observatory of the University of Brasília.

Ruan Roussenq Alves, César Garcia Pavão, Diogo Farrapo Albuquerque, George Sand França, Instituto de Geociências, Observatório Sismológico (SIS), IG-UnB.



## Abstract

The use of geophysical techniques for better understanding geological features and discontinuities within the earth is of great importance for man to know about the interior of our planet. The Reciever Function by Langston (1979) was the tool chosen for this work to such study. Brazilian researchers have been using for years Reciever Function to make estimates of crustal thickness and Vp/Vs ratio. Were used for this work six stations: BRA7 (BSB), CAN3 (Cana Brava Power Plant, GO-TO), FOR1 (Fortaleza-CE), JAN7 (Itacarambi-MG), PDRB (Porto dos Gauchos-MT) and TUCA (Tucurui-PA), that can be seen in Picture 6, and we used then trying to determine the upper crust thickness and their Vp / Vs ratios. Besides the Receiver Function in the frequency domain, PWSS by Bianchi (2008) was also used for such estimates of the upper crust. We achieved good results with almost stations, only TUCA (Tucurui-PA) station did not provide data, maybe because it is defective.

## Introduction

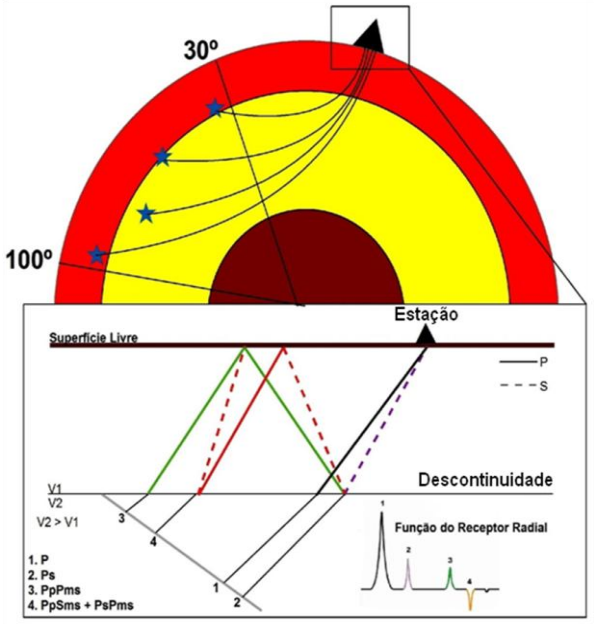
The crustal Brazilian study has been done in recent years with the help of Reciever Function(RF) by Langston (1979), a tool that is used extensively for such studies, and PWSS by Bianchi (2008), which is a relatively new tool that will help us in this study . Thus, we have had advances to a better understanding of the evolution of geological features found within the earth. In this project, this technique was used to study the relationship between upper crust and lower crust.

So that we could study this relationship, we used a network of broadband stations spread throughout Brazil and teleseismic events captured by such stations. These stations are located in five tectonic provinces: Amazon, Borborema, Parnaiba, San Francisco and Tocantins. As these provinces encompass a large area of Brazil we might have an idea of how the upper crust behaves in different geological features found outside the country.

Our main goal of this work is to find the right thickness and Vp / Vs ratio of the upper crust, so with that we can better understand the geological differences of Brazil crust.

## Method

Reciever Function by Langston (1979) is a very important tool for estimating crustal thickness which is directly below the station. For this teleseismic events are used, which have an epicentral distance between 30 and 90 degrees. This study is based on the fact that when a P wave passes through discontinuities, such as between upper crust and lower crust that is called Conrad, even between crust and mantle, there is a conversion of its energy into another type of wave called S, the conversion is called Ps. In Reciever Function, the axes are rotated in order to have the arrival of the P wave directly on these axes, they are called radial and tangential. These axes are rotated depending on how the P wave arrives at the station. The answer we get from the Reciever Function is the deconvolution of the radial component from the vertical, thereby the reciever reponse is isolated, thus giving us the representation of the phases and their multiple reflections.




Picture 1 – Simplified ray diagram showing the major conversion of the P wave to S wave that compose the RF radial. Except for the first arrival, the capital letters denote the route to low, lower case letters denote the route to up.

PWSS (Phase Weighted Slant Stacking, Bianchi, 2008) is a tool that eliminates stacked signals that are not consistent. Involving the phase stacks as a consistent measure we can sum the seismic traces. The main goal in this technique is to make the phase stacks have time-weight independency of the linear stacks.

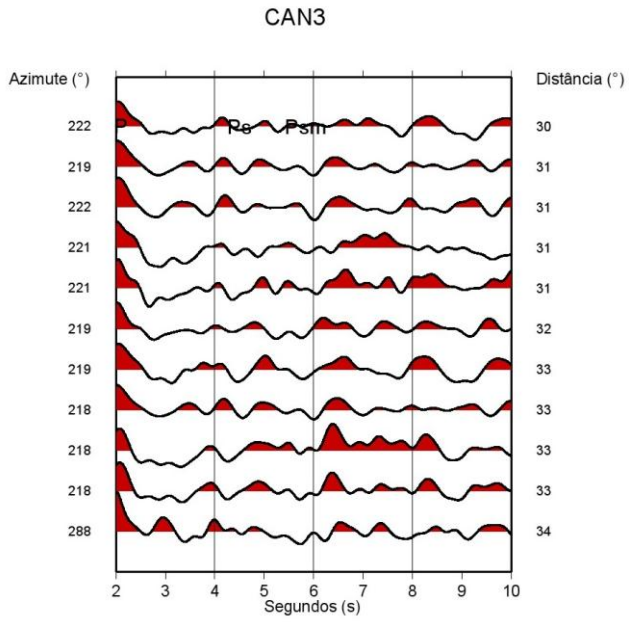
**Data processing**

In the Reciever Function, the value used in the gaussian filter was 5, which represents a low pass filter cutoff equal to 2,5 Hz, and the best water level values were found between 0.001 and 0.0001.

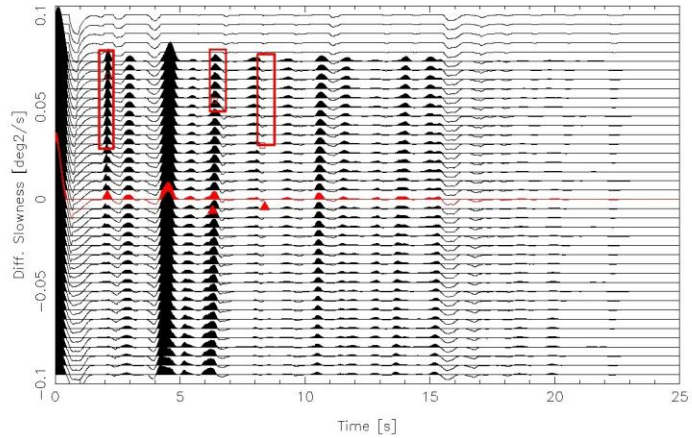
First a visual screening was done by SAC (Seismic nalysis Code, Goldstein & Snoke, 2005), then we used the receiver function for choosing the best traits. Finally, PWSS (Phase Weighted Slant Stacking, Bianchi, 2008) was used for the stacking and final data analysis. The teleseismic events that were used had the epicenter between 30 and 100 degrees, with magnitudes above 4.5.

**Results and Discussion**

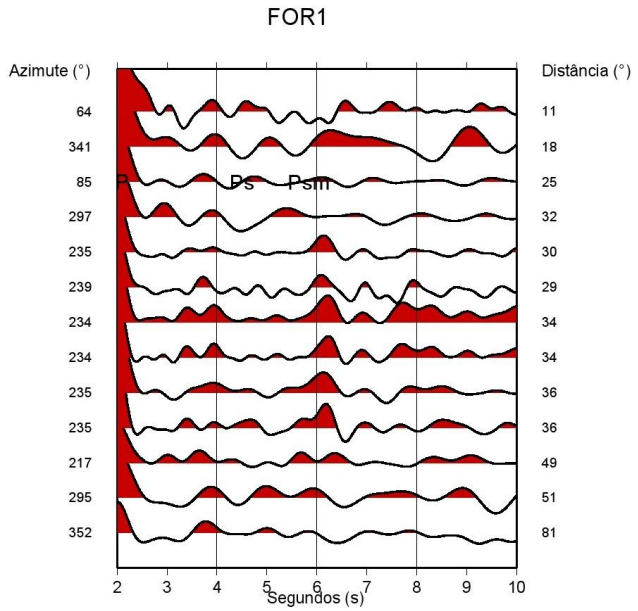
Pictures 1 and 3 show the results obtained from the Receiver Function in the frequency domain for CAN3 and FOR1 stations, the images 2 and 4 show the results obtained of PWSS for the stations already mentioned above. All the results are shown in the Table 1 for each station.



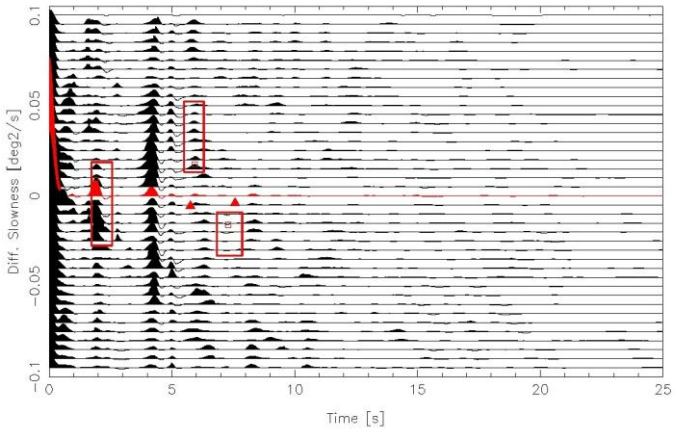

*Picture 2 – Receiver Function for seims of different azimuth and distance of the CAN3 station. Horizontal axis show the time in seconds and vertical axis show azimuth and epicentral distance.*




*Picture 3 – PWSS for the CAN3 station with crustal thickness of* 14,91±0,48 *and Vp/Vs of* 1,80±0,04*.*



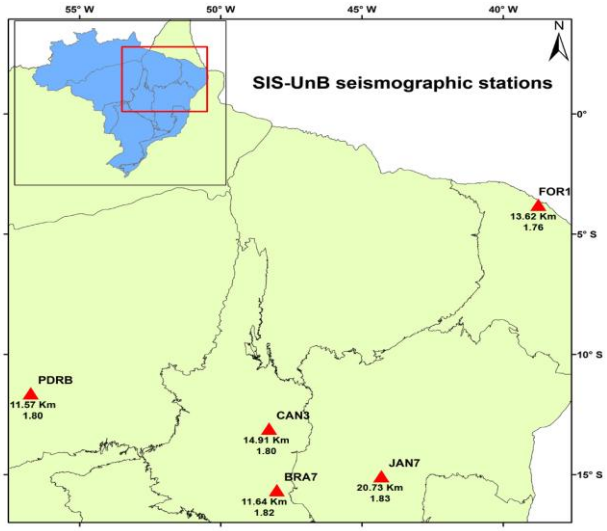

*Picture 4 – Receiver Function for seims of different azimuth and distance of the FOR1 station. Horizontal axis show the time in seconds and vertical axis show azimuth and epicentral distance.*




*Picture 5 – PWSS for the FOR1 station with crustal thickness of* 13,62±1,22 *and Vp/Vs of* 1,76 ± 0,12.

*Table 1 –Shows the results of depth, velocity of the P wave (Vp) and the velocity ratio between the O and S waves (Vp/Vs) for the several seismological stations.*

| Station | Depth (Km) | Vp (Km/s) | Vp/Vs |
|---|---|---|---|
| **BRA7** | 11,64±0,31 | 6,1 | 1,87±0,04 |
| **CAN3** | 14,91±0,48 | 6,1 | 1,80±0,04 |
| **FOR1** | 13,62±1,22 | 6,1 | 1,76±0,12 |
| **JAN7** | 20,73±0,19 | 6,1 | 1,83±0,01 |
| **PDRB** | 11,57±0,99 | 6,1 | 1,80±0,14 |
| **TUCA** | XXX | XXX | XXX |




*Picture 6 –Shows the results of depth and Vp/Vs ratios for the several seismological stations.*

From the results, we can see from Pictures 1 and 3 which represents the responses of Reciever Function, there is a clear alignment to aproximately 2s after of the P wave arrival, which represents the P wave which has been transformed in Ps. In the other 3 stations we didn't had a good result as the one we got of CAN3 and FOR1.

In images 2 and 4, the first mark is the Ps wave, since the other two markings are its multiple. The best result was of CAN3 for having very clear phases. We have seen in the alignments of FOR1 stations, but the second multiple is not so clear. The results obtained in the other three stations were inferior of the both shown at the work, but we can identify phases with some effort.

## Conclusion

With this work we could prove from the obtained results by receiver function the existence of a discontinuity between the upper and lower crust from the phase alignment that is around two seconds, which would be the Conrad discontinuitie, even the existence of a discontinuity between the crust and mantle called Mohorovicic. This shows the efficiency of this method, along with the PWSS who gave us good results in thickness and Vp / Vs ratios. The data of BRA7, FOR1 TUCA stations will be revised so that there will be a reduction of errors in the results. In the future we will try to get a geological correlation to justify these estimates.

## Acknowledgements

The authors would like to thank the Seismological Observatory, for providing the seismographic data and facilities to work; the Program of Undergraduate Research of the Deanship of Research and Post-Graduation of the University of Brasília; and Marcelo Bianchi A, Goldstein & Snoke for the programs available.

## References

Langston, C.A., 1979. Structure under Mount Rainier, Washington, inferred from teleseismic body waves. *J. Geophys. Res.* 85, 4749–4762.

Diogo Farrapo Albuquerque, César Garcia Pavão, George Sand França & Paulo Gustavo N. Silva, Instituto de Geociências, Observatório Sismológico (SIS), IG-UnB.

Albuquerque et al. O Estudo da espessura crustal e razão Vp/Vs para as estações da Rede Sismográfica Nacional (RSN-SIS-UnB). IV Simpósio Brasileiro de Geofísica

Ammon, C.J., 1991. The isolation effects from teleseismic P-waveforms. *Bull. Seism. Soc. Am.* 81, 2504–251

Ammom, C. J., G. E. Randall & G. Zandt, 1990. On the nonuniqueness of receiver functions inversions, *J. Geophys. Res.*, 95, 15303-15318.

Asmus, H.E. & Baisch, P.R. - 1983 - Geological evolution of the Brazilian continental margin. Episodes, 4: 3-9.

Assumpção, M., An, M., Bianchi, M., França, G.S.L., Rocha, M., Barbosa, J.R., Berrocal, J., 2004. Seismic studies of the Brasília Fold Belt as the western border of the São Francisco Craton, Central Brazil. Tectonophysics, 388: 173-185.

França, G.S.L., 2003. Estrutura da crosta no Sudeste e Centro-Oeste do Brasil usando a Função do Receptor. Tese de Doutorado, Instituto de Astronomia, Geofísica e Ciências Atmosféricas-USP (São Paulo, Brasil), 143 p.

Maria, F N B. Estimativa de espessura crustal na província Borbotema (NE/Brasil) através de Função do Receptor. Dissertação de mestrado $N^{0}$70/PPGG.

Pavão, C. G., 2010. Estudo de descontinuidades crustais na Província Borborema usando a Função do Receptor. Dissertação de mestrado, Programa de Pós Graduação em Geociências Aplicadas, Instituto de Geociências, Universidade de Brasília, 143 p.

Castro, D.L., W. E. Medeiros, E. F. Jardim de Sá, & J.A.M. Moreira, J.A.M. 1998. Mapa gravimétrico do Nordeste Setentrional do Brasil e margem continental adjacente: interpretação com base na hipótese de isostasia. *Rev. Bras. Geof.*, 16 (2/3):pp 115-131.

DNPM, 1984, Geologia do Brasil, Divisão de geologia e Minerologia, Departamento Nacional de Produção Mineral, 501p.

Jardim de Sá, E.F. - 1994 **-** A Faixa Seridó (Província Borborema, NE do Brasil) e o seu significado geodinâmico na Cadeia Brasiliana/Pan-Africana. Tese de Doutorado, UnB, Brasília, DF, 804 pp.

Matos, R.M.D. 1992 . The northeast brazilian rift system. *Tectonics*, 11 (4): pp 766-791.

Mooney, WD, Laske, G. and Masters, G., 1998. CRUST 5.1: A global crustal model at 5°x 5°. *J. Geophys. Res.*, 103, 727- 747.

Thiago N. C. Estudo de espessura sedimentar na Bacia do Paraná com função do receptor de alta frequência. Dissertação de mestrado, ao Institudo de Astronomia, Geofísica e Ciências Atmosféricas/USP,São Paulo, Brasil,91pp.

Ussami, N. N. C. Sá & E. C. Molina, 1993. Gravity Map of Brazil, 2. Regional and residual isostatic anomalies and their correlation with major tectonic provinces. *J. Geophys. Res.*, 98: 2199-2208.

Vilar C. S., 2004, Estrutura tridimensional da onda S na litosfera do Nordeste Brasileiro. ON/MCT:pp 257.

Zandt, G., S. C. Myers & T. C. Wallace, 1995. Crust and mantle structure across the Basin and Range-Colorado Plateau boundary at 37° latitude and implications for Cenozoic extensional mechanism, *J. Geophys. Res.,* 100, B6, 10529-10548.

Zhu, L., and H. Kanamori, 2000. Moho depth variation in southernCalifornia from teleseismic receiver functions, *J. Geophys. Res.*, 105 , 2969–2980.