The Journal of Open Source Software

rfsed: Receiver function analysis and dealing with sediment effects

Stephen Akinremi [1], **Islam Fadel** [1], **and Mark van der Meijde** [1]

1 Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, The Netherlands

DOI: 10.21105/joss.06612

Software

- Review
- Repository
- Archive

Editor: Jayaram Hariharan

Reviewers:

- @paudetseis
- @alistairboyce11

Submitted: 25 January 2024
Published: 21 August 2024

License
Authors of papers retain copyright and release the work under a Creative Commons Attribution 4.0 International License (CC BY 4.0).

Introduction

The receiver function technique is a well-established technique to image velocity contrasts in the subsurface (such as the crust-mantle boundary - Moho) using isolated P–to-S wave conversions (P-receiver functions) and the reverberations generated at such discontinuities. Several methods such as H-k stacking (Zhu & Kanamori, 2000), have been developed to investigate the average crustal thickness and Vp/Vs ratio using receiver functions. However, the presence of a near-surface low-velocity sedimentary layer can obscure Moho phases due to the additional P-to-S wave conversions and associated reverberated phases created at the sediment-basement discontinuity. These additional intra-crustal phases can have large amplitudes and similar arrival times as the Moho phases, which makes it difficult to retrieve Moho information using standard receiver function techniques.

Statement of need

`rfsed` is a Python software for receiver function analysis that includes methods for dealing with sediment effects. `rfsed` presents a new approach for retrieving reliable crustal thickness and Vp/Vs from stations overlying sedimentary layer. The technique derives sediment thickness and Vp/Vs using H-K stacking of the high-frequency receiver function, followed by a waveform fitting approach to retrieve the average crustal thickness and Vp/Vs (Akinremi et al., 2024). Moreover, `rfsed` contains implementations of the most common receiver function approaches for dealing with the sediment effect with possible synthetic testing capabilities.

Key Functionality

`rfsed` contains modules to carry out H-k stacking (Zhu & Kanamori, 2000), sequential H-k stacking (Yeck et al., 2013), resonance filtering and modified H-k stacking (Yu et al., 2015), and waveform fitting (Akinremi et al., 2024) with possible synthetic waveform generation for 1D earth models to test the different methods. It comes with tools to create high-quality figures, which include result plots for H-k stacking, sequential H-k stacking (e.g., Figure 1), resonance filtering, and waveform fitting methods (e.g., Figure 2). Besides these methods, `rfsed` has modules for extracting earthquake waveforms from local seismic record files. There are multiprocessing options for waveform fitting and extracting earthquake data from local seismic record files for higher efficiency.

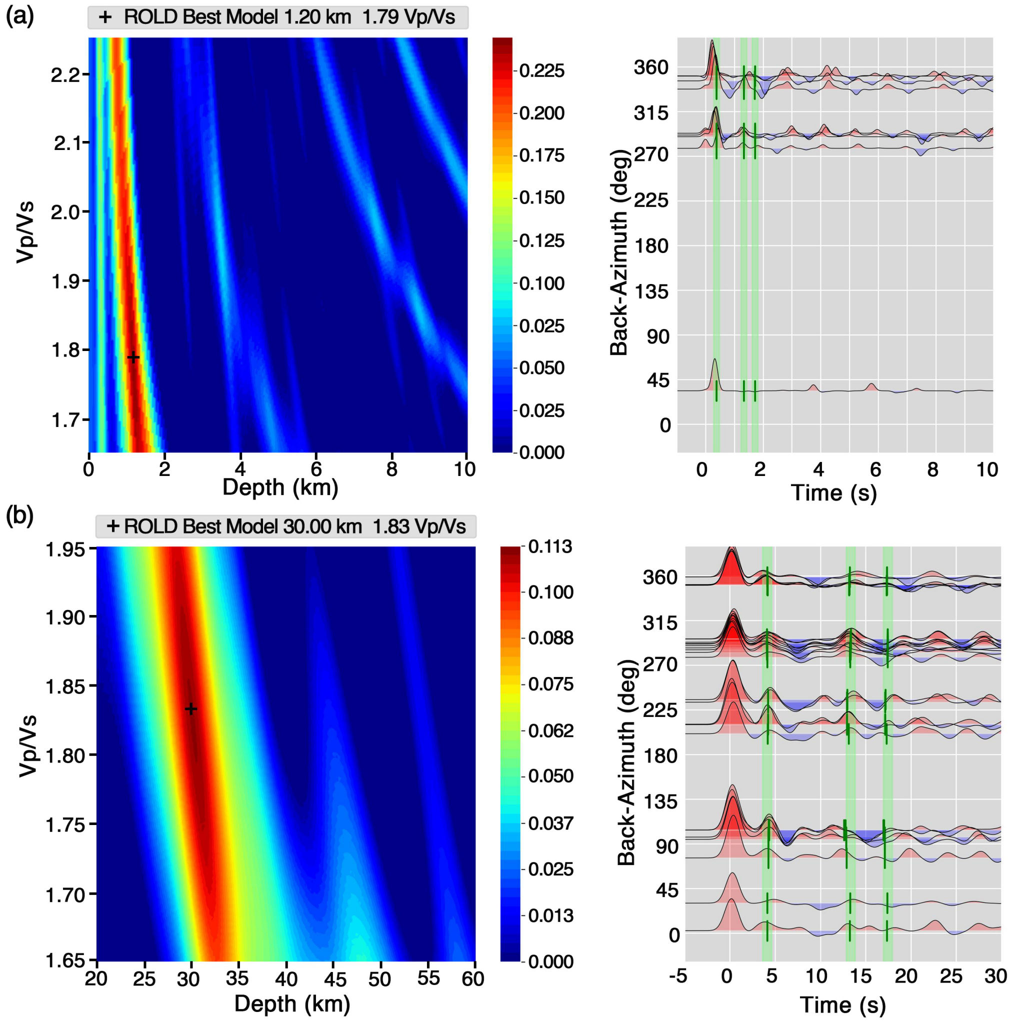

Figure 1: Example of a sequential H-k stacking plot for receiver functions obtained from station ROLD (Network: NL) (a) sediment layer (b) Moho layer, generated using `rfsed`

`rfsed` is adaptable, efficient, and easy-to-use by both researchers and students. Receiver function streams in `rfsed` are handled by the 'RFStream' class of `rf` (Eulenfeld, 2020). `rfsed` can be installed from PyPI. Online documentation and tutorials are available on the project site.

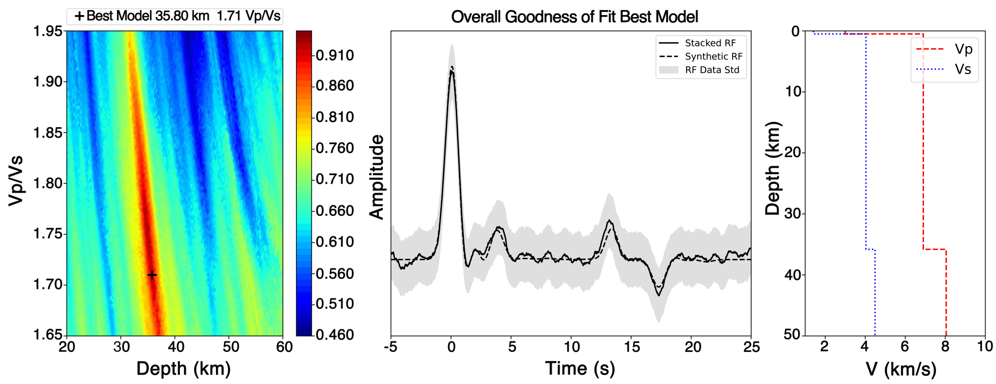

Figure 2: Example of a waveform-fitting result plot generated using `rfsed`

Availability

The software is distributed under a BSD License and is available from rfsed.

Acknowledgements

`rfsed` was initiated as part of the DeepNL-DICTUM project supported by the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) DeepNL program grant number DEEP.NL.2020.010. The data used in creating Figure 1 is from the Netherlands Seismic and Acoustic Network operated by Royal Netherlands Meteorological Institute (KNMI), with network code NL.

References

Akinremi, S., Meijde, M. van der, Thomas, C., Afonso, J. C., Ruigrok, E., & Fadel, I. (2024). Waveform fitting of receiver functions for enhanced retrieval of crustal structure in the presence of sediments. *Journal of Geophysical Research: Solid Earth*, *129*, 1–11. https://doi.org/10.1029/2023JB028393

Eulenfeld, T. (2020). Rf: Receiver function calculation in seismology. *Journal of Open Source Software*, *5*, 1808. https://doi.org/10.21105/joss.01808

Yeck, W. L., Sheehan, A. F., & Schulte-Pelkum, V. (2013). Sequential h-k stacking to obtain accurate crustal thicknesses beneath sedimentary basins. *Bulletin of the Seismological Society of America*, *103*, 2142–2150. https://doi.org/10.1785/0120120290

Yu, Y., Song, J., Liu, K. H., & Gao, S. S. (2015). Determining crustal structure beneath seismic stations overlying a low-velocity sedimentary layer using receiver functions. *Journal of Geophysical Research: Solid Earth*, *120*, 3208–3218. https://doi.org/10.1002/2014JB011610

Zhu, L., & Kanamori, H. (2000). Moho depth variation in southern California from teleseismic receiver functions. *Journal of Geophysical Research: Solid Earth*, *105*, 2969–2980. https://doi.org/10.1029/1999jb900322