Mapping Crustal Structures of the Nechako Basin Using Teleseismic Receiver Functions

Hyun-seung Kim[1], John F. Cassidy[1,2], Stan E. Dosso[1], and Honn Kao[1,2]

renplus@gmail.com

[1] School of Earth and Ocean Sciences, University of Victoria, Canada

[2] Pacific Geoscience Centre, Geological Survey of Canada, Victoria, Canada

1. ABSTRACT

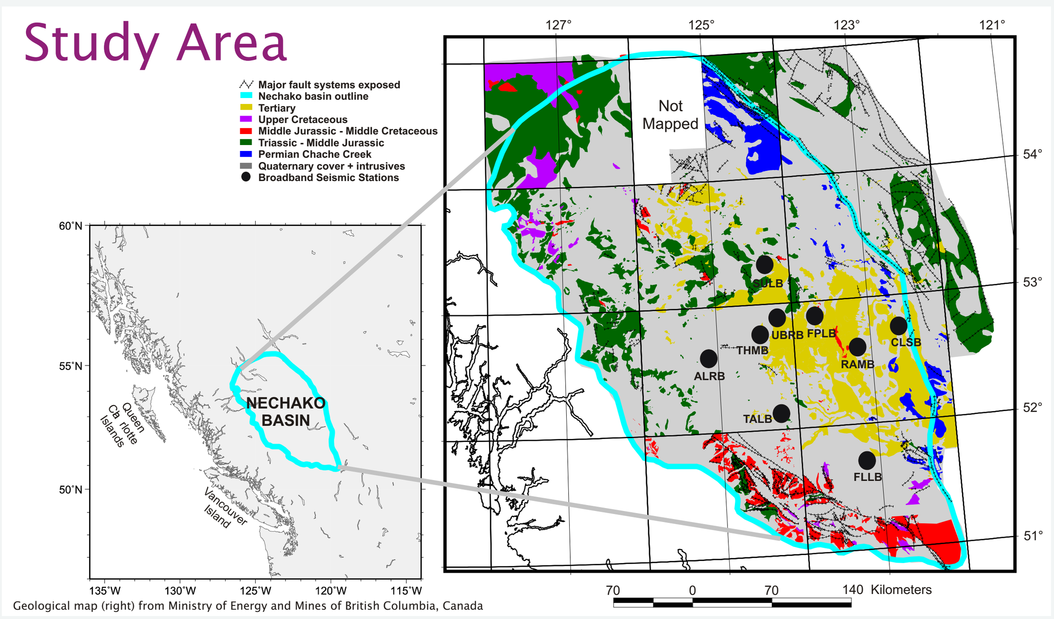
This poster describes a passive-source seismic mapping project in the Nechako Basin of central British Columbia (BC), Canada, with the goal of assessing the hydrocarbon and mineral potential of the region. An explosion of the mountain pine beetle population in central BC over the last decade has devastated the lodgepole-pine forest industry on which many communities depend. Mineral or energy extraction may provide an alternative economic opportunity for the region. The Nechako Basin has been the focus of limited hydrocarbon exploration since the 1930s. Twelve exploratory wells were drilled; oil stains on drill chip samples and the evidence of gas in drill stem tests indicate the presence of a hydrocarbon system. The basin contains mainly Mesozoic sedimentary and volcanic rocks which are blanketed by Eocene and Neogene volcanic rocks. Because only limited seismic energy is able to penetrate this hard volcanic cover, seismic data collected in the 1980s are generally of poor quality. The present study utilizes recordings of distant earthquakes at an array of seven broadband seismic stations deployed over much of the basin in September, 2006. Receiver functions are calculated from the recorded teleseismic waveforms by deconvolving the radial components with the vertical components, and subsequently inverted for shear-wave velocity structure using the Neighborhood Algorithm. Preliminary results indicate that the crustal thickness of the basin is about 40 km with a low velocity zone at around 20-30 km depth and low-velocities near the surface, which may represent the existence of sediments. This study will complement independent active-source seismic studies planned for the region by providing site-specific images and constraints on the shear-wave structures. This study will also complement magnetotelluric measurements currently underway, providing critical new information on porosity, fractures, and fluids.

2. INTRODUCTION

- To assist with minerals and energy assessments as alternative economic opportunities for the Nechako Basin
- To contribute to independent active source seismic studies planned for the region
- To provide critical new information on porosity, fractures, and fluids for MT studies

Photograph of Nechako seismic station RAMB, showing the typical station layout, with solar panels and a satellite dish (seismic vault is not visible).

Study Area



Seismic Stations

Seismic Station Location	Code	Latitude	Longitude	Elevation (km)
Anahim Lake, BC	ALRB	52.510	-125.084	1.237
Cack lake, BC[1]	CLSB	52.759	-122.555	0.792
Fletcher Lake, BC	FLLB	51.739	-123.106	1.189
southwest Quesnel, BC	RAMB	52.632	-123.123	1.259
south of Vanderhoof, BC	SULB	53.279	-124.358	1.171
Tatla Lake, BC	TALB	52.015	-124.254	1.127
Thunder Mountain, BC	THMB	52.549	-124.132	1.126
upper Baezaeko River, BC	UBRB	52.890	-124.083	1.243
Fishpot Lake, BC	FPLB	52.954	-123.779	1.005

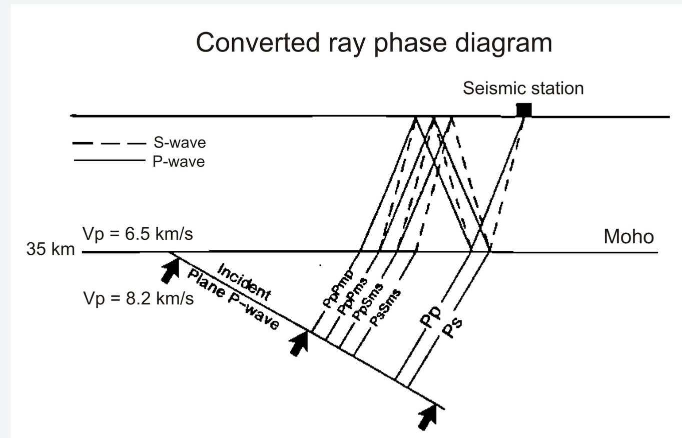
[1] unofficial place name

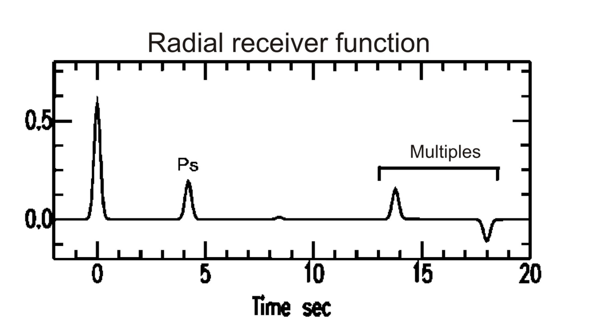
3. RECEIVER FUNCTION METHOD

Using waveforms from distant earthquakes

- Shear wave velocity
- Site-specific
- Interface geometry

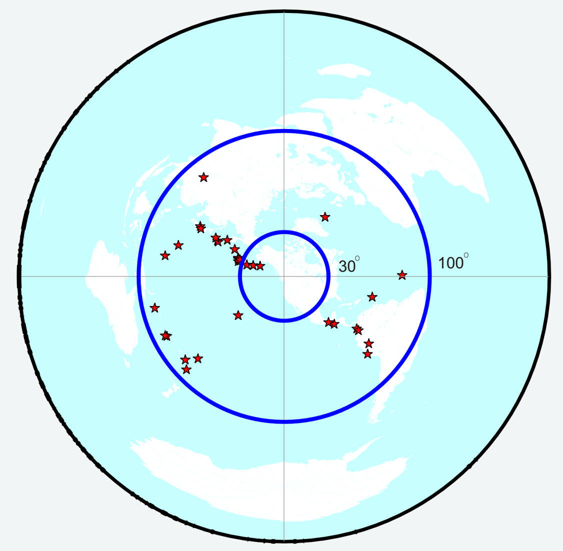
- Simple
- Relatively inexpensive



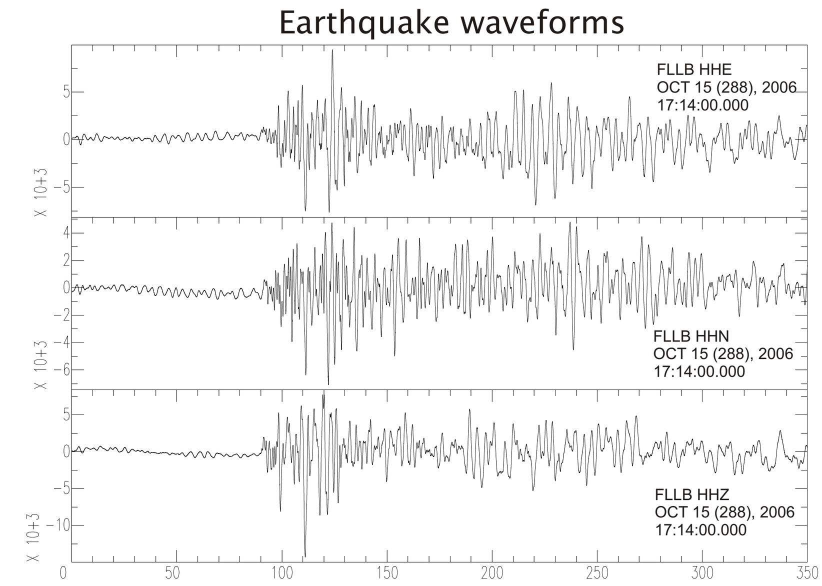


Schematic diagram of the receiver function method. When incident P-waves from distant earthquakes encounter S-wave velocity boundaries beneath a seismic station (top), some of the energy is converted to an S-wave (Ps). The amplitude and arrival time of the Ps phase, relative to the direct P-wave, provides constraints on the velocity contrast and depth to the interface.

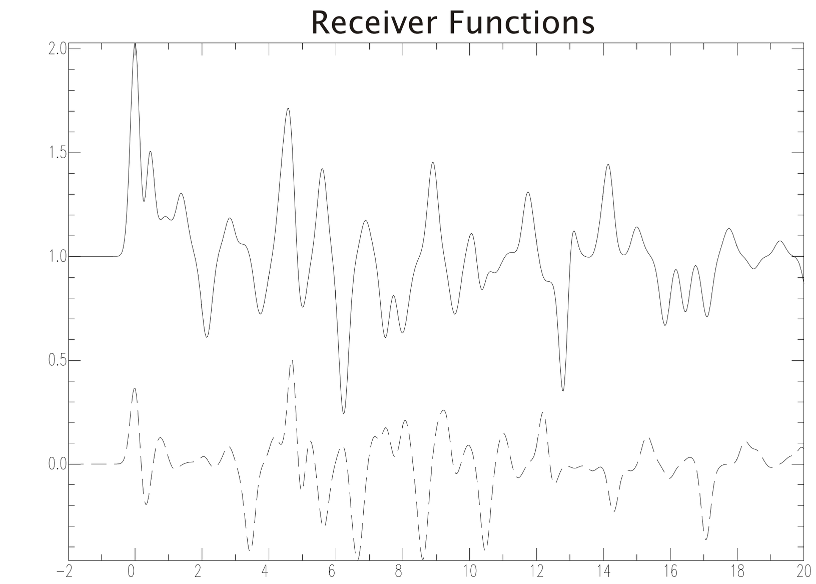
4. DATA



Distribution of distant earthquakes used in this study. Stars indicate large (magnitude >6), distant earthquakes. The map is centred on the Nechako Basin seismic array, with distances (Δ) of 30° and 100° indicated. This is the useful distance range for receiver function studies.

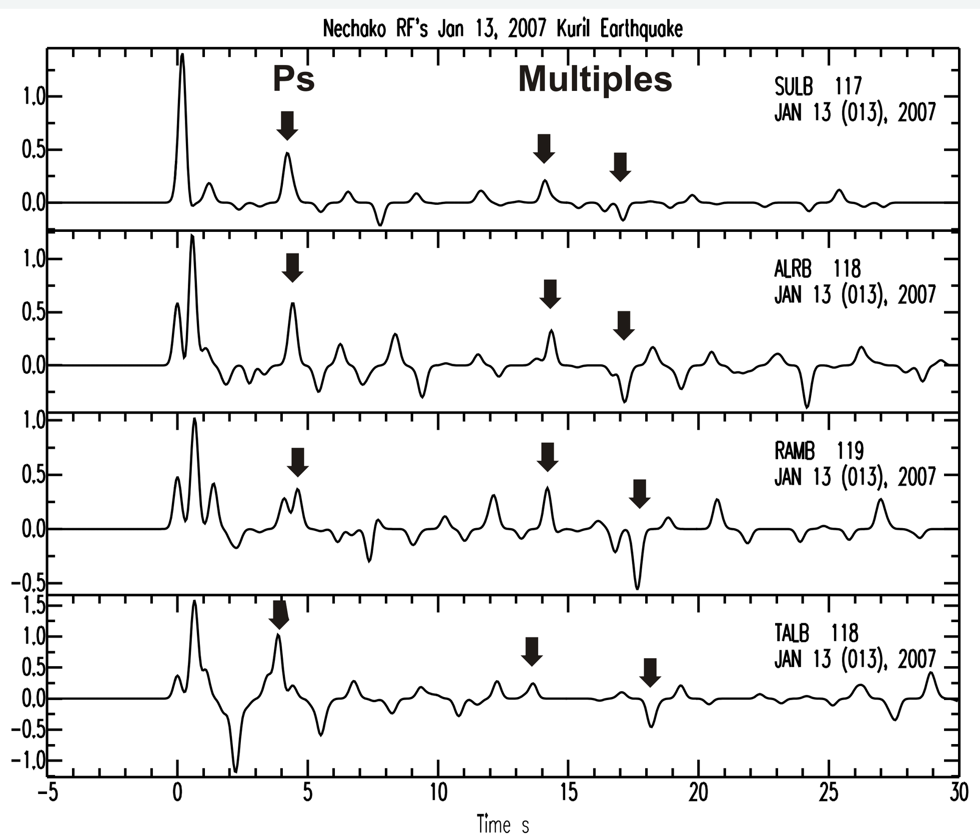


Sample waveforms (M 6.7 earthquake near Hawaii) recorded on the Nechako seismic station FLLB. These waves contain information on the subsurface structure under the station.

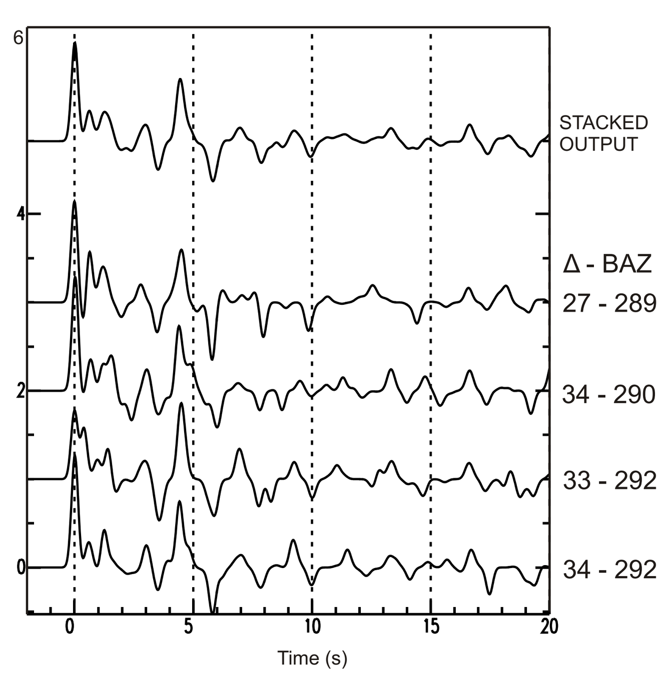


Sample receiver functions calculated from the selected event (waveforms are on the left). Radial component is on the top, transverse component is on the bottom.

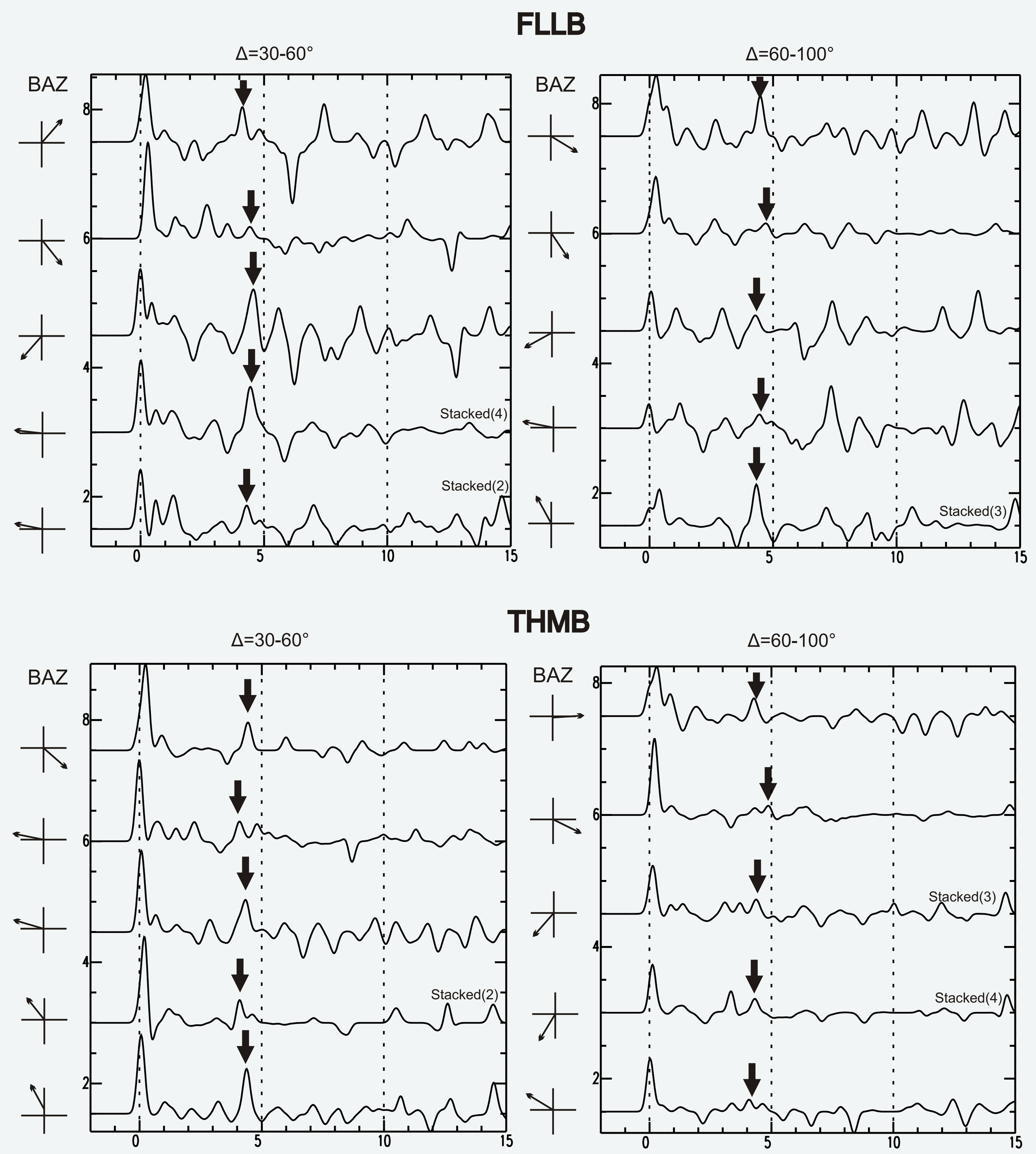
5. RESULTS



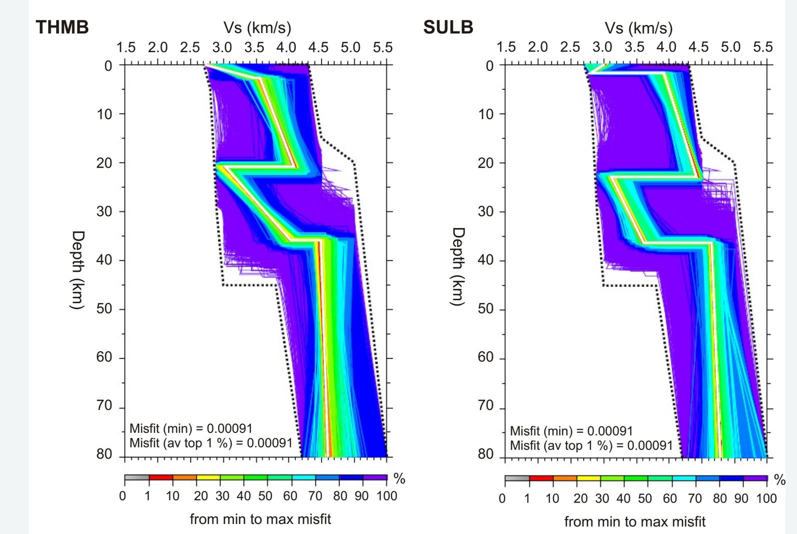
Sample receiver functions for select Nechako Basin stations. The arrival at "Time 0" is the direct P-wave. Subsequent arrivals are locally-generated P-to-S converted phases and free surface multiples. A small amplitude arrival at T=0, followed immediately by large amplitude arrivals, is indicative of near-surface low-velocity sediments. The large arrivals indicated by arrows are consistent with a Ps conversion from the continental Moho (near T=4 s) and free-surface multiples of this phase near T=12-17 s.

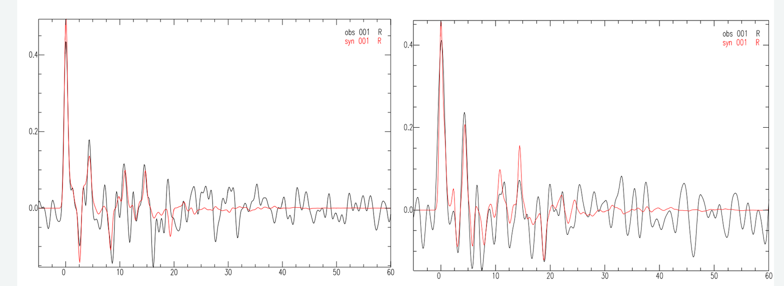


Weighted, stacked radial receiver function for station FLLB (top). Epicentral distances and back azimuths are indicated next to the receiver functions.



Receiver functions from stations FLLB and THMB, ordered by back azimuth for two different distance ranges (30 - 60° and 60 - 100°). Thin arrows on the left show the back azimuth for each event. Thick arrows indicate the shifting of arrivals corresponding to the same phase (likely the Moho Ps phase). Stacked receiver functions are labeled.





The sample S-wave velocity models calculated from a single receiver function for THMB (top-left) and SULB (top-right). The best-fit model is in white. The black solid line shows the average of 1% models with the best data fits. Dotted lines show the minimum and maximum range of allowable models. The observed receiver functions in black and synthetics in red (bottom).

6. FUTURE WORKS

Receiver functions will be computed for all suitable events for remaining stations. These will be also stacked into distance and azimuth bins and modelled for S-wave velocity structures for all stations within the Nechako Basin. Amplitudes and arrival times will be used to constrain the S-wave velocity contrast and depth of the boundary, and azimuth variations in the receiver functions will help constrain the geometry of the interfaces.

REFERENCES

Cassidy, J.F. (1992): Numerical experiments in broadband receiver function analysis; Bulletin of the Seismological Society of America, v. 82, p. 1453-1474.

Cassidy, J.F., Al-Khoubbi, I. and Kim, H.S. (2008): Mapping the structure of the Nechako Basin using passive source seismology; in Geoscience BC Summary of Activities 2007, Geoscience BC, Report 2008-1, p. 115-120.

Sambridge, M. (1999a): Geophysical inversion with a neighbourhood algorithm I. Searching a parameter space, Geophysical Journal International, v. 138, no. 2, p. 479-494.

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