Seismic Tomography of the Nechako Basin, South-Central British Columbia (NTS 092N, O, 093B, C, F, G) Using Ambient Seismic Noise

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Introduction

Ambient seismic noise is gaining popularity as an effective method for imaging large-scale crustal structure (e.g., *see* Bensen et al., 2007, 2008). Assuming that seismic noise contains waves propagating in all directions, cross-correlating sufficiently long noise records recorded simultaneously at two instruments will recover a Green's function—that is, a record equivalent to a seismogram recorded at one station from a source at another station. Given the frequency distribution of microseismic noise, this Green's function is typically dominated by high-frequency Rayleigh waves reflecting large-scale crustal structure, and is well suited to imaging sedimentary basins on a broad scale.

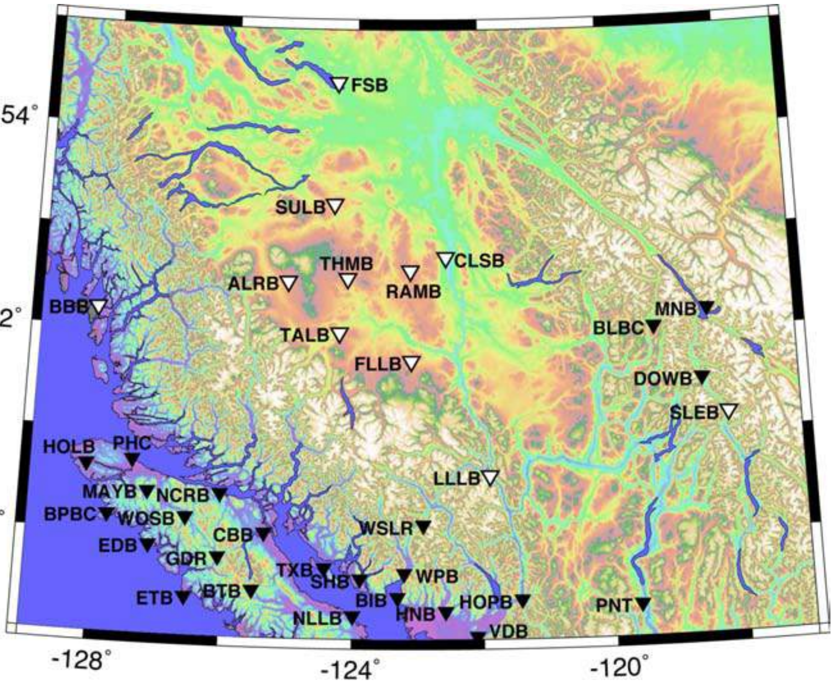

Figure 1. Location of seismic stations in the Nechako Basin and surrounding area. Stations used in this study are indicated by white triangles.

The authors are in the process of using ambient-noise surface-wave tomography to examine the Nechako Basin, British Columbia. The basin has been difficult to explore due to the presence of Tertiary volcanic outcrops. The volcanic rock that covers a major part of the basin has a strong velocity inversion at its base, making it difficult to use conventional seismic methods. Ambient-noise surface-wave tomography will help unravel the structural composition of the basin by estimating thicknesses of volcanic and sedimentary rocks, lateral velocity variations and crustal thicknesses within the basin area. These results will have applications to mineral and hydrocarbon exploration in the region by providing constraints on S-wave velocity, P-wave velocity, Poisson's ratio and layer thickness. In this study, the method, data and preliminary results as of October 2008 are described. In a related study (Kim et al., 2009), teleseismic receiver functions are providing site-specific constraints on S-wave velocity.

Data and Method

This study cross-correlated the vertical component of ambient seismic-noise data recorded by 12 POLARIS and Canadian National Seismograph Network CNSN seismic stations between September 2006 and November 2007. The stations used (white triangles on Figure 1) lie between latitudes 50.8–55.1 N and longitudes 122–128 W (Figure 1). A typical station layout is shown in Figure 2. The data processing procedure was based on that of Bensen et al.

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Figure 2. Photograph of the seismic station THMB (*see* Figure 1 for location).

(2007). The time lengths of some data are shorter than 14 months as a result of station down-time.

Data were corrected for instrument response, normalized using a one-bit process to equalized amplitudes, and then spectrally whitened. Data for all possible station pairs were then cross-correlated in day-long blocks. Single-day cross-correlations (Figure 3) were quite noisy; stacking all available cross-correlations (Figure 4) greatly improved the results.

The stacked signal (Figure 4a) contains signal at both positive and negative lags, representing propagation in both directions between the two stations. For evenly distributed noise sources, the signal should be symmetric about zero-lag time; the presence of asymmetry in our results is indicative of a preferred noise direction. For further analysis, we summed the positive-lag and negative-lag signals together (Figure 4b).

The main signal in our reconstructed seismograms is a high-frequency Rayleigh wave. As Rayleigh waves are dispersive (i.e., they have frequency-dependent velocities), and the dispersion is controlled by velocity distribution with depth, frequency-time analysis was used to measure the group velocity dispersion relation for each station pair. The technique involves applying a sequence of Butterworth filters at selected frequency bands and measuring the group arrival times on the envelope of the filtered signals (Figure 5; Levshin et al., 1972). In order to estimate the error on these measurements, dispersion characteristics were measured on all sequential three-month stacks, so that for each Rayleigh waveform, that are approximately five dispersion curves instead of one from the 14-month stack. If at least three out of the five dispersion curves are repeated or nearly repeated measurements, their standard error was computed at 95% certainty. Also, if the calculated standard error is >0.3 km/s, the measurement was rejected. Where the above requirements are satisfied, the authors are confident in the dispersion curve measurement from the 14-month stack, which will be used to generate dispersion maps and 1D velocity models.

Preliminary Results

Figure 6 is an example of some of the dispersion curves estimated from Rayleigh-wave velocity values after determining uncertainties in the dispersion curves. The dispersion curves tend to converge at frequency <0.30 Hz and >0.55 Hz. Significant variation in the dispersion curves was observed between 0.30 Hz and 0.55 Hz, probably resulting from crustal velocity variations between paths. Further processing of these curves will involve two forms of inversion: linear tomographic inversion of group velocities, which will produce a map of group velocity for each frequency range, and 1-D nonlinear inversion of individual dispersion curves, which will produce models of seismic velocity as a function of depth. From the tomography maps, relating the observed group-velocity variations to lateral changes in geology within and outside of the Nechako Basin can be expected. One-dimensional models will reference these changes to depth and define major crustal layers. Both modes of inversion are ongoing and are expected to be complete by May 2009.

Acknowledgments

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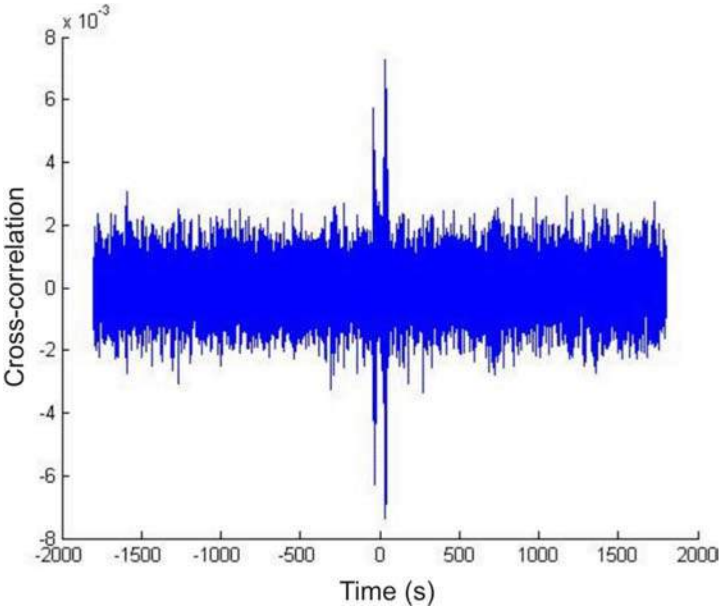

Figure 3. Example of a single-day cross-correlation for the travel path between SULB and ALRB.

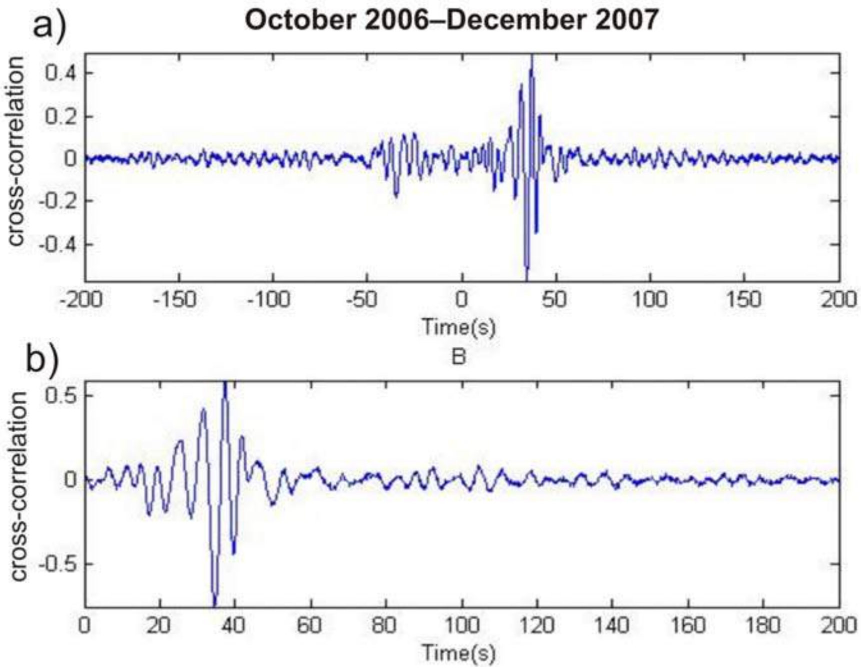

Figure 4. a) Asymmetric waveform, produced by stacking 14 months of cross-correlated signals. **b)** Symmetric waveform, produced by summing the causal and noncausal portions of the waveform in a).

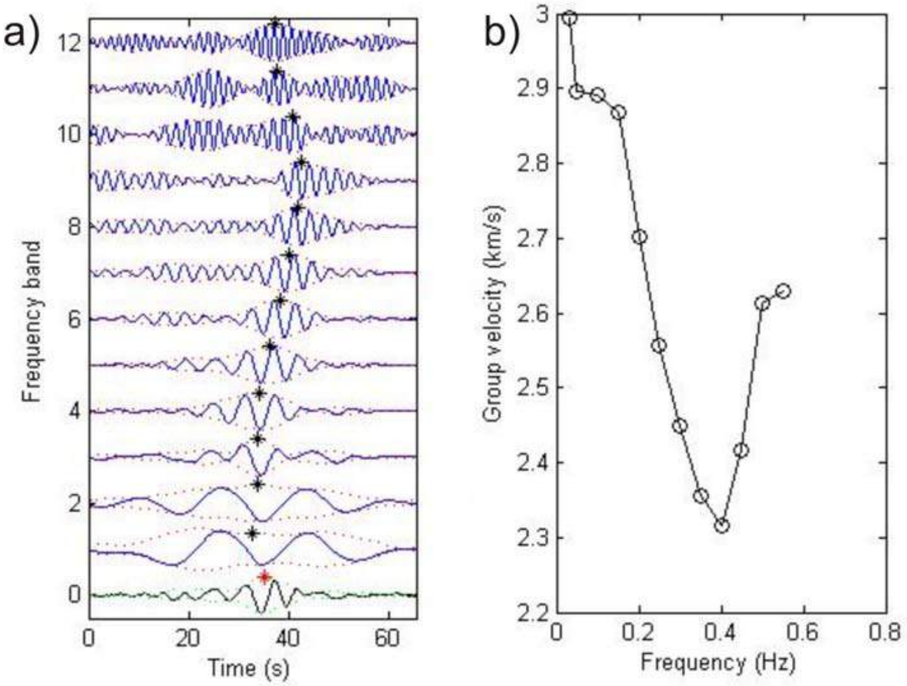

Figure 5. Graphs showing the estimation of dispersion characteristics: **a)** estimated Rayleigh waveform produced between station SULB and ALRB is filtered at selected frequency bands; the group arrival time corresponding to the peak of the envelope is measured in each band; the group velocity is the ratio of the distance between the two seismic stations and the group arrival time; **b)** the dispersion curve, made by plotting the group velocity (km/s) against the centre frequency of each band (Hz).

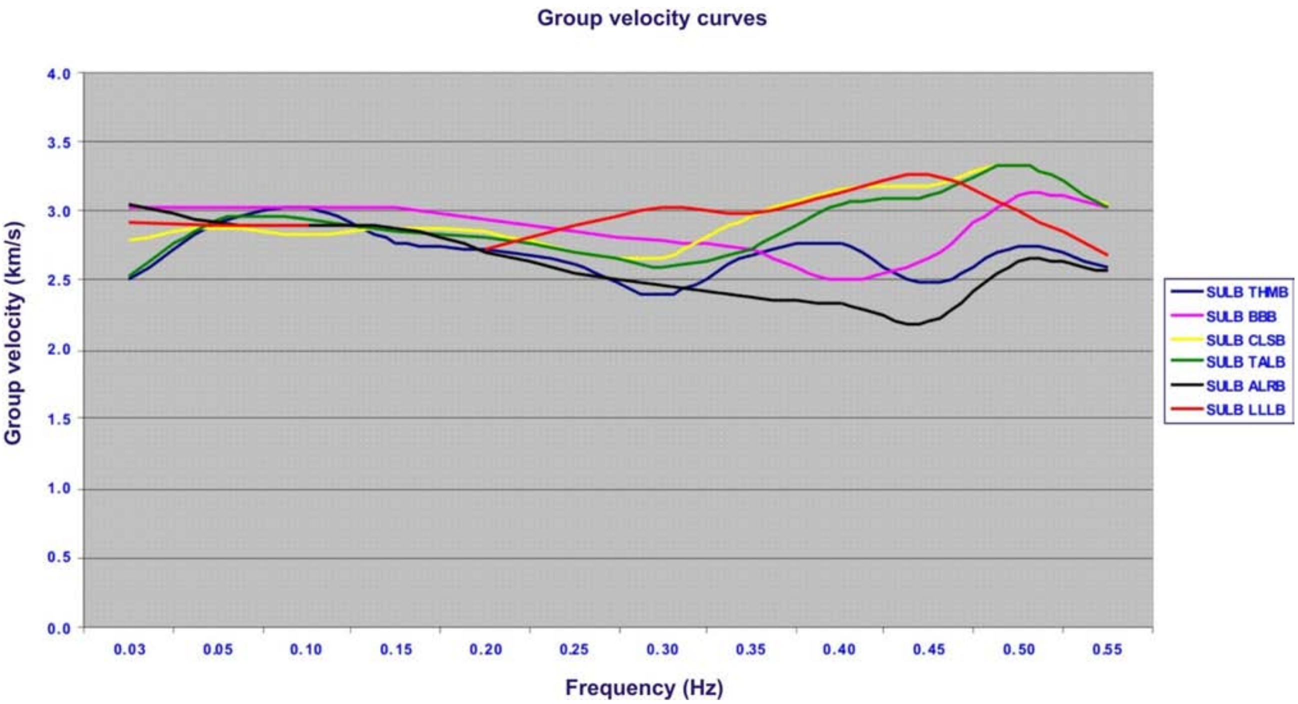

Figure 6. Dispersion curves between station SULB and six other stations: THMB, BBB, CLSB, TALB, ALRB and LLLB. Location of these seismic stations are shown in Figure 1.

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