Characterization of Earthquake Site Amplification in Alberta, Canada, for Induced Seismicity *ShakeMap* Applications

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Introduction

This work aims to provide Alberta site amplification functions for *ShakeMap* applications (e.g., [7]) and to aid in the interpretation of earthquake records. Empirical amplification functions are developed from earthquake and microtremor recordings collected at each station. Potential site descriptor metrics such as V_{S30}, surficial geology, site period and depth-to-bedrock are cross-evaluated with the empirical amplification functions.

Here we present dispersion curves (phase velocity versus frequency) estimated from analyses completed on active and passive seismic data collected at select Alberta seismic stations over a two-week period in the summer of 2016. We also compare horizontal-to-vertical spectral ratios (HVSRs), a known proxy for site amplification (e.g., [5]), derived from earthquake and microtremor records.

Dataset Overview

Collectively, array and single-station based measurements were acquired at 28 seismograph locations in Alberta, Canada, which co-locate with 18 seismograph stations that have existing earthquake HVSRs (EHVSRs), as seen in **Figure 1**. Measurements from array based methods (active and passive) provided phase velocity spectra, whereas microtremor HVSRs (MHVSRs) are derived from passive single-station measurements (see **Figure 2**).

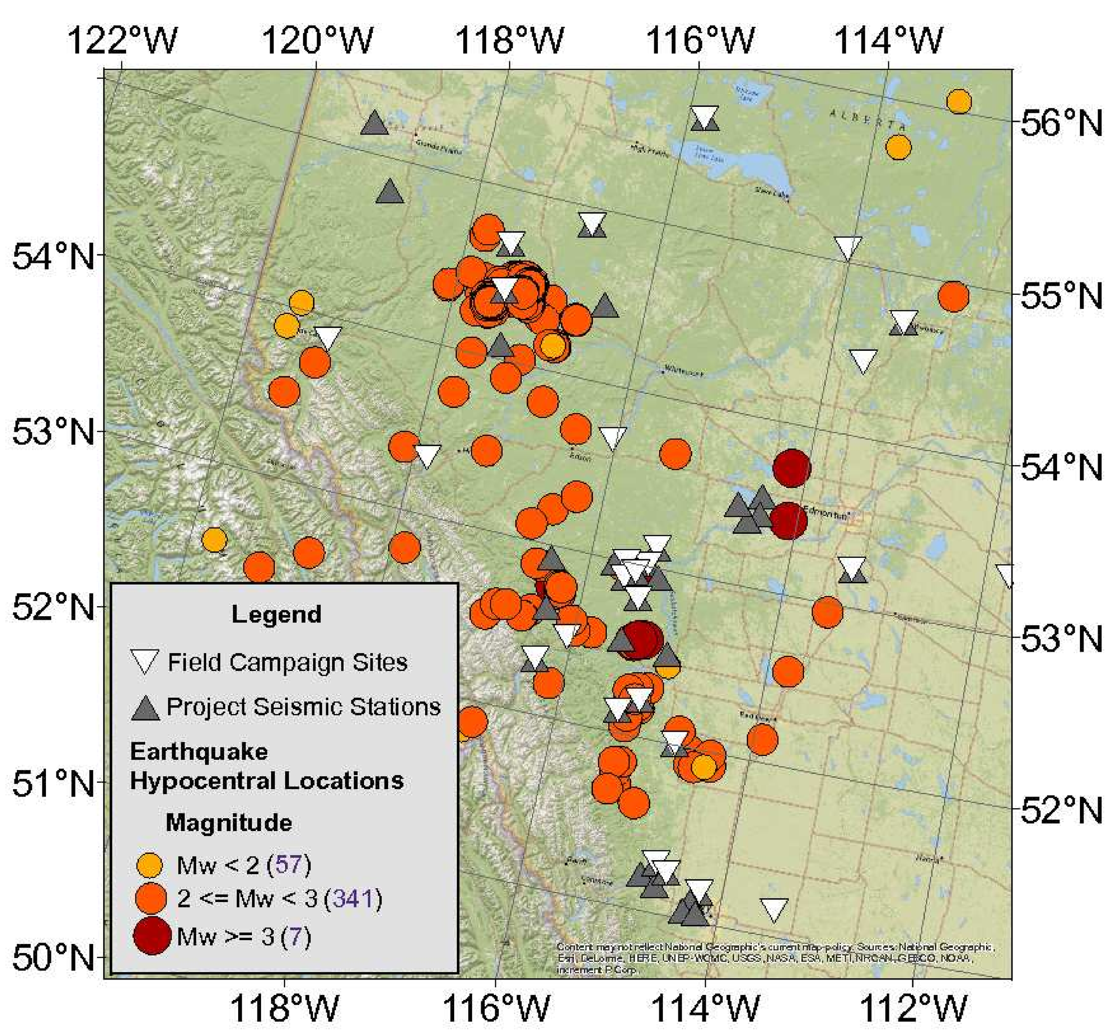


Figure 1 (right) — Inverted white triangles indicate the sites visited during the summer 2016 field campaign. Grey triangles show the locations of Alberta seismic stations with EHVSRs. The locations of earthquake hypocentres are given and sized according to magnitude (M_W). Earthquake catalogue complete from September 2013 to February 2016 (405 earthquake total).

Figure 2 — Images from the summer 2016 field campaign. (**A**) A 5-sensor array deployed for ambient noise (passive) data collection at station RDEA. (**B**) and (**C**) demonstrate the implementation of the multi-channel analysis of surface waves (MASW) acquisition technique (active, impact source), and (**D**) a Tromino® (portable three-component seismograph) is used to record ambient vibrations and demonstrates the single-station MHVSR method implemented at station ATHA.

Preliminary Results

We applied HVSR analysis to earthquake and microtremor recordings to estimate the fundamental frequency of each seismograph location, as others have done successfully (e.g., [1], [4] and [5]). In **Figure 3**, we observe excellent agreement in peak frequency and amplitude between EHVSRs and MHVSRs of the same station. These results are the first validation of the rapid low-cost microtremor HVSR method for earthquake site amplification in Alberta's geologic setting.

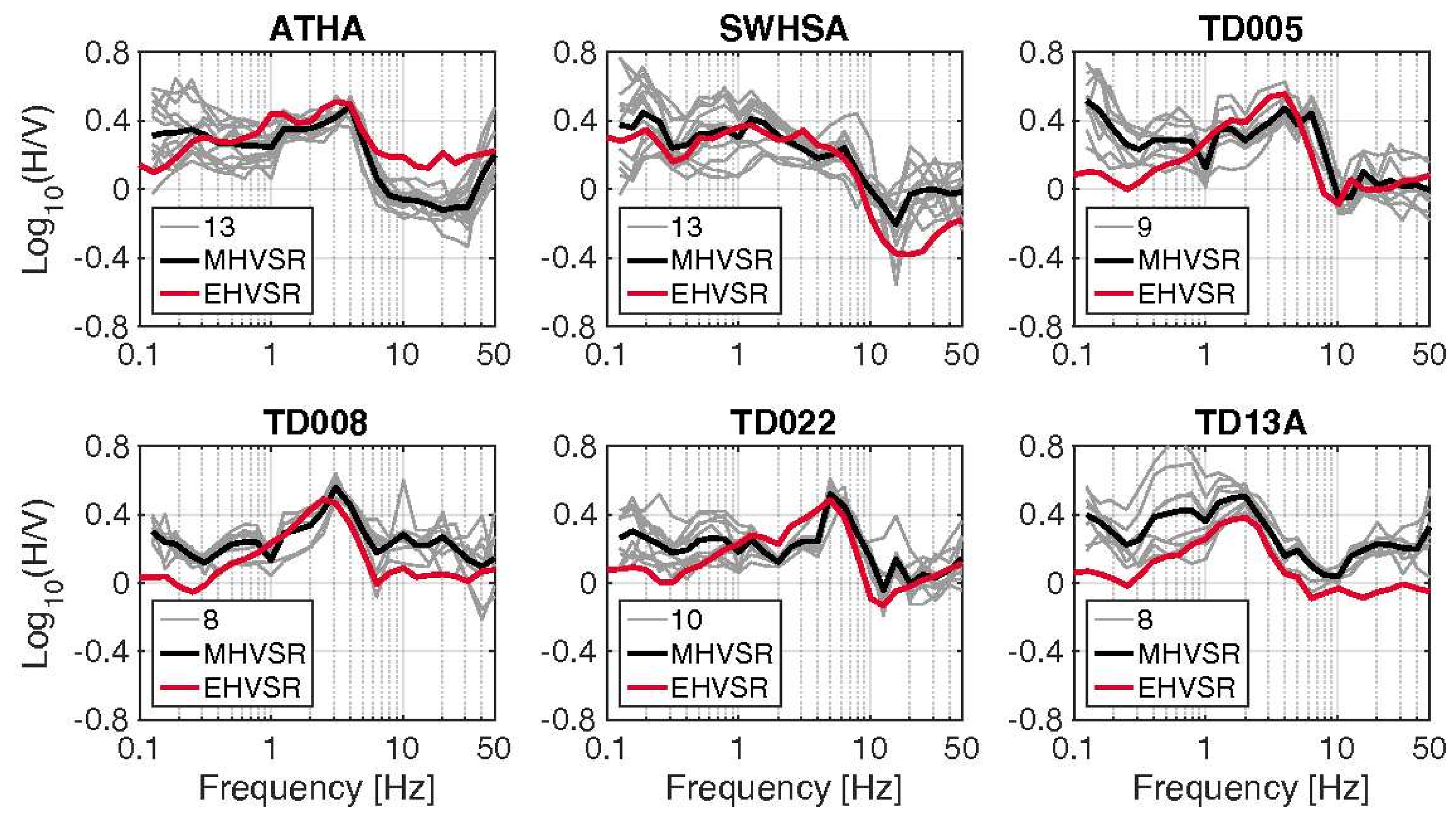


Figure 3 — Horizontal-to-vertical (H/V) spectral ratios derived from microtremor (MHVSR) and earthquake (EHVSR) recordings. Bold black and red lines represent the station average H/V and the thin grey lines are the individual Fourier spectral ratios derived from single-station measurements of ambient vibrations.

Active (MASW) and passive (microtremor array) surface wave recordings provide dispersive phase velocities via high-resolution frequency-wavenumber (HRFK) and spatially averaged coherency spectrum (SPAC) analysis that will be inverted for shear-wave velocity profiles. Dispersion-inverted velocity models may be further improved by including HVSRs via joint inversion. **Figure 4** shows the steps involved to produce a dispersion curve for inversion, in the case of HRFK analysis ([2]).

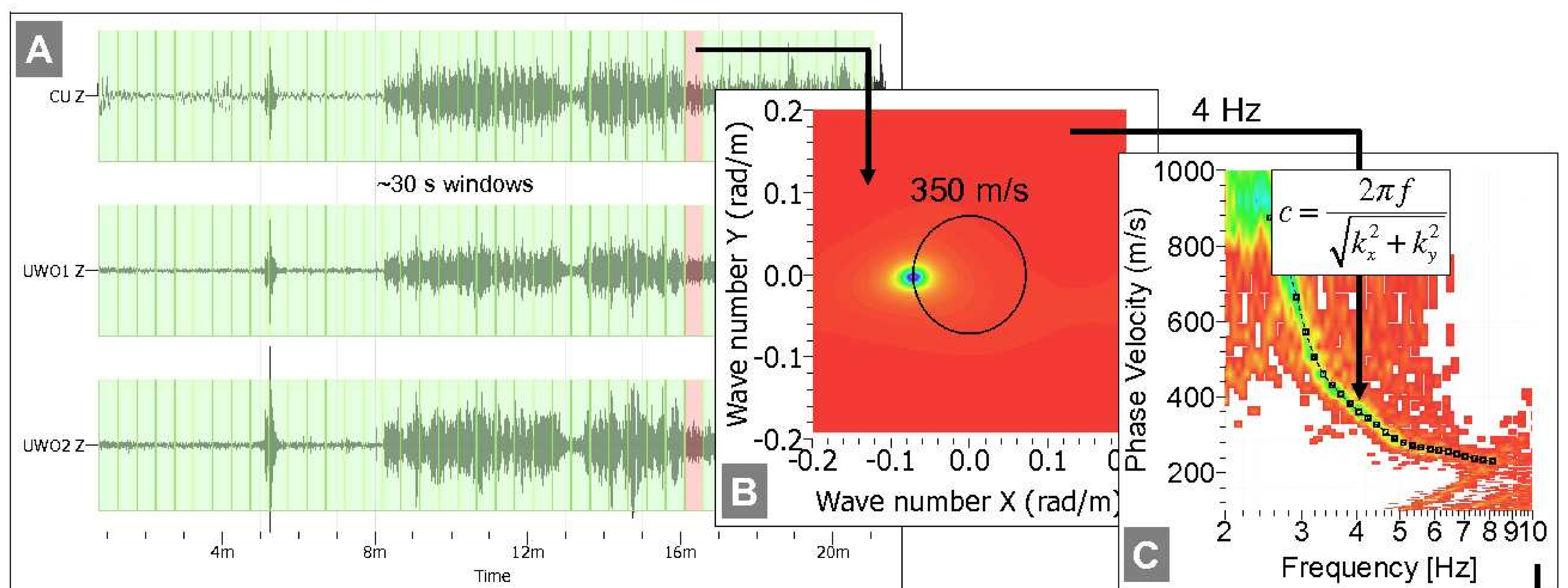
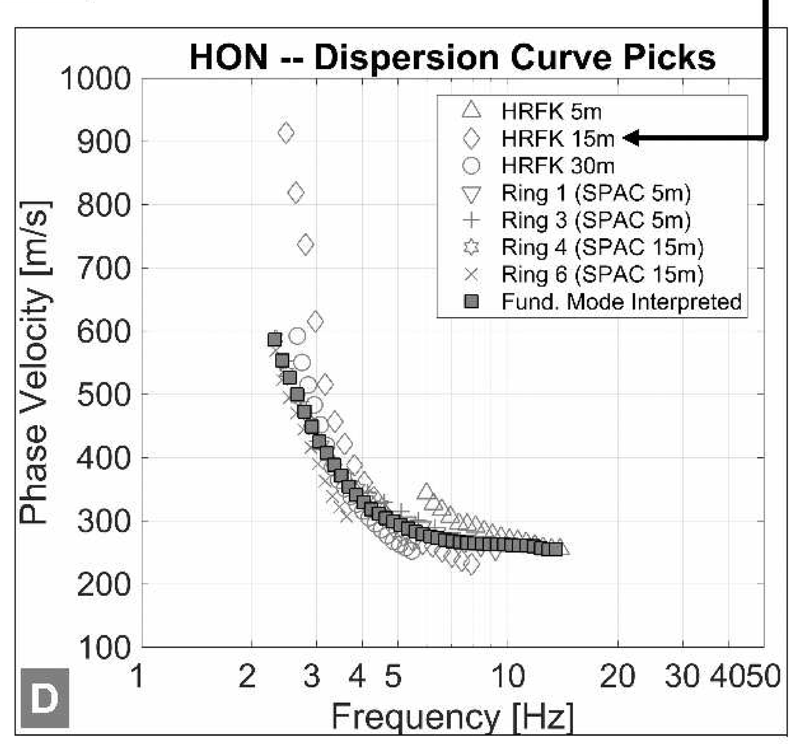


Figure 4 — Workflow for the high resolution frequency-wavenumber (HRFK) processing method at HON. Ambient noise recordings in (**A**) are time synchronized, cross-correlated and Fourier transformed to provide the frequency-wavenumber (f-k) spectrum. For each frequency, f, the wavenumber coordinates (k_x, k_y) of the peak in the wavenumber plane are found in a grid search and used to estimate phase velocity (c). A histogram of phase velocities is computed for all time windows and frequencies (**C**). Dispersion curves are picked and the fundamental mode is interpreted (**D**).



Preliminary Results Cont'd.

The time averaged shear-wave velocity in the upper 30 m (V_{S30}) of a site is an important input parameter for engineering design and ground motion prediction equations. Using an empirically derived equation [6], we are able to make preliminary estimates for V_{S30} and the corresponding site class for each seismograph station (**Figure 5**).

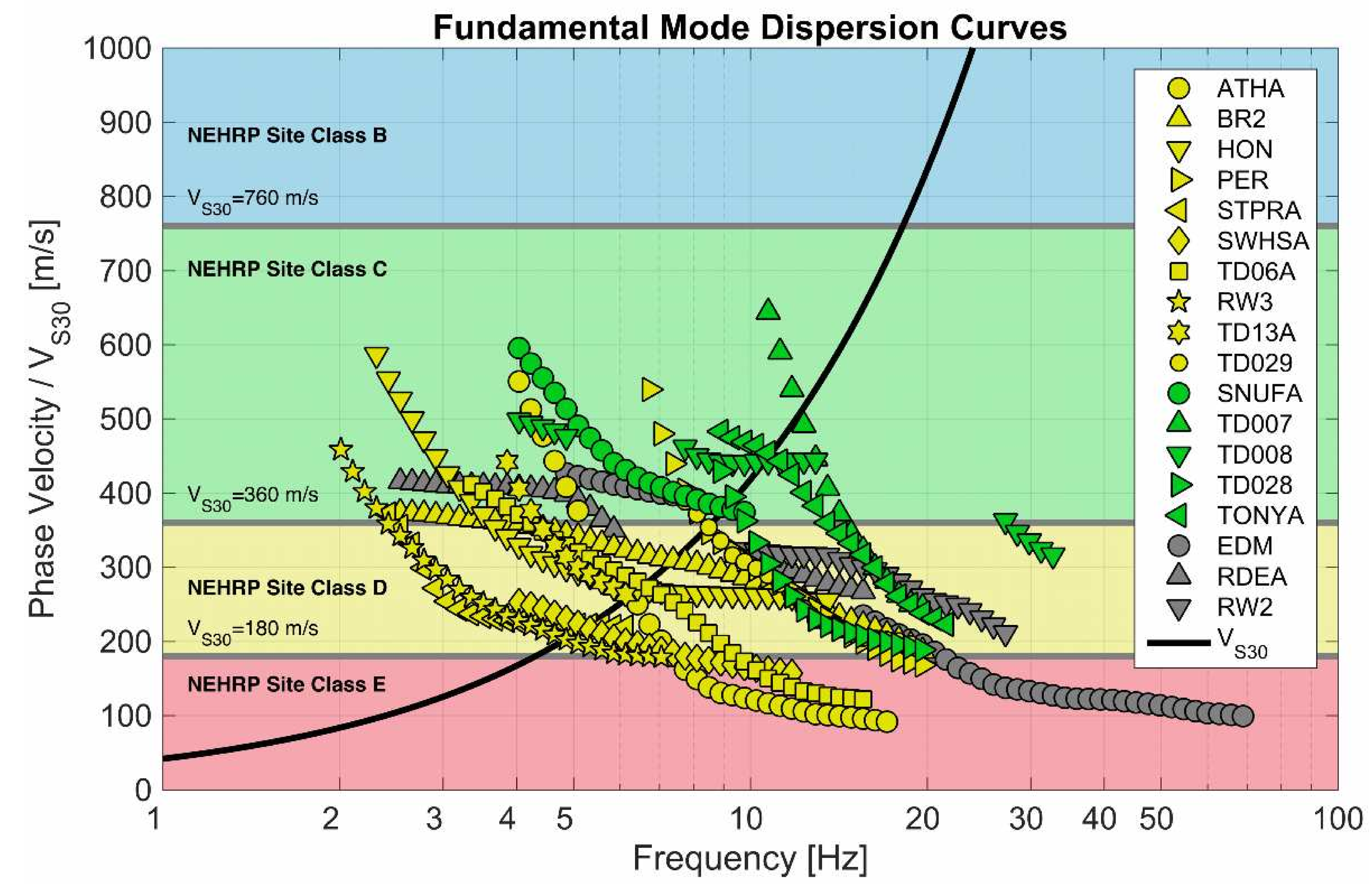


Figure 5 — Displaying seismograph station dispersion curves with colors corresponding to the interpreted site class (according to NEHRP provisions). The thick black line is calculated using the equation V_{S30}=1.045*V_{R40} following Martin and Diehl (2004), where V_{R40} is the phase velocity of a Rayleigh-wave with a wavelength of 40 m. Grey filled markers represent those dispersion curves that do not intersect with the V_{S30} line, and thus are not assigned to a site class.

Ongoing Work

- Derive 1D shear-wave velocity profiles.
  - Surface wave methods in general poorly resolve bedrock velocity—mainly because of the high-pass filtering effect of the sedimentary cover ([3]). We will be using simplified velocity profiles interpreted from available dipole shear-sonic imager logs (DSI) for calibrating dispersion-inverted velocity profiles. Depth-to-bedrock data available from the Alberta Geological Survey will also aid in the calibration phase.
- Correlate site descriptor variables with observed ground motions.
- Develop parameterized amplification functions for Alberta.

References

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