Seismic Site Characterization: Horizontal-to-Vertical Spectral Ratio (HVSR) for Determination of Site Periods

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Abstract

Seismic site characterization is important in understanding the behavior of a site during an earthquake. This is because a stiffer site and a softer site will shake differently depending on the seismic energy. The fundamental site period (T_0) is a good indicator of the energy required to amplify ground shaking at a particular location. As a result, the goal of this project is to measure the T_0 at a number of locations and use kriging to estimate the spatial distribution of T_0 where measurements were not made. In this way, we can estimate the seismic site response hazard over a larger area.
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Experimental Design

Two different locations were selected for T_0 measurements using HVSR. The first is Tarzana Clubhouse which recorded one of the largest ground motions during the 1994 **Mw** 6.7 Northridge earthquake. The second is the VA Medical Center in Brentwood, CA which is located at the northern edge of the L.A. Basin. As such, these two locations provide a good starting point to understanding site amplification due to site characteristics.

(1) Recording microtremors:

- Samples of microtremor data was collected via 10 Nanometrics Pegasus Trillium Compact 120 Seismometers
- Apache hard cases were used to store each battery in lower temperatures during recordings and 5-gal buckets covered each individual seismometer to protect against wind and temperature*
- We found that digging a hole and burying each seismometer with surrounding dirt provided better HVSR because they are better coupled to the ground surface.

(2) Processing data in Python:

- Initial processing involved seismometer station streams from the IRIS database.
- Field data was recorded as miniseed (.mseed) files which were processed by modified HVSRpy functions and kriging was generated by gstools in combination with new code.

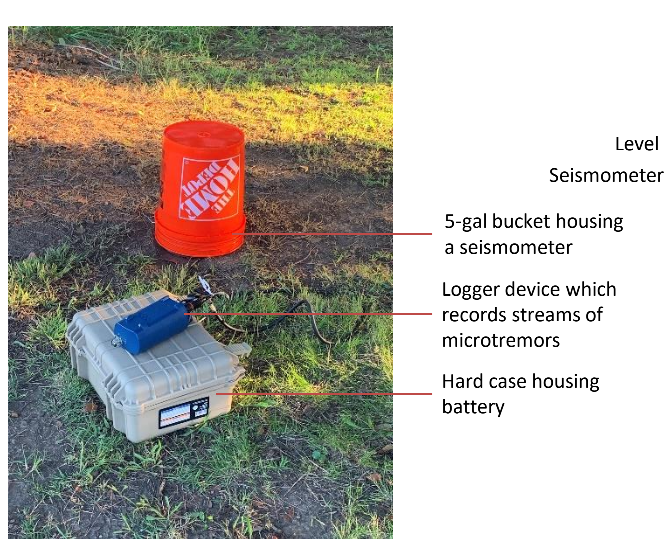

Figure 1: Deployment configuration

Figure 2: Sensor-ground coupling by embedding device

Results

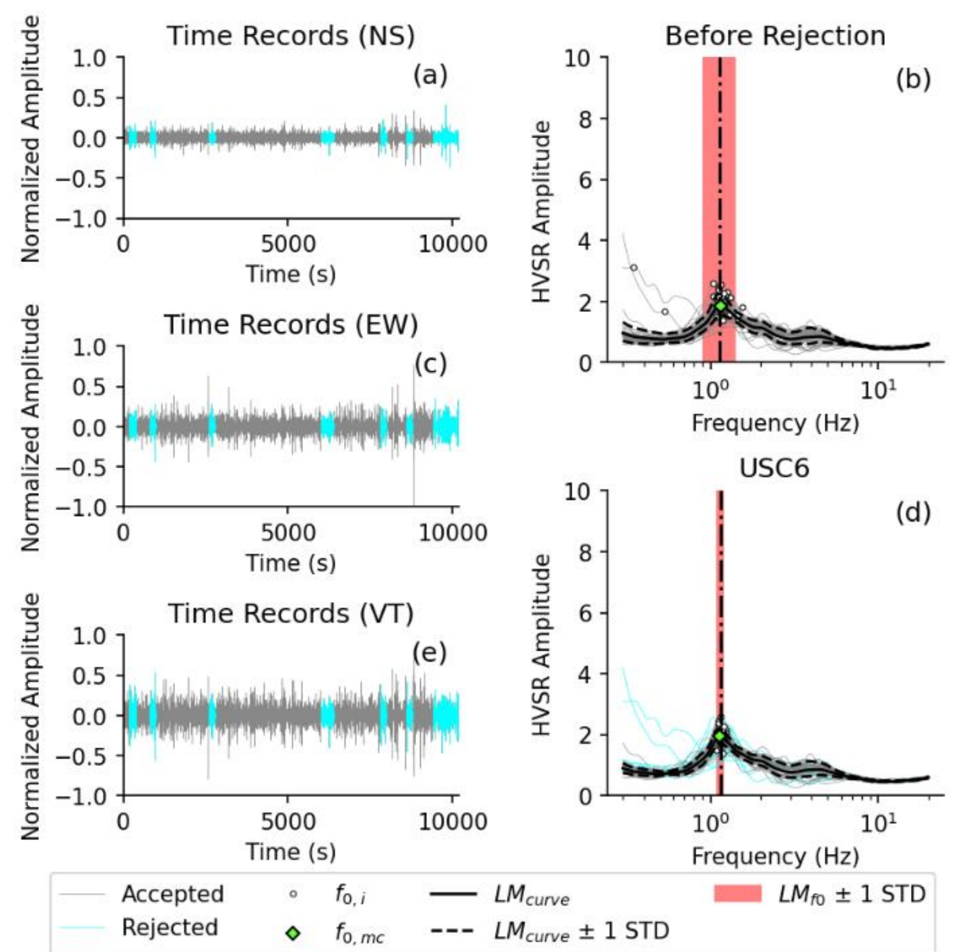

Figure 3: HVSR of station USC-6 from Tarzana 1

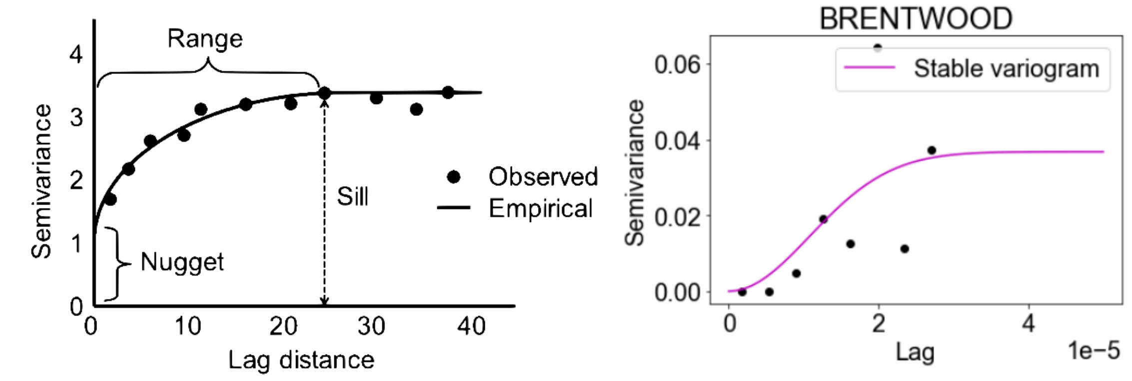

Figure 4: (Left) Example semivariogram.[4] (Right) Semivariogram using data collected at VA Medical Center in Brentwood, CA

Figure 3 is the HVSR computation results for a station at one of the measurement areas using the HVSRpy package (Vantassel 2021).[2] It shows the recorded ambient vibrations in three directions and the estimated peak at the T_0.

Figure 4 shows an example semivariogram as well as a computed semivariogram from Brentwood. Kriging builds upon the variogram of each area because a line of fit approximately provides information on the spatial continuity for spatial variability.

Figure 5 shows the final results which is a spatial estimate of T_0 at the three sites where the actual value is measured at the circle markers. As it moves away from the markers it shows the estimate of the T_0 at any location based on the closeness to the measurements and the variance in the area as determined by the semivariogram. Also shown are the terrain maps with measurement locations for comparison to geologic setting.

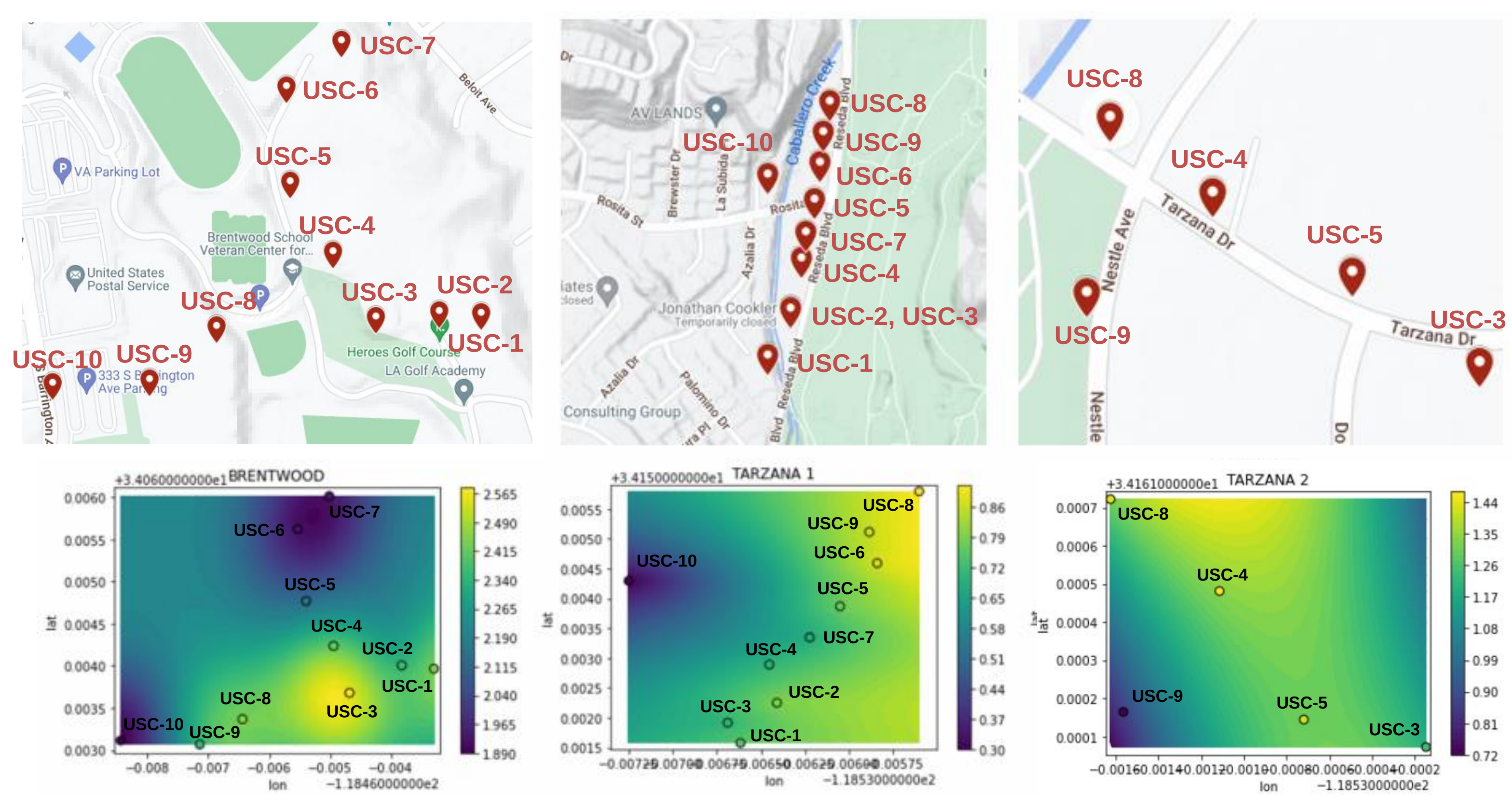

Figure 4: (Top) Terrain maps showing locations of Measurements at the three sites. (Bottom) Kriging maps showing spatial distribution of estimated fundamental T_0.

Discussion

- Extreme heat (50+ ℃) affected some of the data streams; however, drift was handled by filtering of transients and ambient noise.
- When plotting HVSR in HVSRpy, 20-40 windows gave the best 'After Rejection' data, (pinpointing the peak frequency). However, more windows decrease uncertainty. We recommend changing the filter bool to True and decreasing the high-cut frequency for bandpass filter to 50.[3]
- The T_0 is calculated by taking the inverse of the peak frequency. In some cases, multiple peaks were found in the HVSR plotting. Through our own discretion, we chose which peaks were most reasonable according to trends in the data and knowledge of surrounding rock forms.
- Original plotting of variograms using the Haversine formula resulted in less accurate plots (assumes Earth is a perfect sphere) versus Universal Transverse Mercator (UTM) conversion. However, we found it best to create a variogram using a list of data in gstools.
- A longer T_0 comes from softer sites which are either deeper or are composed of softer material such as soil layers. Conversely, a shorter T_0 comes from stiffer sites which are closer to a rocky area or are composed of stiffer material such as sedimentary rock.
- During our field work, we experienced several incidents of attempted theft which disrupted the seismometers and corrupted some of the recorded data.

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