This study is based on a dense broadband survey done across the Los Angeles Basin from Long Beach to Puente Hills. The array consisted of 71 stations that were deployed by students and faculty at Cal Poly Pomona (Jascha Polet), UCLA (Paul Davis), USGS/Pasadena (Elizabeth Cochran), Caltech (Robert Clayton), NodalSeismic Inc (Dan Hollis), and Occidental Petroleum – now California Resources. The network was deployed for approximately six weeks in the Fall of 2014. For more details see http://web.gps.caltech.edu/~clay/LASSIE/LASSIE.html The survey is named LASSIE (Los Angeles Seismic Syncline Interferometry Experiment). This component of the study resulted in two published papers listed below.

The array crosses the main part of the Los Angeles Basin as shown in Figure 1. The goal is to find the shape and shear-wave velocity of the basin. These are done using surface analysis using virtual sources created by ambient noise correlation, and by receiver functions using teleseismic recordings. The problem of utilizing surface waves in sedimentary basins is discussed in Paper 1, and the chief issue is the presence of higher modes. A method based on the difference between retrograde (fundamental mode) and prograde (1st overtone mode) motions is used to separate the modes. Both Love and Rayleigh waves are used in constructing the velocity model.

The structure and velocity results are presented in Paper 2. The shear wave velocity is determined from a standard dispersion curve inversion. The structure is done with receiver functions, and both the basin-basement interface and Moho are found. Under the Los Angeles Basin, the Moho rises by approximately 10 km, a feature that
is not present in any of the SCEC models. This is expected if the basin is in isostatic equilibrium.

This study resulted in two papers:

Horizontal-to-Vertical (H/V) spectral ratio analysis is a well-established approach to estimate the resonance periods and seismic amplification of a site and therefore is useful for site characterization and microzonation. Since resonance periods are produced by strong impedance contrasts at depth, spectral ratio analysis may also be used to map subsurface geological structures and is particularly advantageous to investigate sedimentary basins and the interface between unconsolidated sediments and the basement rocks. Since LASSIE was a short-term deployment, no large earthquakes occurred during this time window, and therefore we used the microtremor approach.

The basic method (e.g. Nakamura, 1989; Lermo and Chavez-Garcia, 1993) has been confirmed to reveal the dominant soil resonance frequencies of a site, although the interpretation of the amplification factor is not as well understood (Pilz et al., 2009). The Geopsy software (Di Giulio et al., 2006; Wathelet et al., 2008) was used to generate H/V spectral ratio curves for all LASSIE stations, and the SESAME criteria (SESAME European research project, 2004) were used to assess the reliability of the resulting peak frequencies and peak amplitudes. Based on the findings by Zhao et al. (1997), H/V spectra are insensitive to the origin and the propagation path, but are sensitive to the subsurface structure located near the observation point.

We found several coherent sets of spectral ratio peaks in our data set of the LASSIE deployment, with a group of peaks that could most easily be tracked along the entire network in the frequency range of 0.05 Hz - 0.17 Hz (Figures 2 and 3). The peak amplitude and peak frequency both show significant variation across the Los Angeles basin. Highest peak amplitudes (above 5.0) were measured for the Long Beach area, with a decrease in amplitude with distance to the North - East. Peak frequencies show a decrease with distance towards the North - East. These frequencies do not appear to correspond to the resonance period that would be predicted for the interface represented by the basin basement in the SCEC UCVM CVM-H model, but suggest a more shallow contrast in acoustic impedance may be responsible.

To investigate lateral heterogeneity, we explore azimuthal variations in microtremor H/V ratio for two stations, A134 and N118, in the LASSIE transect. Microtremor H/V azimuthal variations have been used in previous basin studies to qualitatively interpret the location and effect of the basin edge. Station N118 is
located above the deepest portion of the LA basin and station A134 is located near the basin edge of the CVM model. Results indicate that the orthogonal azimuths that produce a maximum difference in amplitudes for directional H/V at A134 correspond with the major and minor horizontal axis of the LA basin, whereas no significant variation is seen for N118.

This study resulted in two CPP MSc theses:
Ng, R. (Fall 2016), Evaluation of Site Response in the Los Angeles Basin from Spectral Ratio Analysis of Microtremor Data from a High Density Temporary Broadband Deployment
Herrman, M. (Winter 2017), Seismic Waveform Modeling of Broadband Data From a Temporary High-Density Deployment in the Los Angeles Basin

References

Figure 2. Typical spectral ratio curve for typical LA basin station. A peak is found at a frequency of .15Hz, with an amplitude of 4.7.
Basin Edge Focusing

Because focusing at damaging seismic frequencies requires highly convex basin structures the most likely geometries are basins edged by reverse faults such as the LA basin. The reverse motion can underthrust low-velocity sediments beneath higher velocity bedrock. Ma and Clayton (2015) have used noise correlation to obtain phase velocities along the LASSIE line. They inverted that data for S wave structure and find a low velocity convex zone under the Puente Hills (next to station 134) that is a candidate structure for generating focusing.

We find that local events exhibit anomalously large amplitudes indicating focusing in this region. The seismograms (from event 657) were band-passed filtered, and the absolute amplitude of the Hilbert transform is plotted to view the energy in the envelopes. An S-wave window of about 2 sec long was chosen, and the RMS amplitude calculated. The amplitude as well as the noise are shown in Figure (4). A peak occurs at stations A132-A133-A134-A135 (Figure 4). A smooth model of spatial decay and attenuation was fit to the data. Figure 4 illustrates how the inner

![Figure 3. Map of peak frequency and amplitude for the lower frequency peaks across the network. Color of the circle indicates the frequency of the spectral ratio peak, the radius of the circle the amplitude.](image)

4 stations just mentioned rob the energy of the stations either side to form a focusing peak.
Figure 4. Example of focusing. Red curve is RMS energy in windows of S-wave seismograms. Blue curve is simple smooth spatial decay model. Black curve is RMS noise of seismograms before arrival of P waves. Focusing apparently occurs at stations A133-135 that are within 1 km of the damage zone of the Whittier earthquake.