H/V Spectral Ratios of the Jackson Purchase Region, Kentucky Using 5Hz Nodal Geophones

Russel Rogers, Seth Carpenter

Kentucky Geological Survey

College of Arts and Sciences, Department of Earth and Environmental Sciences

Introduction and Motivation

Seismic ambient noise is influenced by the dynamic properties (e.g., shear wave velocity, density, and damping) of the geologic layers through which seismic energy propagates. Though ambient noise is composed of all frequencies, certain frequencies may be amplified by the near surface geologic layers beneath a given site, the recordings of which allow for estimating the dynamic properties of those layers.

Recent studies (Nakamura 1989,Carpenter *et al*. 2018) have found that horizontal amplitude spectra, ***H,*** divided by vertical amplitude spectra,***V,*** derived from ambient noise seismograms, called H/V spectral ratios, can be used to estimate those dynamic properties. The following equation relates the lowest frequency at which amplification occurs, the fundamental frequency, f0, to the shear wave velocity, Vs, sediment thickness, H, and shear wave damping, ξ, which is generally negligible.

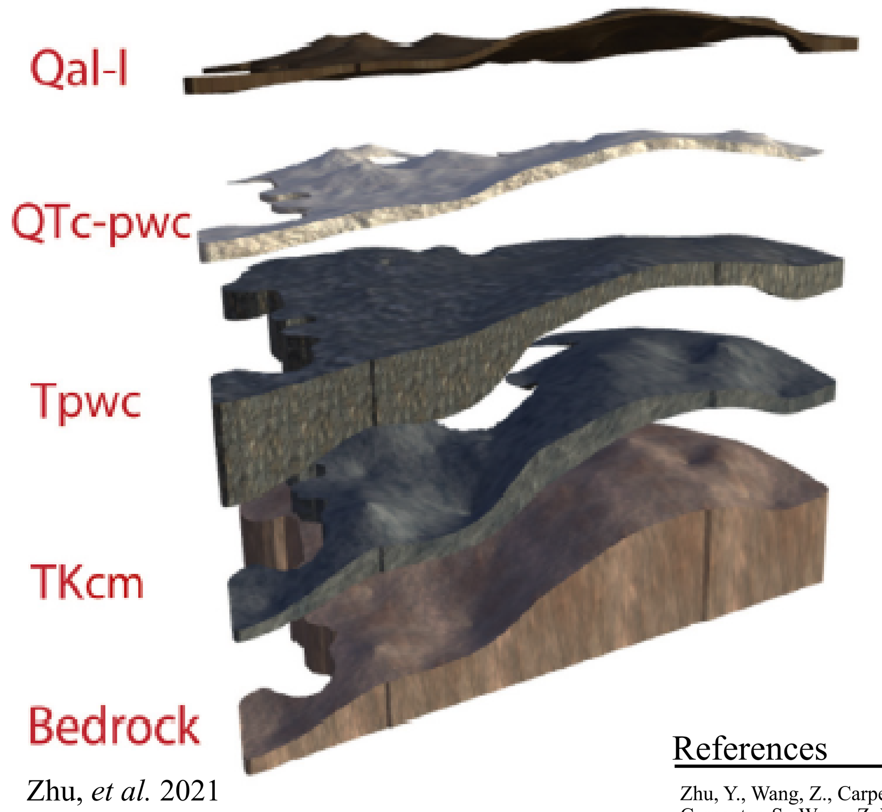
$$f_0 = \frac{V_S}{4H}\sqrt{1-\xi_S^2} \qquad \text{Equation 1}$$

Zhu *et al*. 2021 utilized previously obtained shear wave velocity profiles (the locations of which can be seen in the map to the right) to generate a 3-D model of the sediments and bedrock of the Jackson Purchase region of the Mississippi Embayment (below).

In this study SmartSolo IGU-16HR 3C 5Hz nodal geophones, recently acquired by KGS, were used to acquire ambient noise at 24 of the locations used by Zhu *et al*. 2021. These nodes are small, self contained, three-component seismometers. Geopsy software was used to obtain H/V spectral ratios to measure f0.

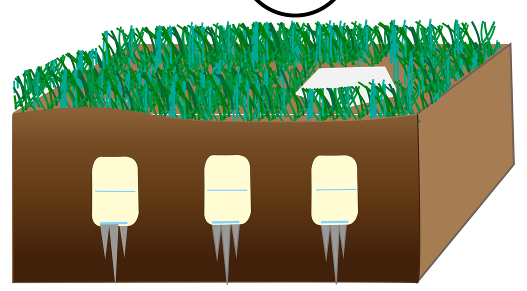
Purposes of this study were to:

- test the SmartSolo IGU-16HR 3C 5Hz nodal geophones, lower left, for low frequency fidelity.
- gain insights on interpreting the H/V spectral ratio curves in the project area.
- use f0 as a means to evaluate the 3-D subsurface model developed by Zhu et al. 202

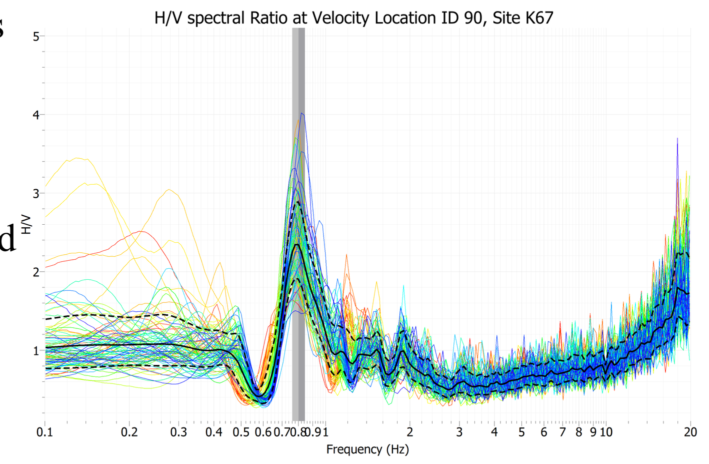


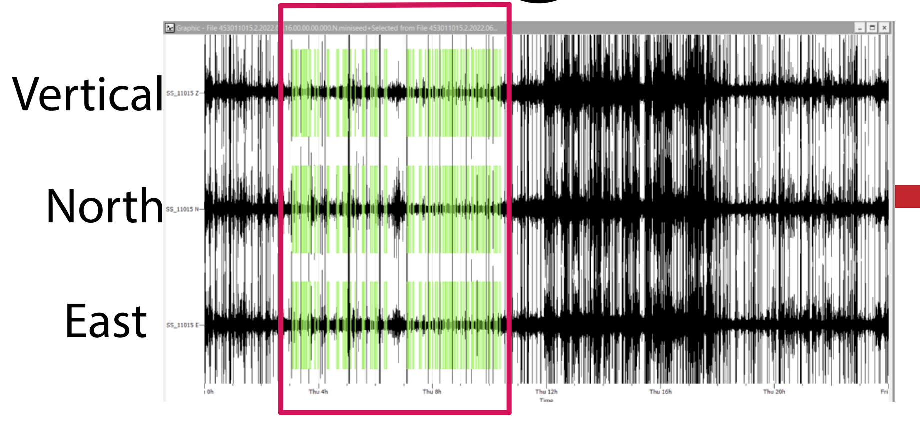
Zhu, *et al.* 2021

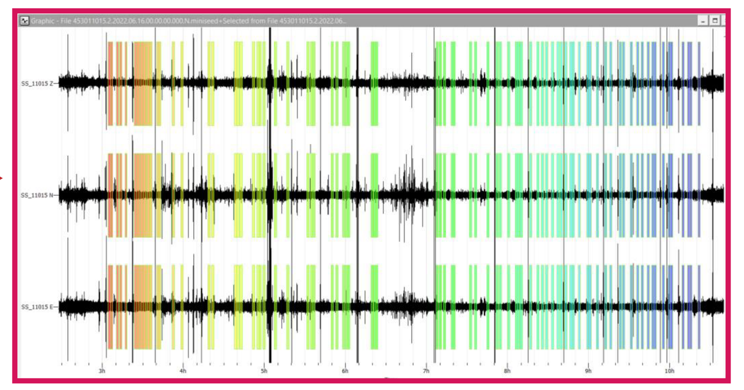
Methods

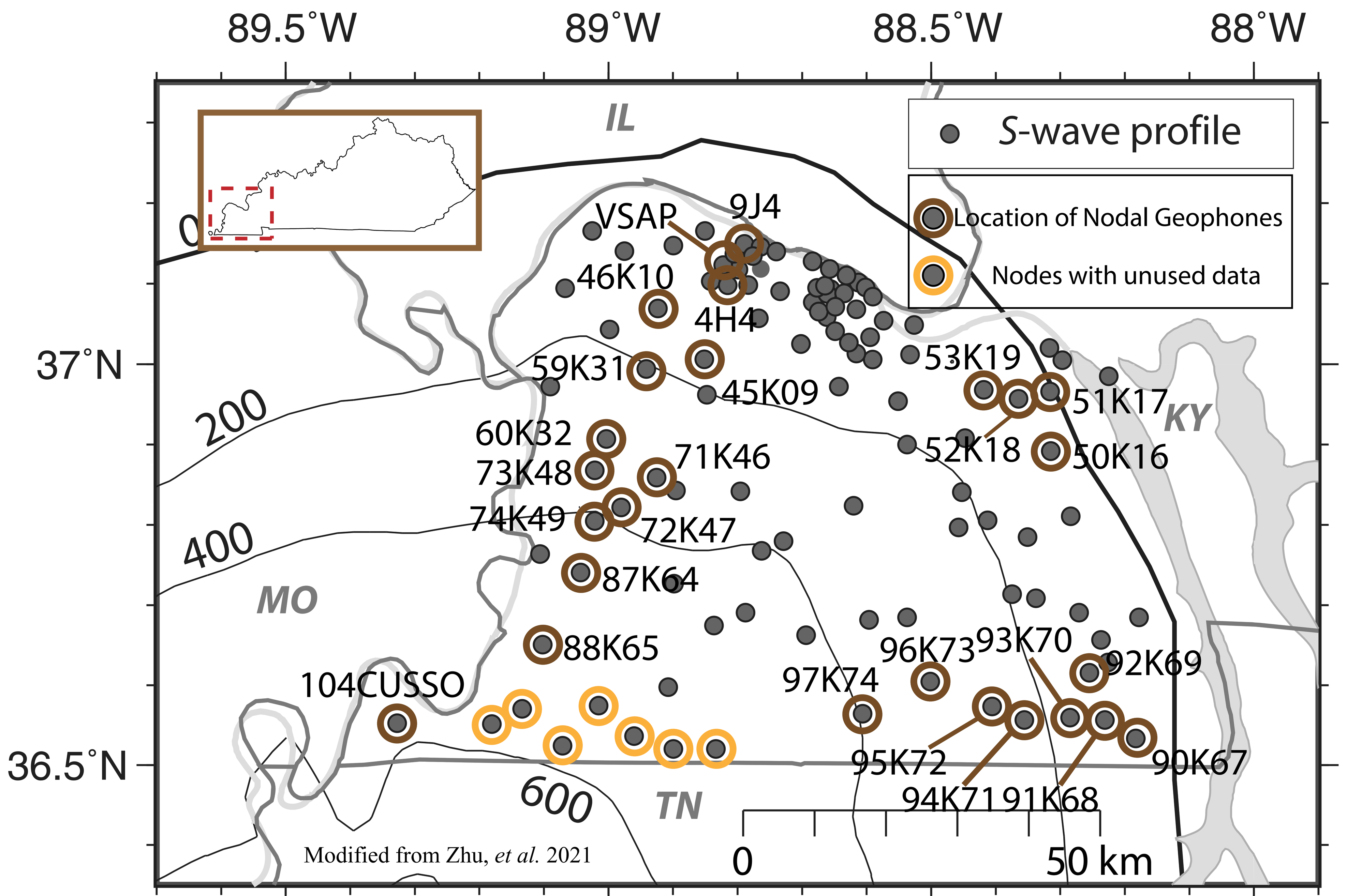


1) SmartSolo IGU-16HR 3C 5 Hz Geophones were buried approximately 10 cm below grade for 5 days
2) Using the quietest portion of 24 hr recordings (between 3 and 8 AM), 100 s windows were used to sample the seismogram
3) Geopsy software was used to select the best data and convert these win dowed samples into frequency dependent spectra for all 3 components
4) the horizontal amplitude spectra were divided by the vertical amplitude spectra to obtain H/V ratios.





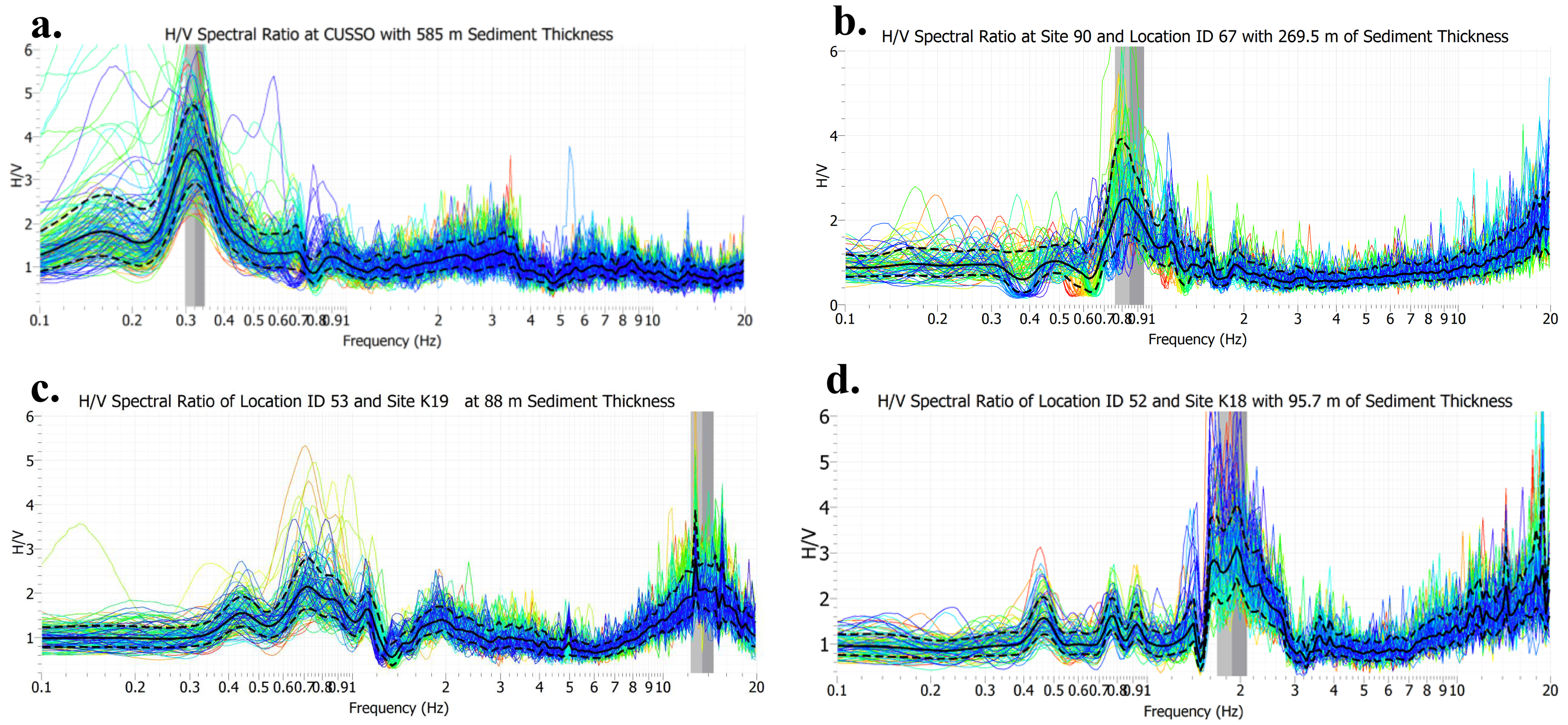




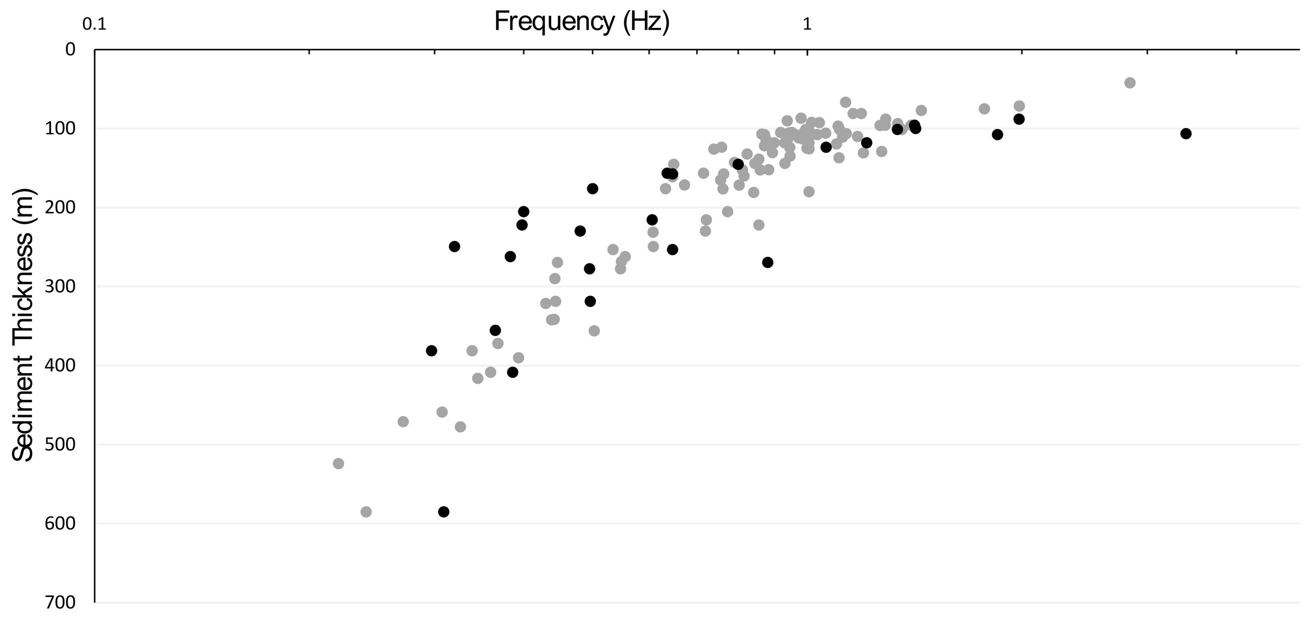
The above map shows the locations where shear wave velocities (Vs) were previously gathered (grey circles), usually done along roads. An attempt was made to install the nodal geophones within 100 m of the Vs locations (brown circles). Orange circles represent undownloaded data. Sediment thicknesses (contour lines in meters) generally decrease from southwest to the northeast.

Results

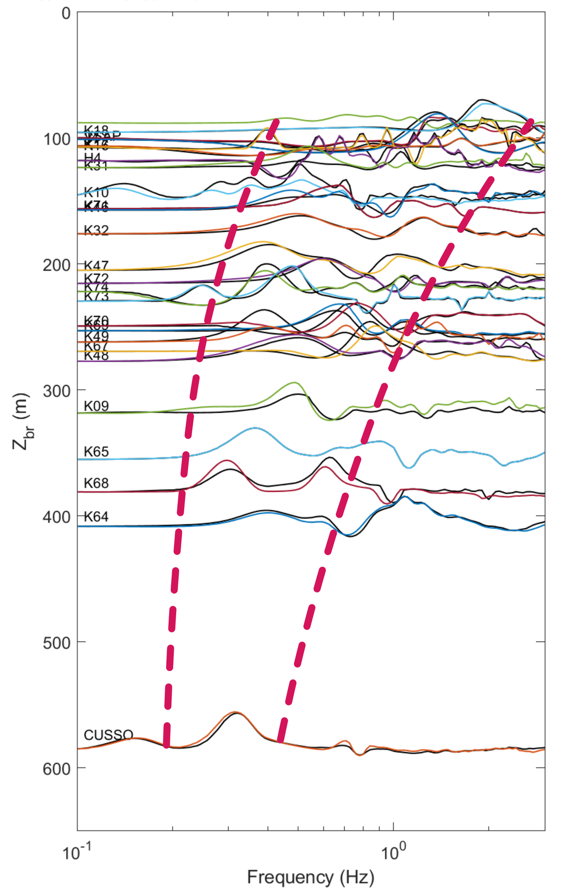
Typically the fundamental frequency is the lowest peak frequency (e.g., Figure a.)



a. f0 peak at CUSSO. Other studies have confirmed the f0 at CUSSO as being around 0.3 Hz: this particular spectral ratio was found to be reliable.
b. A higher frequency f0 peak obtained at a site with shallower sediment thickness (Z_br).
c. and d.. Multiple low frequency peaks making f0 identification difficult.



Graph 1. Sediment thickness vs fundamental frequency (black dots). Grey dots are f0 values determined from the Zhu *et al.* 2021 dataset using equation 1.



Graph 2. Site HVSR curves plotted at the corresponding Z_br.

Discussion/Conclusions

- The Smart Solo IGU-16HR 3C 5Hz nodes were able to resolve frequencies down to 0.1 Hz.
- In spite of significant noise, the H/V spectral ratios still often produced consistent f0 peaks regardless of the day, or time, of sampling.
- Graph 1 displays an inverse relationship between f0 and Z_br as predicted by equation 1 and suggests that the Zhu et al 2021 model is reasonable.
- Many sites with different Z_br values have similar H/V curves (in particular at f0), suggesting that the model Zhu et al. 20221 generated is based upon an incomplete understanding of subsurface Vs and/or Z_br at particular sites.

References

Zhu, Y., Wang, Z., Carpenter, S., Woolery, E., Haneberg, W., (2021). Mapping Fundmaental-Mode Site Periods and Amplifications from Thick Sediments: An Example from the Jackson Purchase Region of Western Kentucky, Central United States, *Bull. Seism. Soc. Am.* **111**, no. 4, 1868-1884.
Carpenter, S., Wang, Z.,Woolery, E., Rong, M., (2018). Estimating Site Response with Recordings from Deep Boreholes and HVSR: Examples from the Mississippi Embayment of the Central United States, *Bull. Seism. Soc. Am.* **108**, no. 3A, 1199-1209.
Nakamura, Y., (1989). A Method for Dynamic Characteristics Estimation of Subsurface using Microtremor on the Ground Surface, *Q. Rep. Railway Tech. Res. Inst.* **30**, no. 1, 25-33.