Using Noise Correlation to Improve the 3D Seismic Velocity Model of the Seattle Basin

Alex Hutko, Mouse Reusch, Douglas Gibbons, Paul Bodin - Pacific Northwest Seismic Network, University of Washington, Seattle
ahutko@uw.edu

Abstract

The Seattle sedimentary basin beneath Seattle is known to significantly amplify long period ground motions. The basin has been characterized by past seismic and other geophysical experiments. The goal of the Seattle Urban eXperiment (SUX) is to use ambient noise cross-correlation of broadband data recorded along receiver-receiver lines throughout the city to understand the basin structure in areas not previously studied and help guide larger experiments in the city scheduled later this year. Ambient noise cross-correlation can be used to extract Green's functions between two receivers since the cross-correlation functions are similar to surface waves excited by earthquakes. Analysis of the surface wave dispersion is used to generate a near-surface velocity model. Our experiment currently uses data recorded by six portable broadband stations as well as existing broadband stations sited in the city. Only a few weeks of data are needed for stable correlelegrams after which the stations are moved. As long as the portable instruments are not needed for other purposes, we plan on continuing to collect data throughout the Puget lowlands and will potentially target other structures such as the Tacoma basin.

Experiment & next steps

-6 broadband T40 sensors & RT130 data loggers

-Occupy garages/basements for 2-6 weeks while the portable array is not in use monitoring aftershocks (this is a background project)

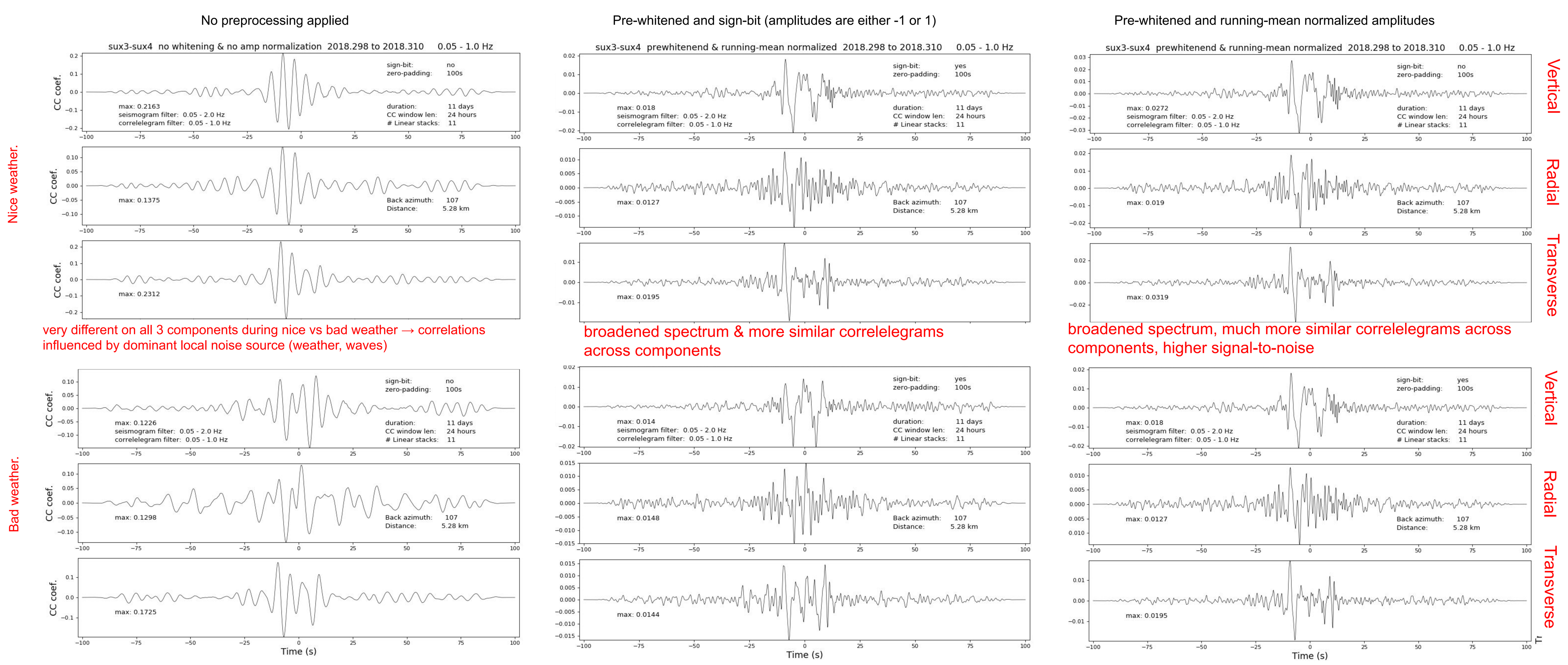
-Gradually move the array southward, in particular near Tacoma

-Dispersion curves: measurements seem stable from about 2-10 s period

-Forward modeling/inversion for structure

Weather (directional noise-source) and processing effects on correlation functions

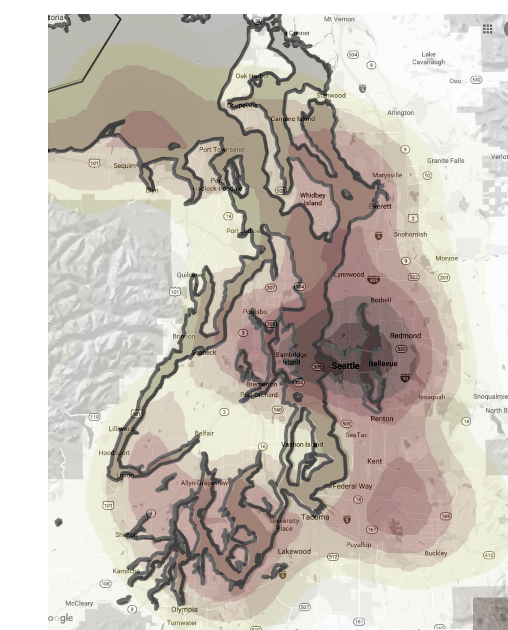
Same 2 stations. Same processing. Back-to-back 11 day-long windows.

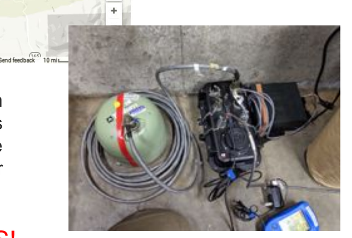


Prewhitening the data broadens the measurement band and also minimizes contamination from spatially localized microseisms (Bensen *et al.*, 2007).

Running absolute mean spatially homogenizes the noise field allowing unbiased estimates of traveltimes and is more sensitive to sources with long durations and less likely to be influenced by a dominant source direction such as the from microseisms from the coast (Chen *et al.*, 2016).

Want to host a site?

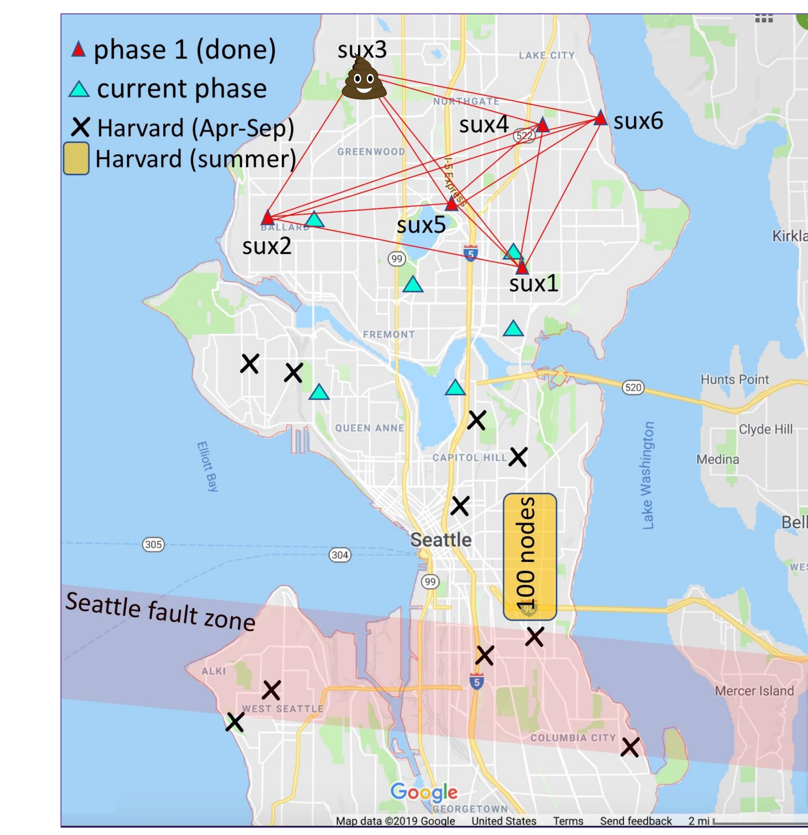




Basin map of the Puget Sound based on depth to an isovelocity contour in the Vs model of Stephenson *et al.*, 2017. We are focusing on shallow structure in the upper few kms only.

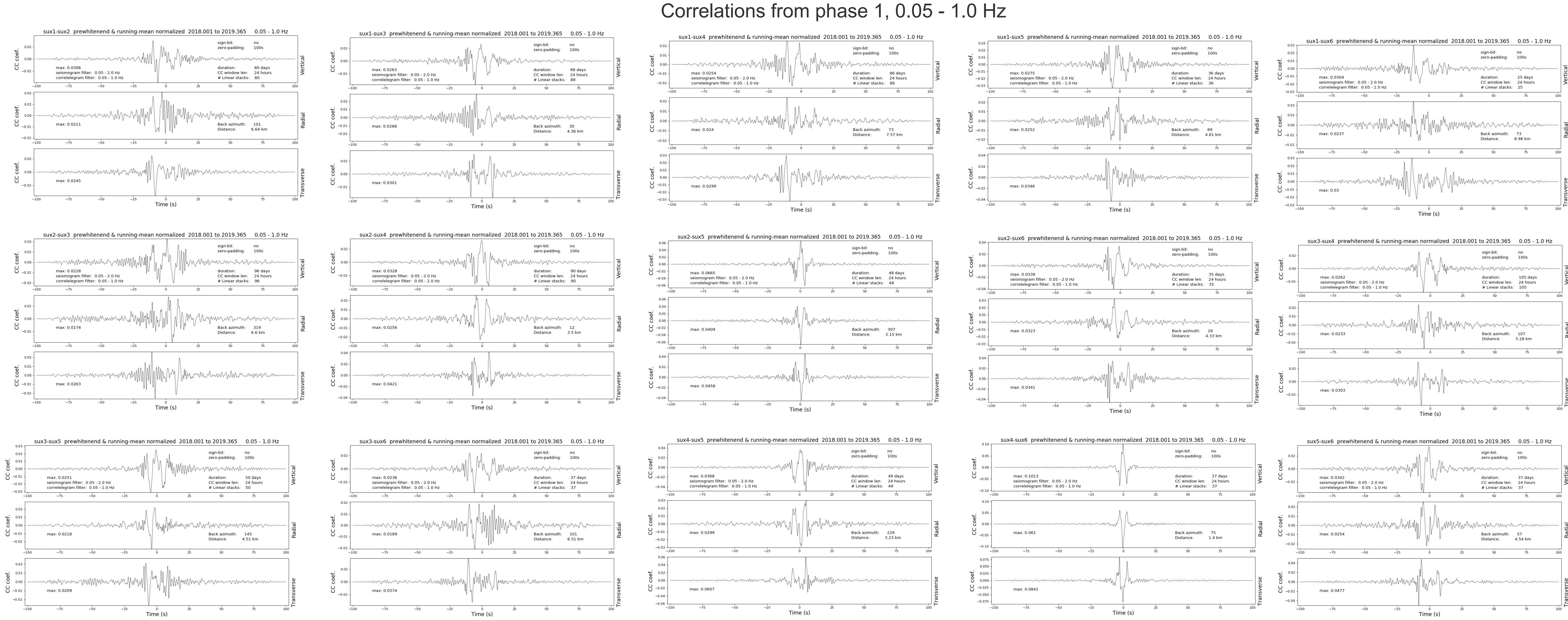
WE NEED MORE STATION HOSTS!
-Do you live within the contoured area?
-Do you have a garage or concrete floor basement?
- 3-6 weeks, draws less power than a night light

Sign up:
https://pnsn.org/about/seattle-tacoma-urban-experiment



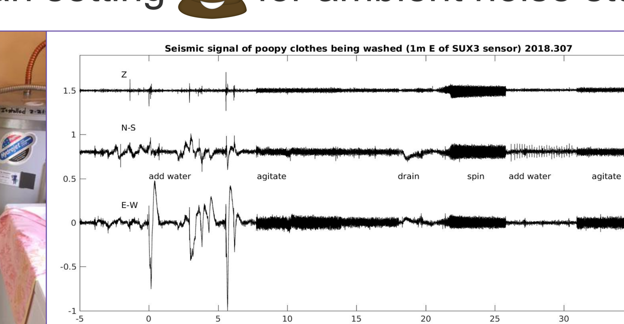
Locations of SUX stations during different phases of the experiment. Also shown are stations of a parallel experiment by N. Toghramadjian and M. Denolle (Harvard), poster #78, focused more on the Seattle Fault zone with whom we will exchange data to increase coverage for both experiments. Our stations occupy sites for a few weeks and then are currently gradually leapfrogging south. We plan to target the Tacoma basin and area in the summer with an IRIS intern.

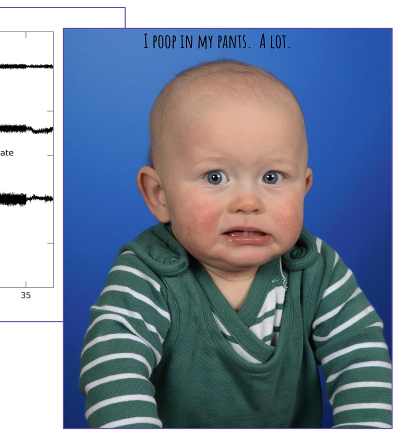
Correlations from phase 1, 0.05 - 1.0 Hz



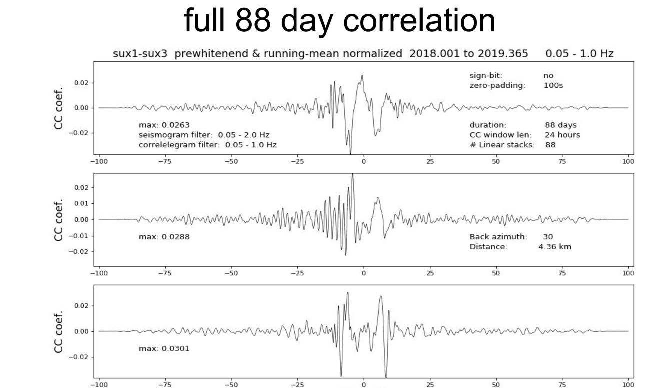
Is an urban setting 💩 for ambient noise studies?

Terrible field siting.

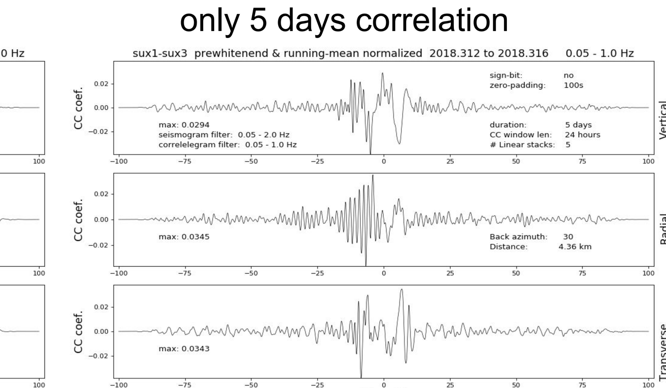




full 88 day correlation

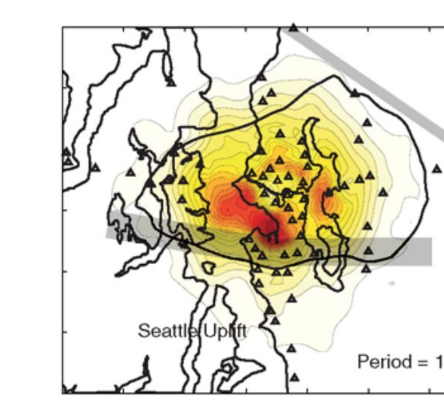


only 5 days correlation

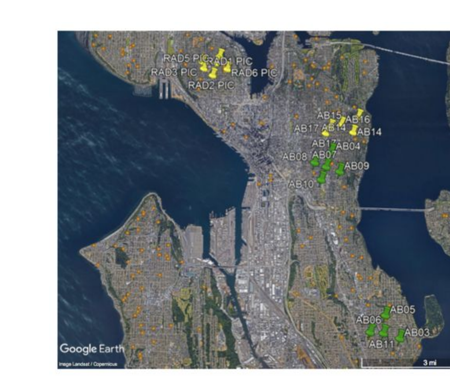


Despite a very noisy urban setting with much cultural noise including close proximity to a washing machine and hot water heater, adequate correlation functions for measuring lag can be achieved in only 5 days. Note: the 5 days were during a time of relatively low microseism noise.

Other similar work



Delroy (2011) used data from the Seismic Hazards in Puget Sound (SHIPS) experiment from 87 L22 short period sensors to meaure Rayleigh wave velocity and dispersion between 0.1 - 0.5 Hz. Our work aims to expand on this by modeling Love waves and eventually rolling the array of 6 stations further south into the Tacoma and surrounding area.



A. Frankel (this meeting) will show the results of a 3 week deployment of 20 stations. Love wave group velocities are measured to update the local 3D Vs model.

References

Bensen, G.D., M.H. Ritzwoller, M.P. Barmin, A.L. Levshin, F. Lin, M.P. Moschetti, N.M. Shapiro, and Y. Yang (2007) Processing seismic ambient noise data to obtain reliable broad-band surface wave dispersion measurements, Geophys. J. Int., 169, 1239-1260, https://doi.org/10.1111/j.1365-246X.2007.03374.x.

Chen, Zhao, Peter Gerstoft, Peter D. Bromirski (2016), Microseism Source Direction from Noise Cross-correlation, Geophys. J. Int, 205, 810-818, doi:10.1093/gji/ggw055.

Delorey A.A., JE Vidale (2011) Basin shear-wave velocities beneath Seattle, Washington, from noise-correlation Rayleigh waves BULL. SEISM. SOC. AM., 101, 2162-2175.

Stephenson W. J. Reitmann N. G., and Angster S. J. (2017). P- and S-wave velocity models incorporating the Cascadia subduction zone for 3D earthquake ground motion simulations—Update for OFR 2007-1348, U.S. Geol. Surv. Open-File Rept. 2017-1152 , 17 pp., doi: https://doi.org/10.3133/ofr20171152.