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"Never be afraid to raise your voice for honesty and truth and compassion against injustice and lying and greed." -William Faulkner

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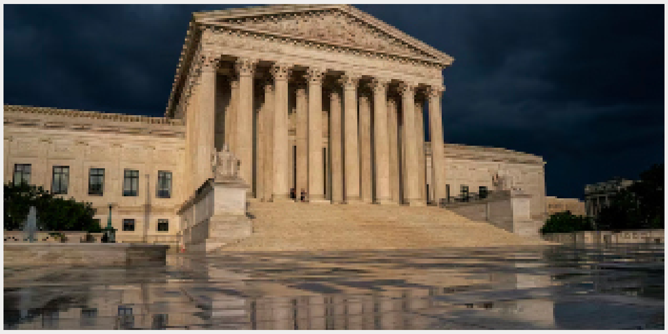

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Innovation

Mapping Near-Surface Seismic Velocities in Southern California Using Raspberry Shake

By: Kalina Li

Abstract:

In this study, I used Raspberry Shake seismometers to estimate near-surface seismic velocities in Southern California. These small instruments record earthquakes and background vibrations, called ambient noise. By cross-correlating the signals between different stations, I measured how long it takes surface waves to travel between them. I then converted these measurements into velocity estimates and made a velocity map of the Los Angeles Basin. My results show slower velocities in the sedimentary basin and faster velocities in the nearby mountains, which matches what scientists expect based on the geology of the region. Even though the sensors are noisier and less accurate than professional instruments, my study shows that community networks like Raspberry Shake can help improve earthquake hazard studies.

Introduction:

Southern California is one of the most earthquake-prone regions in the world. The Los Angeles Basin, where millions of people live, is filled with sedimentary rock that can trap and amplify earthquake shaking. One of the most important factors that controls how strong the shaking will be is the speed of seismic waves in the ground. In particular, shear wave velocity tells us how stiff or soft the ground is. Softer materials have slower velocities and cause stronger shaking.

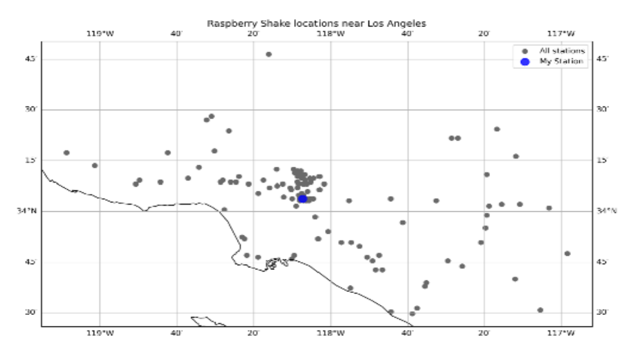
Professional seismic networks can measure these velocities, but they are expensive and limited in number. Raspberry Shake seismometers have been created as small, low-cost alternatives. These devices can be installed in homes or schools, and upload data through the internet. While they are not as sensitive as professional instruments and often record more background noise, they can still detect earthquakes and ambient vibrations. One useful method for studying seismic velocity is to use ambient noise. This is the “background hum” of the Earth, mainly caused by ocean waves. By cross-correlating noise recorded at two different stations, it is possible to measure how surface waves travel between them and then estimate their velocity.

In this project, I used Raspberry Shake data and ambient noise analysis to make a first version of a velocity map for Southern California.

Methods and Analysis:

Data Sources:

I collected seismic data from Raspberry Shake stations in Southern California by downloading them in the form of miniSEED files. The data was cut into daily sections, resampled to 40 Hz, and filtered to focus on the frequency range of 0.1–1 Hz, where most microseism energy is found.



Preprocessing:

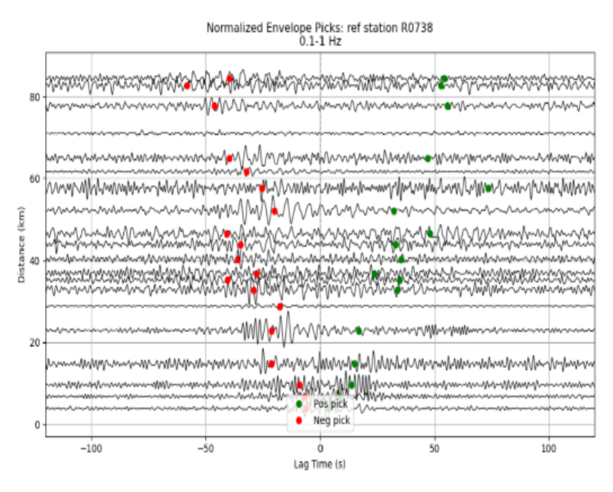
To make the signals easier to compare, I normalized the data so that no single earthquake or loud event would dominate. I then cross-correlated pairs of stations in short time windows and stacked the results together.

Cross-Correlation and Velocity Picking:

From the cross-correlations, I measured the time lag of the largest arrival. To do this, I used the Hilbert envelope method. The Hilbert transform takes the original signal and creates an “envelope” that traces the overall shape of the wave. This makes the strongest arrivals easier to see, since the envelope smooths out the smaller oscillations of the waveform. I then picked the peak of the envelope as the arrival time.

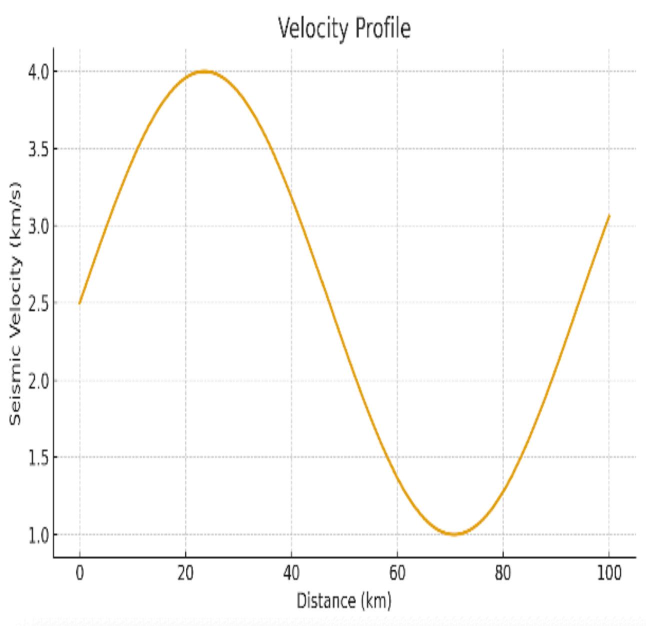
After measuring the time lag, I calculated velocity by dividing the distance between two stations by this travel time.

Not all of the cross-correlation results were easy to use. In some cases, the peaks were hard to identify or there were multiple peaks that made it unclear which one was correct. I removed these outliers so they would not affect my results. I also set reasonable limits for velocity values. If a velocity was below 0.5 km/s or above 5 km/s, I assumed it was caused by noise or an error and left it out. This helped me focus on the measurements that were most reliable.



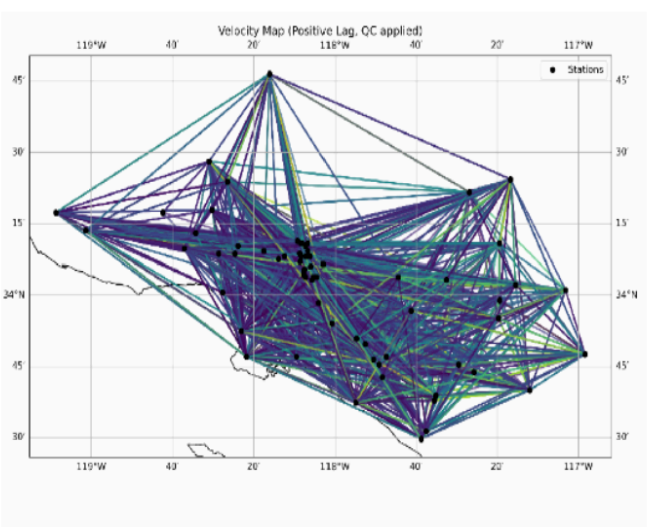
Velocity Map Construction:

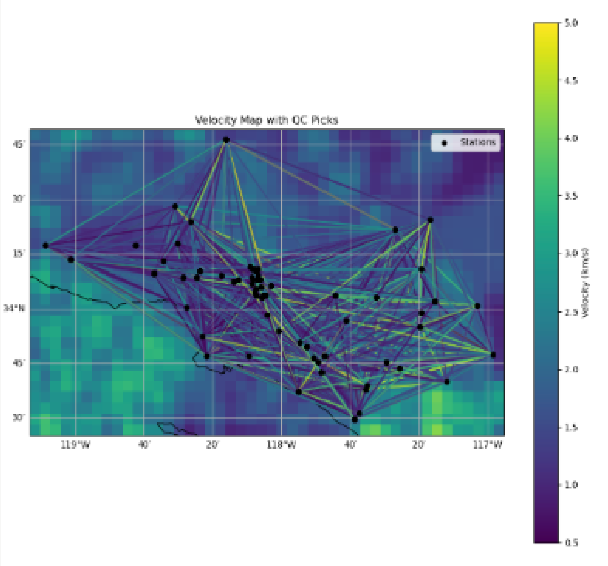
The velocity values from all station pairs were averaged and interpolated across the study area to make a continuous map.



Results:

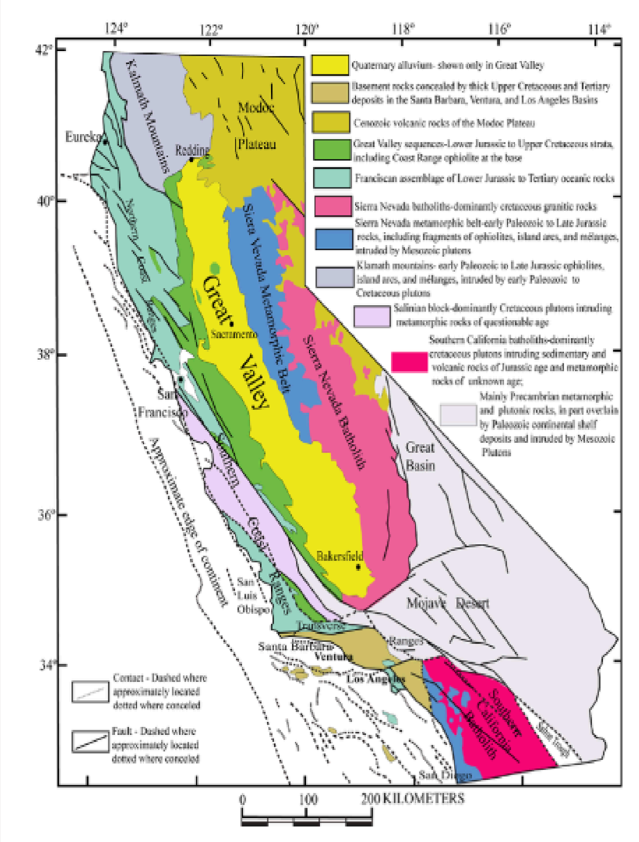
I found that the measured velocities ranged from about 0.5 km/s to 5km.s. The lowest velocities were in the Los Angeles Basin, which is filled with softer sedimentary rocks. The highest velocities were in the mountains surrounding the basin, where the ground is made of harder bedrock. Outliers and unclear picks were removed during quality control, which improved the clarity of the velocity map.



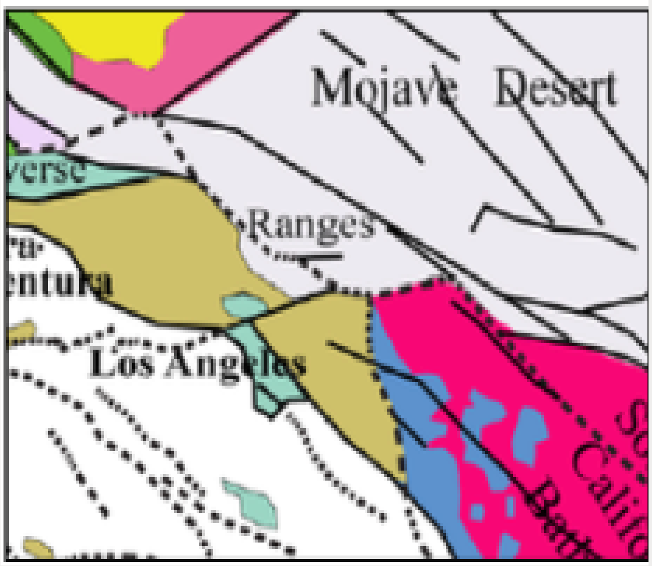


Discussion and Conclusion:

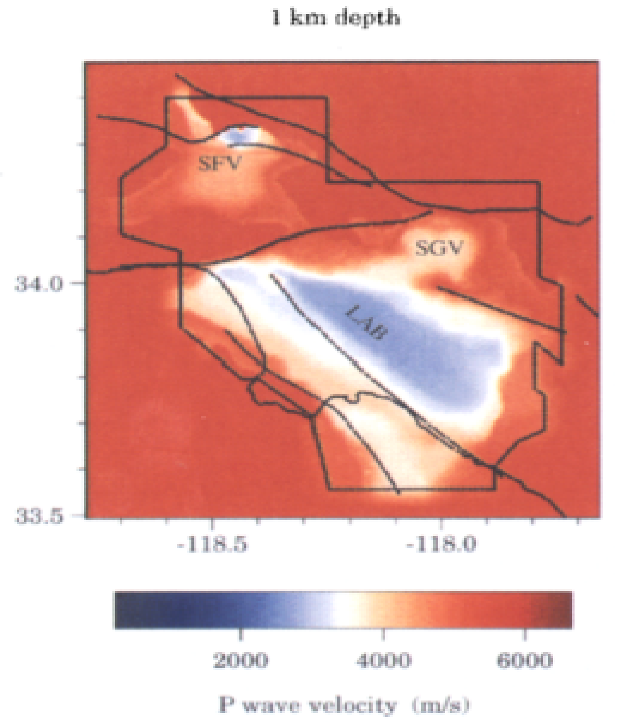
My velocity map shows patterns that match well with what is already known about the geology of Southern California. The Los Angeles Basin has low velocities because it is filled with sediments, while areas north and east of Los Angeles show higher velocities.



Simplified geological map of California (Koirala & Hayashi, 2010)



From the two maps, regions Los Angeles containing Franciscan assemblage of Lower Jurassic to Tertiary oceanic rocks have lower sub-surface velocities compared to the surrounding basement rocks concealed by thick Upper Cretaceous and Tertiary deposits.



Map of P-wave velocity at a depth of 1 km (Magistrale et al., 1996).

There are also limitations to my study. Raspberry Shake stations are not as sensitive as professional seismometers, and since many aren't placed in controlled areas, they pick up extra noise from human activity. The coverage of the network is also uneven, which makes the map less accurate in areas with fewer stations. In addition, some station metadata is incomplete, which can cause errors in distance calculations.

Another limitation is that quality control sometimes requires removing a lot of data. This meant that not all frequency ranges or station pairs could be used. While this reduced the total number of measurements, it made the final velocity map more trustworthy because it was based only on clearer signals.

Even with these challenges, my study shows that Raspberry Shake data can be used to estimate seismic velocities.

With more stations and longer time series, the maps could become much more detailed and reliable.

I used Raspberry Shake data and ambient noise cross-correlation to estimate seismic velocities in Southern California. My results show that the Los Angeles Basin has lower velocities while the surrounding mountains have higher velocities, which agrees with the known geology. Although the data is noisier and less precise than that from professional seismic networks, my results prove that community-based seismology can provide useful scientific information. As the Raspberry Shake network grows, it can help improve earthquake hazard maps and increase public involvement in earthquake science.

References:

Koirala, M. P., & Hayashi, D., (2010). Fault Type Analysis along the San Andreas Fault Zone: A Numerical Approach. Journal of Mountain Science 7(1):36-44. doi:10.1007/s11629-010-1015-5

Magistrale, H., McLaughlin, K., Day, S., (1996). A Geology-Based 3D Velocity Model of the Los Angeles Basin Sediments. Bulletin of the Seismological Society of America, Vol. 86, No. 4, pp. 1161-1166