

Interactive comment on “Seismic signature of the COVID-19 lockdown at the city-scale: A case study with low-cost seismometers in the city of Querétaro, Mexico” by Raphael S. M. De Plaen et al.

Anonymous Referee #1

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This manuscript uses ground motion data from 7 Raspberry Shake RS4D stations located throughout Queretaro, Mexico to demonstrate reductions in seismic noise in response to COVID19 lockdown measures implemented by the Mexican government to mitigate the spread of the disease. The paper then compares these reductions with independently attained mobility data from google and shows the expected positive correlations between seismic noise and transportation, shopping, and recreation. Additionally, seismic recordings are compared at two soccer games between identical clubs both prior to the pandemic (with approximately 30,000 spectators) and after the

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pandemic when in-person attendance was forbidden. Processing of the seismic data is carried out using the Lecocq et al (2020) software package and is appropriate for the study. Overall, I found the study convincingly demonstrated reductions in cultural noise in response to lockdown measures. I enthusiastically recommend the manuscript for publication in the EGU special issue on Social Seismology and the effect of COVID19 lockdowns following moderate revisions to substantially improve the presentation and reproducibility of the work.

Despite some of these presentation issues, I found the paper fun to read – something that can't often be said about technical manuscripts! Nice work on the study!

Main Points

I think one of the conclusions of the study, “that traffic noise is dominating the high-frequency noise environment within cities” could use more support in the discussion section. It would be good to have a better tie-in between the observations in this study with previous work to demonstrate this conclusion.

Additionally, I think that several (mostly tangential) points in the manuscript are misleading or were stated incorrectly. These should be addressed in a revision and I point them out in the line edits below.

Otherwise, I have no overarching concerns from a scientific standpoint. The seismic and mobility data was analyzed using known, accepted methods by the seismological community that is appropriate for the study. Overall, Figures are of high-quality and are easy to parse, though some more information in the caption would be useful.

The following line edits are my opinion and are meant to improve the presentation and reproducibility of the manuscript.

Line Edits

L10: Long-lasting “pandemic” for “lockdown” – this is being discussed in a global context, lockdown measures were highly variable across the globe – lumping them all

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together and calling them “long-lasting” when some cities didn’t even implement measures seems inaccurate to me.

L16 and Elsewhere: “sporting” for “sportive.” In this manuscript “Sportive Events” refers to soccer matches, not an endurance bike race (the typical definition of a “Sportive event”

L27: Suggest discussing more broadly here the changes in society that have been observed as resulting from COVID19 lockdown measures, and then drilling down into the seismological observations later. Right now, this seems redundant with L49-50.

L30-34: I found these sentences very difficult to follow. Suggest re-writing and including a definition of “informal economy” as seismologists and geophysicists probably don’t know what this is.

L40 – This sentence seems like it should be included in the previous paragraph, and as written doesn’t really make sense. I would re-write it as: “For instance, internet adoption in rural areas of Mexico is estimated at 39.2% in urban areas with 53.8% of the population owning smartphones. In contrast, 71.2% of urban residents have access to the internet and 77.7% use smartphones.”

L41 – Bringing up DAS technology to monitor ground motions seems totally out of place here (seismic analysis hasn’t even been introduced yet). This would be better to bring into the discussion.

L49 – Another sentence that makes no sense as written. Suggest splitting into 2 sentences

Suggested wording “. . . .correlates with mobility data (references). Therefore, analysis of seismic noise may off the ability to attain mobility information without the privacy-related concerns and limitations of using mobile technology.”

L52: “Even though this area has lower seismicity rates than other parts of Mexico, it is.”

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Table 1: Dates and events for “phase 1” are confusing because 2 dates are given. Can these be separate rows in the table or is the 14-03-2020 event needed?

Table 2: Red row: suggest “encouraged” for “invited” – “invited to shelter at home” isn’t really correct English.

Figure 1 – Suggest a box outlining the “historic center” as stated on L78

L75 – Anthony et al, did not use Raspberry Shakes to densify networks as this sentence suggests - rather they tested the performance of the sensors and found them to be acceptable for use u regional networks. “from all magnitudes” is misleading – for instance, a Raspberry Shake cannot see a M5 teleseism. Finally, it might be nice to note that only data from the geophones is considered.

Suggested edit: “These low-cost sensors were demonstrated to perform suitably well for monitoring a large range of local and regional earthquake magnitudes (Anthony et al., 2019). However, while the accelerometers are capable or recording larger, more powerful earthquakes, they have high self-noise levels and are not able to resolve most cultural activity. Therefore, we restrict our analysis in this study to only the vertical component geophone data.”

L81: Are these multiple universities? If so, it would be good to specify which Universities are included here.

L87 – remove “numerical conversion” – I’m not aware of this noise source unless it is digitizer noise, which I would think would fall under the “instrumental noise” umbrella.
L87 – Just leave it as “microseisms” – these are called “primary” and secondary microseisms (not first and second), but you won’t be able to observe the primary with a Raspberry Shake.

L93 – Would probably be good to specify the amount of smoothing used in the Lecocq et al processing algorithm, especially since the data is then bandbassed into 1 Hz bins, and depending on smoothing in this step, these frequencies may not actually be being

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isolated.

L94 – Would be good to make it clear that these are displacement RMS timeseries data (As opposed to acceleration or velocity).

L95 – Would be good to specify how the 1 Hz RMS displacement bins were constructed. Was the data simply bandpassed? How many poles on the bandpass filter and where were they?

Figure 2 – Nice Figure! I would specify in the caption that what is being plotted is something along the lines of “normalized RMS displacement in 1 Hz frequency bins.” I also suggest noting the move of R2013 directly in the Figure since the change of noise is so striking.

Figure 3 – It would also be good to specify in the caption the time-period over which the correlation analysis was performed as well as the meaning of the dashed lines (I assume they indicate the threshold for correlations to be significant at the 95% Confidence Interval?)

L116 – Can the normalization time period of the mobility data be changed to match that of the seismic (L138)?

L135 - Probably worth noting in the text why station R6BB7 was chosen for this analysis as well as that the determined 4-14 Hz frequency band is identical to that used in the Lecocq et al. (2020) study.

L152 – Is it possible that the work in the industrial park is seasonal? E.g. there is more activity in the spring and summer? It might be worthwhile to look at another year of data to make sure that seasonal trends are not being interpreted as COVID19-related here.

Figure 4 I don't think panels b-d were discussed in the text. Also, it wasn't clear to me if only a single day of data was being plotted or a date range. I suggest removing them from the manuscript if they are not needed. Figure 4A stands nicely on its own I

think. . . .

It would be good to specify in the caption that this is 4-14 Hz noise (at least I think it is).

What do the red and green shaded areas below the RMS noise curves mean?

The “blue” holiday lines look “green” to me in the Figure.

It might be helpful to plot all stations on the same Y-axis to facilitate direct comparison between stations. It took me a while to realize the axis was not consistent.

L160 – Date of Easter would be helpful

L161- “.displayed the smallest change with noise levels dropping by less than 10%,.”

Figure 5 – Consider adding a dashed “0-line” to the plot as in Figure 4a.

The holiday dashed lines look more black than blue to me. . . especially early on. It might be better to use solid and dashed lines here to distinguish between lockdown measures and holidays.

Give date range of cross plots in Figures 5b and 5c. It wasn’t clear to me over which time period these correlations were performed – particularly for Figure 5b

L177 – Suggest giving the data of “Good Friday Holiday”

L181 – Suggest referencing figure 4a here

L190 – citations of Vidale (2011; SRL) and Diaz et al (2017, Scientific Reports) are probably warranted here as they also considered the seismic signatures of fans responding to scoring events at football games (Vidale is American football, but same idea).

L204 – This conclusion that the uptick in noise after the game is related to the home-team winning seems to conflict with Figure 7, where the same uptick is seen in 2019 even though Gallos Blancos lost the game.Could this uptick not be due to people

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starting their cars and driving home after the game?

Figures 6 and 7

- Label colorbar - Specify the frequency band plotted in the “E” panels. - Add median noise level for the week (as discussed in L205) to panel E

L232 – Over what time period were these correlation coefficients attained from? They don’t match Figures 5b or 5c. I assume it is from a longer period than either of these plots?

L234 – This sentence seems to argue that the only reason a positive correlation between seismic noise and people staying at home isn’t observed is because the seismometers were not installed near residential areas. I don’t think this is correct.

I think the negative correlation with “residential areas” is expected as people don’t make many seismic signals when they are sitting at home watching TV or working remotely. As is alluded to in the conclusion – most high frequency noise is likely coming from traffic – and this is simply reduced when people are staying at home.

L242 – It seems like the argument is being made here that traffic noise is the dominant high-frequency noise source that is being modulated throughout the study? Can this be made more clear? Can you find some studies that show this? This is stated as a conclusion on L264, so a bit more support and clear thought that traffic is indeed the dominant noise source is warranted here.

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