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# *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.

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Review of SE_2020_194: Plaen et al., "Seismic signature... Querétaro, Mexico" Several papers have now been published describing the reduction of seismic ambient noise due to Covid-19 lockdown measures. So, this is not really an entirely new contribution. However, high frequency ambient seismic noise recorded in cities has many different contributing sources, mainly related to traffic, and it is not always easy to separate their sources and estimate their distance range. In this respect, the Querétaro case study, describing different noise behaviors in different parts of the town, is interesting and



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deserves publication as it may contribute to further more detailed analyses. The paper is generally well written and clear, and the figures are of good quality. Some points, however, would benefit from better descriptions. I recommend publication with minor revisions, especially addressing the main points below.

>We are grateful for the positive comments and helpful recommendations.

Main points: 1) Mobility measures. It would be good to describe more clearly the meaning of the "Google mobility index". For example, does a 30% increase in residential mobility mean that there are 30% more people (i.e., 30% more cell phones) in residential areas, compared to the baseline period? Does the Google "mobility index" record only when people change their location ("movement trend" as in lines 113-114)? Or when they use their location app in the cell phones, even if not moving ("the time spent" in each category of place, as in lines 115-116). This is important to interpret the correlations of Fig. 5, for example.

>The confusion may arise from a difference in how the index is calculated for each category. The variation of the mobility index in the residential category is associated with the average amount of time in hours spent at places of residence by individual users relative to the count of unique users who spent any time at residences in a given day and geographic area. This method is specific to the residential category, as the workplace index is calculated as a count of users spending more than 1 hour at their places of work each day and is aggregated by place of residence of the users. In contrast, the other categories count the number of unique users who visited a public place of a given category in a given day. In this latter case, for each geographical location, individual users can contribute at most once to each category and up to 4 pairs of category-location per day (Aktay et al. 2020). We amended the explanation on the index for clarity.

2) In line 143, the sentence "The resulting time series show less impact from weekends, but they are characterized by lower noise levels ( Figure 4)" was not too clear for me.

You mean that noise on weekends also decreased compared to the baseline, but the decrease was not as large as for weekdays?

>Not exactly. The noise level is typically lower during weekends than during weekdays, this is the pattern that characterises the vast majority of urban environments. This pattern can still be observed with lockdown measures, probably due to essential activities mainly taking place during weekdays. However, when observed relative to the baseline (based on past corresponding days of the week), weekends exhibit a decrease that is consistent with the weekdays.

3) Lines 151-152 explains the increase in noise levels in the industrial area as possibly due to increase of "delivery of food and supplies". Is this just a hypothesis? Is there a way to help confirm this explanation?

>This is indeed a hypothesis. To the best of our knowledge the information necessary to confirm this explanation is not openly available and we had to perform an informed guess based on the possible essential activities that could generate such change.

4) section 3.2 Correlation of noise with mobility: 4.1) Lines 235-236. I did not quite understand the explanation for the anti-correlation with mobility in the residential areas. if increased mobility in the residential category indicates more people are staying at home, then less traffic will occur both in the residential areas as well as elsewhere in the city.

>As answered to Reviewer 1, this sentence attempted to swiftly discard a specific scenario in which a strictly residential area could see a decrease in traffic generated seismic noise less significant than the rest of the city. We acknowledge the potentially confusing nature of this explanation and removed it for better clarity.

4.2) Lines 236-239. I did not understand why the lower correlations in the "New norm" period, compared with the "Early lockdown phase" imply that the mobility pattern is "more complex" during the relaxation period. For example, a 30% mobility reduction

(assuming this is mainly related to traffic reduction) should produce the same RMS noise reduction, independent of the lockdown or new-norm period. I do not understand why traffic (the main source of seismic noise) should relate to the google mobility in different ways in the lockdown and in the new-norm phases. The problem, I think, is that correlation coefficients may not the best measure as they are much influenced by the scatter. The slope of the straight-lines in Fig. 5 may be a better proxy for the relationship between mobility and seismic noise. For example, the red lines (transit stations) have very similar slope in both phases, during the lockdown (Fig. 5b) and during the whole period (Fig. 5c): about 37% noise reduction/100% mobility reduction.

>The assertion that the mobility pattern is more complex during the Nueva Normalidad than during the early lockdown phases is also associated with the limitations of Google's community mobility index. The location history is based on users' mobility regardless of whether they are driving or not. As a result, more uncertainty is introduced when analysing the relationship between the seismic noise and the mobility index under the assumption that traffic is the dominating source of anthropogenic noise. With non-essential activities shut down during the early lockdown, fewer activities were available. As a result, the categories of mobility were likely more distinct and as their reduction translated into a decrease in traffic, the relationship with the decreasing anthropogenic noise strengthened. When the city progressively re-opened, it triggered a progressive increase in mobility in all the non-residential categories, potentially more that 4 pairs of category-location per day (as limited by the Google algorithm) and not necessarily involving automotive transport. This increasingly complex mobility pattern has the potential to decrease the relationship between seismic noise and mobility as an increasing part of it (e.g. pedestrians and bicycles) does not generate traffic noise, the dominant source of anthropogenic seismic noise.

5) In section 4 (Conclusions) the authors seem to conclude that "traffic appeared to dominate observations" of seismic noise. Strictly speaking, the paper does not "prove" this link between traffic and seismic noise. However, all stations are near roads and

highways with heavy traffic ("< 5 km"); in addition, it is well known from the literature that traffic is the main contributor to seismic noise in stations close or within cities. So, it would be better to conclude that the observed correlation between seismic noise and mobility is consistent with the traffic-dominated nature of seismic noise in urban areas.

>The scope of the paper is not to prove that traffic is the dominant source of anthropogenic noise. For this purpose, we are limited in this study by the instruments available since the network was not designed for this purpose. As Reviewer 2 understood, the assertion that traffic dominates the noise in our observations is an interpretation based on the scientific consensus and the analysis of the configuration of the network near major roads. The point the paper is making is that although traffic typically dominates anthropogenic noise in cities and can be used to monitor mobility, sources in the near field such as road constructions, deliveries or event sporting/cultural events can significantly influence observations (e.g. R45B4, RB158 and REBDD). Although it may be tempting to use individual seismic stations to interpret the mobility of a whole city, we illustrate the limitations of such an approach. However, the average noise observed by a network at the city-scale offers a more reliable proxy for the variation of mobility, even with low-cost sensors.

We followed the suggestion and rewrote the following sentence to better carry this point across: “While we observed the contribution to anthropogenic noise in the near-field of source such as construction work and sporting events, the observed correlation between seismic noise and mobility at the city scale is consistent with the traffic-dominated nature of anthropogenic seismic noise in urban areas.”

Minor points: a) Fig. 1: Please edit the position of label R6BB7 as it hides one of the other stations.

>Figure updated as suggested.

b) Fig. 4: Please indicate the "baseline period" (perhaps along the time axis) as it may help the readers understand the plot more easily.

>We updated the figure as recommended.

c) Fig. 5: I suggest to remove the probability level, so as not to clutter the figure, leaving only the r-value. This will also avoid hiding some of the data points. All probabilities are extremely small (because the number of points is very large) - it would be sufficient to mention in the text that all correlation coefficients are highly significant (probabilities less than 10E-15).

>Updated as suggested

d) Section 3.1 Sportive events: The analyses of the two football matches is interesting, but it does not add much. It only says that the noise from 22 players running in the field is insignificant compared with that of 30000 supporters jumping in the stadium.

>More than the lack of noise observed from the 22 players, the point is more the contrast with the noise observed with an audience and the perspective it offers when using a single station to characterise the mobility of a whole city. Beyond the entertainment factor of this section, it further emphasizes the benefit of using a network to study mobility at a city-scale, even using low-cost sensors.

e) Paragraph 230: the correlation coefficients mentioned in this paragraph are different from the ones in Fig. 5. Please check.

>Yes, this was a mistake. Those values corresponded to a past window selection that included time before the lockdown implementation. They are now updated to only include the lockdown period, matching Figure 5C.

Please also note the supplement to this comment:
https://se.copernicus.org/preprints/se-2020-194/se-2020-194-AC2-supplement.pdf

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Interactive comment on Solid Earth Discuss., https://doi.org/10.5194/se-2020-194, 2020.

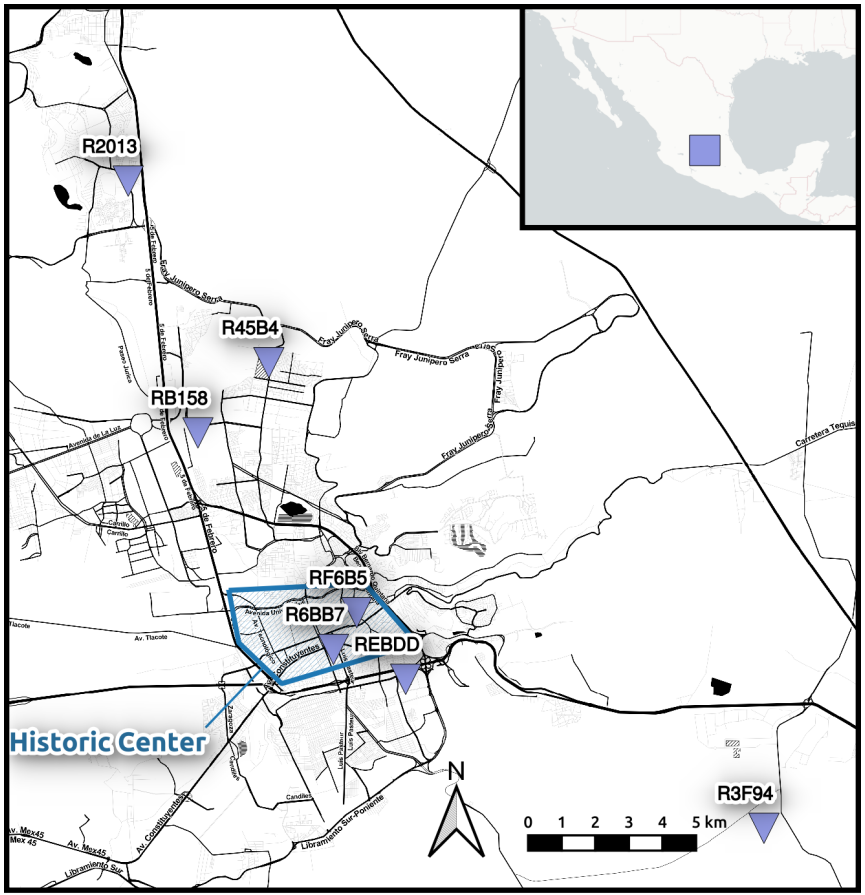


**Fig. 1.**



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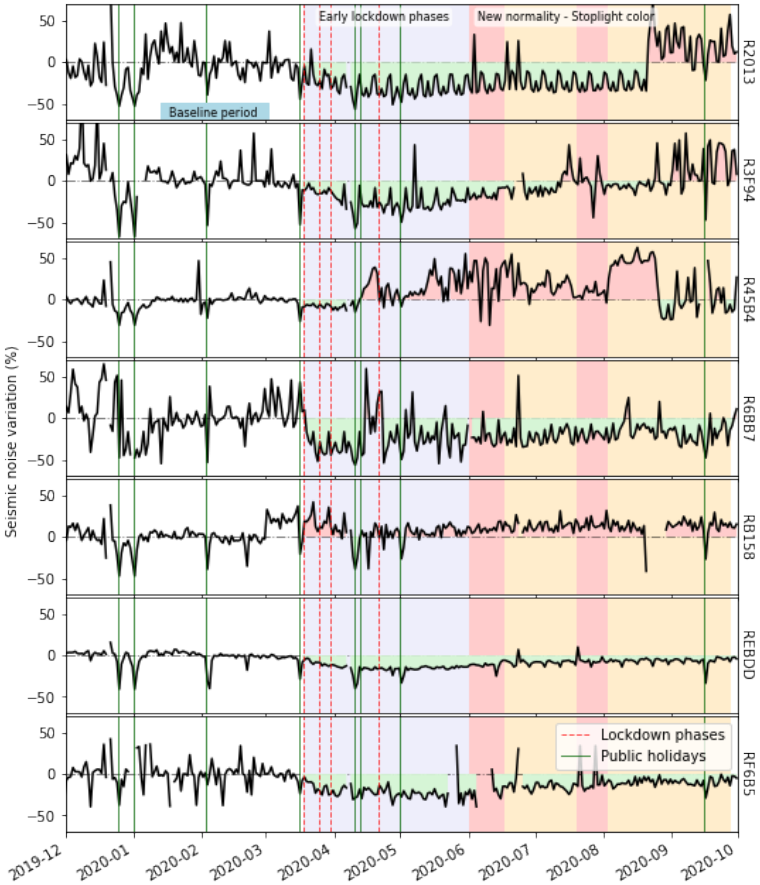


**Fig. 2.**



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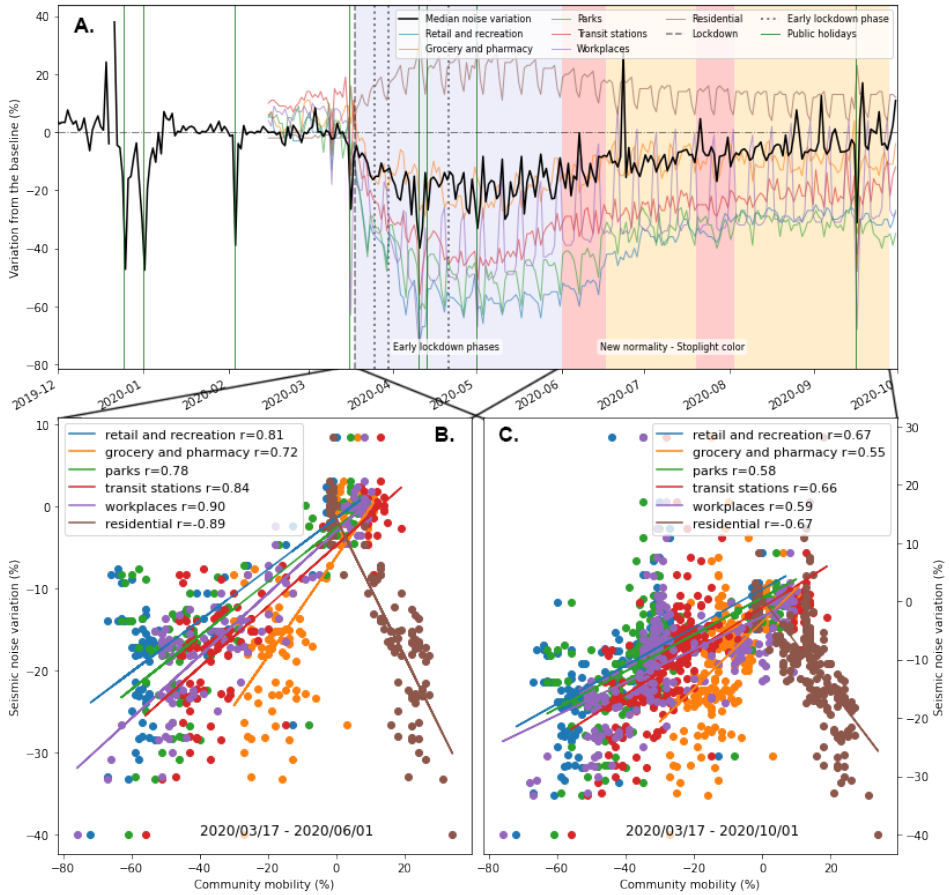
A.
Median noise variation
Retail and recreation
Grocery and pharmacy
Parks
Transit stations
Workplaces
Residential
Lockdown
Early lockdown phase
Public holidays
Variation from the baseline (%)
Early lockdown phases
New normality - Stoplight color
2019-12
2020-01
2020-02
2020-03
2020-04
2020-05
2020-06
2020-07
2020-08
2020-09
2020-10
B.
retail and recreation r=0.81
grocery and pharmacy r=0.72
parks r=0.78
transit stations r=0.84
workplaces r=0.90
residential r=-0.89
2020/03/17 - 2020/06/01
Seismic noise variation (%)
Community mobility (%)
C.
retail and recreation r=0.67
grocery and pharmacy r=0.55
parks r=0.58
transit stations r=0.66
workplaces r=0.59
residential r=-0.67
2020/03/17 - 2020/10/01
Seismic noise variation (%)
Community mobility (%)

**Fig. 3.**