



Interactive comment on “Seismic noise variability as an indicator of urban mobility during COVID-19 pandemic in Santiago Metropolitan Region, Chile” by Javier Ojeda and Sergio Ruiz

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All line numbers added in this reply refer to line numbers in the updated “clean” manuscript i.e. that without the track changes.

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Discussion paper

1 General comment

This paper looks at the links between seismic ambient noise (ASN) recorded in Chile and the implementation and reduction of mobility restrictions imposed due to the Covid-19 pandemic. The work looks at both temporal variations and differences within Chile. An interesting link between the ASN and the “R” value is suggested; it will be interesting to understand how this association may be manifested in other countries with different working/commuting patterns. The strength of this link may be over-stated in this pre-print, but it is worth pursuing, as the authors point out. I raise only queries and technical points for the authors to address, and look forward to them making the needed minor adjustments.

Thank you for your comments and suggestions that improved our manuscript. We tried to answer all of them.

2 Queries

- 1. You link ASN and Re. For the readers who are unused to looking at Re, could you indicate whether the Re timeseries you plot are thought to be a lagging indicator (ie does the value calculated refer to infection on a particular date, or does it refer to detection on a particular date and therefore lag when infection actually took place.)**

The effective reproductive number (Re) is an important indicator to detect changes in the virus transmission over time, their estimation is used to evaluate the policies implemented or population immunity. Re represents the average number of secondary cases generated by a primary case during the pandemic. One of the challenges is to monitor this parameter in near real-time, because it depends on the uniformity in the case-reporting protocols in each country. How-

ever, the R_e timeseries plotted correspond to the real-time in which the infection took place.

We complemented section 2.3 properly describing the R_e indicator (L90), as well as a brief description of how they estimate this parameter:

"The R_e indicator is defined as the actual average number of secondary cases generated by a primary case during the epidemic outbreak (Caicedo-Ochoa et al., 2020; Tariq et al., 2021), their estimation is helpful to the assessment of public policies, to estimate population immunity, to monitor near real-time changes in transmission of the viruses over time, among others (Gostic et al., 2020). To control an epidemic outbreak, the R_e indicator needs to be reduced below one (Riley et al., 2003). Herein, we used the estimation provided by ICOVID Chile (2020) who described the function R_e depending on the proportion of susceptible individuals to be infected, a transmission coefficient and the infectious life expectancy. In other words, the R_e accounts for the coefficient between the new infections and the recovery rates plus mortality rates (Contreras et al., 2020). ICOVID Chile (2020) used the method proposed by Cori et al. (2013) to monitor R_e in real-time, modelling the transmission like a Poisson process calculated on the basis of the last seven days. We considered only the R_e median and 95% credible interval estimated for the urban area in the MR, according to the data given by the Health Service of Santiago City."

New references:

Contreras S, Villavicencio HA, Medina-Ortiz D, Saavedra CP and Olivera-Nappa Á (2020) Real-Time Estimation of R_t for Supporting Public-Health Policies Against COVID-19. *Front. Public Health* 8:556689. doi: 10.3389/fpubh.2020.556689

Gostic, K. M., McGough, L., Baskerville, E. B., Abbott, S., Joshi, K., Tedijanto, C., ... Cobey, S. (2020). Practical considerations for measuring the effective reproductive number, R_t . *PLoS computational biology*, 16(12), e1008409.

Tariq, A., Undurraga, E. A., Laborde, C. C., Vogt-Geisse, K., Luo, R., Rothenberg, R., Chowell, G. (2021). Transmission dynamics and control of COVID-19 in Chile, March-October, 2020. PLoS neglected tropical diseases, 15(1), e0009070.

2. **Following on from the previous point: a little more description of the Re calculations would be helpful. For example, does the Re cover all of the MR, or a district of the MR containing seismic station MT14. This kind of information would be useful to consider in the context of the limited reach of ASN noted in line (line 46) and the mention of small-area lockdown in line 230.**

Thanks for your comment. We added a description of the Re calculations, and what it means. Regarding your question, the Re plotted in Figure 7 cover only the urban area of the MR (Health Service of Santiago in MR). This includes the area of the eastern Santiago district, where MT14 is located. We added the next sentence in section 2.3 (L99):

"We considered only the Re median and 95% credible interval estimated for the urban area in the MR, according to the data given by the Health Service of Santiago City."

3. **You plot changes in ASN and mobility in figure A4. What are these changes relative to? (ie what is 100%?).**

Thanks for your question. The ASN and Apple mobility data plotted in Figure A4 are relative to a baseline value from 13 January, which corresponds to the first day since Apple public their data. We clarify this in the caption of Figure A4.

"The ASN amplitudes and Apple mobility data are normalised by a baseline value of the 13 January 2020."

4. **Figure 4 shows the MT18 data. Why does it end in August when you have data up to October?**

For MT18 we only included data from 23 January 2020 to 10 August 2020. Unfortunately, this station has considerable data gaps during the months of March and August, but we decide to use their seismic data due to the key location within Santiago City. The data ends in August because the Centro Sismológico Nacional operators changed the seismic instrument recording in the location of MT18.

5. Lines 108-112 are results, not methods. Consider moving them to the appropriate section.

We agree with your comment and move this paragraph to the new subsection 3.1 (L110).

6. Was lockdown 2 ever lifted? What are phases 2 and 3? it might be good to have a brief paragraph explaining these (somewhere before the results section would seem to be appropriate). Some of this material is already present in lines 176-184.

Thanks for this comment and suggestion, we added the new Table A1 that includes more information explaining the five different phases included in the step-by-step programme.

In addition, we added the next line in the Introduction section (L21):

“During this first period, the main public health policy addresses the isolation and social distance, including the closure of schools, universities and other educational centres (16 March), national night-time curfew (23 March), and the lockdown of communes. From 19 July 2020, the Chilean government implemented the step-by-step programme, which considers a gradual open of each commune by five phases, based on the monitoring of epidemiological and health system indicators (see Table A1; Tariq et al., 2021).”

Besides, we include the new Table A2, which remarks the days in which the different cities analysed move from lockdown to phases.

Regarding your question, Lockdown 2 was lifted when "Phase 2: Transition" was applied.

7. **You report a "strong correlation" (line 167) between Re and ASN at station MT14. Correlation is often used in a mathematical sense. Do you have a mathematical relationship in mind here, or are you looking more at matching patterns?**

We agree with your comment, we consider more a matching pattern than a "strong correlation". We replace "strong correlation" by "matching pattern" statement in the manuscript (L151).

8. **The link between Re and ASN is stronger before 'phase 2' than after it. Is there any reason for this? Might there be some ASN generating activities which are not linked to changes in Re? (I am not an epidemiologist, and this is not an epidemiological paper, but at least acknowledging that the relationship between Re and ASN changes seems to be appropriate).**

Yes, we think that the better match between Re and ASN before Phase 2 can be explained by the worst implementation of public health policy in those dates, including an early deconfinement in mid-April. Re indicator can assess the effectiveness of the different policies implemented to manage the epidemic outbreak, so we think that during the best matching pattern, the Re peak reflects only the high mobility within city without health cares. After mid-July, the implementation of the step-by-step strategy which proposed a gradual opening according to periodic monitoring of epidemiological and health system indicators reinforced the social distancing interventions and therefore, slowed the spread of the virus (Tariq et al., 2021).

We added the next sentence in the section "Discussions" (L216) "Although the ASN amplitudes increased due to Phase 2 and Phase 3 of deconfinement in eastern MR, the Re parameter was not linked, indicating better management of

the epidemic outbreak with the broad-scale social distancing interventions implemented in MR (Tariq et al, 2021).”

9. **The paper already mentioned other work in other countries, but I would appreciate a brief paragraph which let me know if the links between ASN and other observables are comparable to, or stronger or weaker than, other metropolitan areas. Does the MR look like Barcelona or Mexico City or Rio de Janeiro or Auckland (this may be beyond the scope of the paper and in that case the authors should feel free to ignore this comment).**

Thanks for your comment. We took your suggestion and we added a brief paragraph about the ASN variability and other observables (mobility data) in other cities-countries, as a reference for the potential readers (see L35).

“Previous works in other countries compare the temporal variability between ASN and other observables such as mobility data from cell phone displacements in northern Italy (Poli et al., 2020), Río de Janeiro, Brazil (Dias et al., 2020), Sicily, Italy (Canatta et al., 2021), Auckland, New Zealand (van Wijk et al., 2021), Barcelona, Spain (Díaz et al., 2020), and Querétaro, México (De Plaen et al., 2020). In addition, Xiao et al. (2020) reported cultural noise changes in China, as well as Guenaga et al. (2021) distinguished significant ASN reductions in academic institutions across the United States.”

3 Technical corrections

1. **The first sentence (line 34-35) would benefit from a reference from the scientific policy literature.**

We agree. We added the next reference (L19):

Walker, P. G., Whittaker, C., Watson, O. J., Baguelin, M., Winskill, P., Hamlet, A.,

... & Ghani, A. C. (2020). The impact of COVID-19 and strategies for mitigation and suppression in low-and middle-income countries. *Science*, 369(6502), 413-422.

2. **Line 40 – km2 → km2**

This has been changed. (L28)

3. **Line 46 – anthropic → anthropogenic (we're making the noise).**

This has been changed. (L31)

4. **Line 92 – to better understand the effects of the chosen corner frequency?**

Thanks for your comment, this has been changed. (L74)

5. **Lines 108-110 – be clearer about the time windows over which the ‘gradual’ reduction happens, and when the changes cease.**

Thanks for your suggestion. We modify the paragraph and move to another section (L110) since we described results instead of methods:

“3.1 Lockdown, curfew and ASN amplitudes We analysed the seismic effect caused by the first lockdown in Santiago City using the 24-h clock plots in station MT18 (Figure 4a, 4b). Although we observed a gradual reduction in ASN amplitudes on weekdays due to the day-cares, schools and universities near the station closed (16 March), we also notice a strong reduction on weekends, especially between 11h and 19h local time. Figure A1b shows the area close to MT18 in which we can distinguish the hippodrome “Club Hípico de Santiago” and the O’Higgins Park. The highest ASN amplitudes observed on Saturday before Lockdown 1 (Figure 4a) is explained by the activities of the hippodrome on Saturdays (and some Thursdays during January-February). The hippodrome closed on 21 March 2021, which is in agreement with the decrease in the ASN amplitudes observed after Lockdown 1 (Figure 4b).

We also distinguish the lockdown effect in the hourly grid representation (Figure 4c). The large ASN amplitudes observed during holidays are associated with near activities in both hippodrome and O'Higgins Park, which only persist on weekends during March. After the implementation of Lockdown 1, the ASN amplitudes drop, especially on weekends. Moreover, we observed a systematic behaviour of lower ASN amplitudes between 22h and 5h local time due to the overnight curfew implemented at the same hours, imposed from Lockdown 1 and remain during the full time-window studied.”

6. **Line 112 – the noise doesn't go back after lockdown 1 lifts – can you comment on this?**

Thanks for your question. Yes, the ASN amplitudes did not go back after LD1 lifts (period 26 March - 13 April), we only can see a slight increase in this period. In addition, the government lifts the Lockdown without any public health policy to decrease the number of positive cases of COVID-19. After the school, universities and other educational centres closed during March, the public opinion maintain was sceptic about the first lift and most non-sciential companies preserved the lockdown status to avoid social mobility. Also, in this period the over-night curfew was maintained (22 pm – 5 am).

7. **Line 124 – “Related to mobility data, we analysed” → “the mobility data we analysed is”**

This has been changed. (L101)

8. **Line 125 – What actually is**

To avoid misunderstanding, we modify the sentence (L101):

“The mobility data we analysed is provided by Apple mobile-phone locations in Santiago City, which corresponds to the percentage of change in the public's walking and driving in relation to a baseline value from 13 January (Apple, 2020).”

9. **Line 128 – could you explain what a mobility card is?**

A mobility card is the only system to make transactions in public transport, is better known as BIP! Card in the Metropolitan region. We complemented the information in the paragraph (L104):

“They account for the total number of validations using the public transportation card in the MR. This mobility card is the only system to make transactions in public transport.”

10. **Line 158 – do you know if the local activity is more likely to be anthropogenic or seismogenic, or is it hard to tell from the data available?**

Thanks for your question. We think that at this point is hard to discriminate it from the regional data available. Probably a further study could include more details about the local activity and their relation with anthropogenic activity, but this is out of the scope of our present work.

11. **Line 167 – different to what? (a range of different responses?)**

Yes, with the word “different” we want to include a range of different responses. We modify the sentence (L150) by:

“and the area implemented a diversity of public policies for mitigating the effects of the pandemic”.

12. **Line 194 – might benefit from a reference to oceanic seismic noise for the interested reader?**

We agree, and we added the next reference about oceanic seismic noise (L175):
Cessaro, R. K. (1994). Sources of primary and secondary microseisms. Bulletin of the Seismological Society of America, 84(1), 142-148.

Ardhuin, F., Stutzmann, E., Schimmel, M., & Mangeney, A. (2011). Ocean wave sources of seismic noise. Journal of Geophysical Research: Oceans, 116(C9).

13. **Line 280 – which network code is appropriate? And is there a doi for the seismic network which could be cited here (this will help the network operators if they are looking to see which papers use their data).**

Corrected, we added a new sentence in the “Data availability” section with the appropriate reference (L258):

Universidad De Chile. (2013). Red Sismologica Nacional. International Federation of Digital Seismograph Networks. <https://doi.org/10.7914/SN/C1>

14. **Line 322 – is there a volume + page range for Caicedo-Ochoa et al?**

Yes, and it was corrected

15. **Line 331 – doi or link missing for Cuadrado et al**

Corrected

16. **Line 367 – add the rest of the author list? Not sure what SE editorial policy is.**

Corrected

17. **Line 415 – square → squares**

This has been changed.

18. **Line 428 – you have an otherwise un-defined term in the key (H*Z). I assume it’s because you’ve got two different components used at this location, but it’s not explained anywhere. Consider relabelling/explaining.**

Thanks for notice. We explained the H*Z key in the Figure 3 caption:

“Key legend H*Z can be applied for broadband (HHZ) and strong-motion (HNZ) seismic data.”

19. **Line 435 – the icons for the school closures, and lockdowns 1 2 are really hard to distinguish between. Maybe color more of the icons? Also, is the after-lockdown 1 clock plot (b) for this whole time window, or just until the end of lockdown 1? Please clarify.**

Thanks for your suggestions, we modify Figure 4 and increase the colour size of the icons representing school closures and lockdowns. Regarding your question. The after-lockdown 1 clock plot considers the whole time-window analysed. To better clarify this, we added the dates in the Figure 4 caption:

“(a) before Lockdown 1 (period 23 Jan. 2020 – 25 Mar. 2020) and (b) after Lockdown 1 (period 26 Mar. 2020 – 10 Aug 2020)”

20. **Line 446 – not sure what ratio means here?**

We modify the sentence to avoid misleading. Now, in the Figure 5 caption we wrote:

“the near 2 km distance from stations”

21. **Lines 76, 78 + others + 471 – localized (or localised) → located**

This has been changed.

22. **Line 24-25 – “Finally, we suggest to consider monitoring in real time the changes in ASN amplitudes to be included in the public policies” think about changing to something like “Finally, we suggest that real-time monitoring of changes in ASN amplitudes should be considered as part of public health monitoring”.**

This has been changed in L14:

“Finally, we suggest that real-time changes in ASN amplitudes should be considered as part of public health policy in further protocols in Santiago as well as other high-density cities of the world, as has been useful during the recent pandemic.”

Interactive comment on Solid Earth Discuss., <https://doi.org/10.5194/se-2020-200>, 2020.

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