

# ***Interactive comment on “Unprecedented quiescence in resource development area allows detection of long-lived latent seismicity” by Rebecca O. Salvage and David W. Eaton***

## **Anonymous Referee #3**

Received and published: 17 January 2021

### General comments:

This nicely written and well-structured article examines how seismicity rates during quiescent periods can be used to examine driving factors behind ‘latent’ induced seismicity after direct injection is stopped. The authors study seismicity in the Kiskatinaw area of British Columbia before, during, and after the 2020 COVID-19 government-imposed shutdown to investigate how the seismicity behaves when fluid injection operations in the region temporarily stop. They find evidence for “latent” seismicity during the quiescent period, of which 70% cannot be explained by direct injection, natural seismicity, or triggered earthquakes. After comparing the seismicity trends to those expected from

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fluid migration models, pore pressure diffusion, poroelastic effects, and aseismic slip, the authors eliminate all but aseismic slip as the most likely driving factor to the latent seismicity. Throughout this process, the authors provide clear analysis and evidence to their arguments.

This paper is a unique and timely article with respect to the current pandemic and global lockdowns. The authors apply common and suitable seismological techniques to investigate earthquakes that would otherwise be hidden by direct injection seismicity. I think this article will be of interest to the audience of Solid Earth. Please find the specific and technical comments below.

Specific comments:

Line 28: This number ( $\sim 0.3\%$ ) has been updated in a later publication: “Ghofrani & Atkinson (2020), Activation Rate of Seismicity for Hydraulic Fracture Wells in the Western Canada Sedimentary Basin, BSSA”. Regionally, they now estimate  $\sim 0.8\%$ .

Line 64: Could the authors also include why only the Z-component was used in the study, and not any horizontals.

Line 80 – Section 3: Please explain why you chose to compare to 2018 and not 2019 in this section. You compared the seismic noise levels to 2019 (lines 77-78), why not also the seismicity?

Line 80 – Section 3: Also, please include somewhere how you processed the time series, any band-pass filter applied? SNR?

Line 82-88: More details on the instruments would be good, e.g., sample rates? Are the newly installed stations specifically chosen in some way for certain magnitudes? Site conditions (same for all stations, or different)?

Line 110 – Figure 2: Is the absolute seismicity density the same for the two subplots? I.e. is high density for (a) = high density for (b)? To compare the two periods, it would be good if the colours refer to similar seismicity densities. If not, please make this clear

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in the caption. Also, is the seismicity used the same as in Figure 3?

Line 113 – Figure 3: Could the authors include the magnitude of completeness for the two different datasets in the figure (to make it easier to compare).

Line 149-150: Could the authors include more details on where the KSM08 station is located? Is it far away from cities/towns? Near any wells?

Line 153-155 – Figure 4: Any ideas as to why the seismic noise level is low in July at KSM08? Looks to be down at the same levels as during April. Is this a trend seen at more stations than just KSM08?

Line 165: For the FI value, do you compensate for high-frequency attenuation in some way? You mention that you use one station for all events, won't the low-to-high ratio be different depending on how much high-frequency energy has been attenuated? I.e., events from larger distances have less high-frequency content due to more attenuation than the closer events.

Line 188-189: Visually, Figure 3b appears to have a slightly decreasing magnitude trend with time. The cloud is around ML 0.0 to 1.0 in June, and ML -0.5 to 0.5 in August. Have you looked into this? Any tests done to find trends?

Line 191-204: It would be interesting to see a second plot from before lockdown and a third after seismicity picked back up again. How does the b-value change between the three periods?

Line 356: Would it be possible for the authors to instead plot each event as a circle (e.g., based on magnitude as in previous plots) so that they can highlight the events they identified as triggered by a remote event?

Technical comments:

General technical: figure font size was quite small and needs to be increased.

Line 7-11: Regarding the three sentences: the authors write that “general character-

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istics” are similar between active and shutdown periods, but then go on to state two reasons they are different (magnitude + temporal clusters) and only one reason they are similar (spatially). This makes it seem like they are more different than similar. Perhaps rephrase first sentence.

Line 45: Sentence structure is off. “We call this latent seismicity i.e. seismicity. . .”

Line 62: Comma missing: “Following the methodology of Lecocq et al. (2020) we compute the. . .”

Line 72 – Figure 1: Please also explain what the vertical highlighted (yellowish) periods are in the figure caption (occurring before vertical dashed red line). Also, text is very small.

Line 75-77: Sentence is confusing, consider rearranging: “Following the reopening of some businesses in May and June 2020, the increase in noise is interpreted as the increased movement of people, although it remains lower than pre-pandemic levels.” Or something similar.

Line 87: Why not reference Figure 2 here for the station configuration?

Line 99-101: Sentence doesn’t make sense.

Line 104-107: In Figure 3 caption, you reference Hutton and Boore (1987) as the origin of your ML calculations. This is not who you reference in the text.

Line 112: “ML 3-4+” doesn’t really make sense, either it’s ML 3-4, or ML 3+.

Line 113 – Figure 3: Please use the same y-axis limits on the a) and b) plots since we’re supposed to compare them.

Line 114-115: You only state in the Figure 3 caption that the seismicity increase in 2020 March, August, and September are due to hydraulic fracturing operations. Please include this in the text instead of in the figure caption.

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Line 149-150: Comma placement in this sentence is a bit off.

Line 156: “a pre-lockdown levels” is grammatically incorrect.

Line 161 – Figure 5: Here it says you use the Babaie-Mahani & Kao (2020) formula to compute ML. Same or different to the one in Figure 3?

Line 177-178: “2000 m and 2500 m” please switch to km to stay consistent with previous sentence.

Figure 6: is not referenced in the text.

Line 247-249: Strange sentence structure with the commas and parentheses.

Line 299: ‘it’ is missing: “in areas affected by hydraulic fracturing it is thought to . . .”

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