Letter to the Reviewers of the Manuscript

A repeating earthquake catalog for the Atacama Segment in North Chile (24.5S-30.5S)

Dear Mathilde Radiguet, dear Reviewer A,

thank you for the careful and comprehensive reviews of our manuscript and your comments. We appreciate your considerations and suggestions.

Please understand, and both of you mentioned it, that we need to stay consistent with the 2025 publication for North Chile, as this work here only constitutes a data report. This effects figures and methods, as well as the comprehensiveness of explanations and interpretation. Nevertheless, we tried to implement most of your suggestions. Please see the following point by point responses.

Reviewer A

The paper - A repeating earthquake catalog for the Atacama Segment in North Chile - provides the description of a novel catalog of repeating earthquakes in the Chilean subduction zone. As explicitly stated by the authors, the submitted manuscript is a complement to a former study following the methods used in Folesky et al. (2025). I found the dataset presented in this manuscript valuable, since it provides a foundation for future studies based on repeating earthquakes. However, I believe that the authors should warn future readers about potential sources of uncertainty in the data.

- For example, what is the magnitude of completeness of the template catalog, and what is the magnitude of completeness of the repeating-earthquake catalog?

-> The baseline catalog from Muenchmeyer et al., 2025 has a spatially variable M_c. We could therefore use the highest of these $M_c s$ values as a conservative measure. To measure the corresponding M_c from the repeater catalog will be ineffective because I) the number of events is very limited (when we want spatial resolution), and II) we are not sure if repeating earthquake distributions obey the GR distribution (on a very local scale they do not, because for a given asperity a certain magnitude range is observed). That would require their hosting structures to have fractal distributed sizes, which we can't test. Hence, we prefer to leave the reader with Figure 4, where the magnitude distribution is displayed.

- Between 1998-2014, only one station was used, while 25 stations were used between 2014-2024. Obviously, a very strong bias must exist between these two time periods. I think this discussion must be included since it affects

the detection capabilities of the method both temporally and spatially. In the past, I have used the program ZMap (Wiemer et al. 2001) to analyze temporal variations in the earthquake catalog; it is easy to use and provides a wide range of metrics. Besides, it is not clear to me how the authors identify repeaters between 1998-2014 with only one station. In your methodology, the authors mention that at least two stations are needed to declare a detection.

-> In the Method section, we note that we use two sets of thresholds: 1) for the earlier period, where only one station is available and 2) where more stations got operational. (l75ff)
But we have decided to make this split much more prominent. We added new sentence in the Method section(l75f). Also, we highlight the 2 different observational eras in Figure 2, by adding a shading.
Finally, we split the results tables (supplement files) into a first, a second and a combined part and add a comment in the conclusions (l198ff).

- Another concern is the selection of the bandpass filter (1-4 Hz). This is a very narrow filter, which leads to another long discussion. There is no formal definition of repeating earthquakes. This issue has been addressed recently in these two papers:
Gao, D., Kao, H., and Wang, B. (2021). Misconception of waveform similarity in the identification of repeating earthquakes. Geophysical Research Letters, 48, e2021GL092815. https://doi.org/10.1029/2021GL092815
Gao, D., Kao, H., and Liu, J. (2023). Identification of repeating earthquakes: controversy and rectification. Seismological Research Letters

-> We are aware of the non-existence of a norm concerning repeaters. We concur that the frequency band is narrow. Still, we believe that our criteria are not loose! This is because we use a comparatively long(!) time window, including both p and s phase at once. Therefore, the cc-measurement is very sensitive to the colocation of the events. We hope that the RE selection is described sufficiently to the reader to make that clear. Also, the more in depth description of the processing and discussion are made in our 2025 paper for North Chile. We do not intend to change processing or selection criteria here, and we to our initial comment concerning consistency to our previous publication.

- Based on a quick look at your data, it seems that your conditions are relatively loose (narrow filter and relatively low CC). However, by looking at your data, the recurrence time seems reasonable. So, it would be worth including a log-log recurrence-time-vs-magnitude plot to see how it fits with other studies, either in the main text or in the supplement, such as the one shown in Figure 10 in the paper: Uchida, N. (2019). Detection of repeating earthquakes and their application in characterizing slow fault slip. Progress in Earth and Planetary Science, 6(1), 1-21.

-> That is a good idea. Unfortunately, that does not work for the majority of RES, as the data set is heavily dominated by post seismic RE activity following the 2015 Illapel EQ and some other M6 events. But we add a supplement figure (S9) for those groups that are quasi periodic.

- Also, in this paper, Figure 3a provides a guide for frequency selection for repeating earthquakes. This figure suggests that a 1 Hz corner frequency for small-magnitude earthquakes may not be suitable, which is linked to my next question.

-> That is correct, but we believe that our long time window makes up for that, as explained above.

- Match filters are usually very good at discovering new, unreported events with lower magnitudes than the templates. In your Figure S3, you show that the amplitude can oscillate about (±)0.5 orders of magnitude larger or smaller, and sometimes up to 1 order of magnitude. This is not the behavior I expect from a match filter, which usually performs well for lower amplitudes, since higher amplitudes in theory must already be included in the catalog (easier to detect). So this means that many of the detections may be below the magnitude of completeness of the template catalog.

-> We did not check that. Is that really relevant for the repeater catalog? There might be several reasons for events being missed in the base catalog. Also, in our experience, match filter always find new events that are well above the M_c of the base catalog. This is true for Northern Chile (Folesky et al., 2025) with the baseline by Sippl et al., 2023 and for the Atacama segment in Chile, alike. (Note that seismicity rates there are always pretty high. So we often find overlapping or very closely spaced phase arrivals from different events, which compromise event association procedures much more than TM.)

- Finally, another important concern is the use (or overuse) of the Nadeau and Johnson (1998) empirical relationships. I know this relationship has been widely used in many papers for almost 30 years. However, at least two updates have been published: Nadeau, R. M., and McEvilly, T. V. (2004). Periodic pulsing of characteristic microearthquakes on the San Andreas fault. Science, 303(5655), 220-222. Khoshmanesh, M., Shirzaei, M., and Nadeau, R. M. (2015). Time-dependent model of aseismic slip on the central San Andreas Fault from InSAR time series and repeating earthquakes. Journal of Geophysical Research: Solid Earth, 120, 6658-6679. Even though all of them are tailored for the same area in California, using either one leads to very different results. You can quickly visualize how different they look in Figure 10 in the paper: Dominguez, L. A., Taira, T. A., Cruz-Atienza, V. M., Iglesias, A., Villafuerte, C., Legrand, D., ... and Raggi, M. (2022). Interplate slip rate variation between closely spaced earthquakes in southern Mexico: The 2012 Ometepec and 2018

Pinotepa Nacional thrust events. Journal of Geophysical Research: Solid Earth.

-> It is of course true that there are other slip-moment relationships for repeaters, and we now mention them in a new paragraph (l101ff). For consistency/simplicity reasons, we stick to Nadeau and Johnson (1998) without correction. We have added corresponding comments (same paragraph).

- I believe that this issue must be conveyed to the readers. In my personal opinion, the coefficients of the Nadeau and Johnson (1998) relationship must be calibrated for each area, and they may change over time, especially when large earthquakes occur.

-> We concur. And we try to make that more clear to the reader. Nevertheless, we stick to the simple N&J conversion.

- I have several recommendations about the figures, mainly in the main text. I assume that the authors want similar formatting to the one used in their already published paper.

-> You are right, that we would like to stick with the formatting of the figures to remain similar to our previous publication. We have answered the questions from the pdf in the following.

- In the file nca_event_pairs.txt, the last column mag_t: event origin time seems to be the magnitude of the second event.

-> Thanks! That should read "magnitude of template"

Comments from the annotated pdf

- l40 : Figure 1 should be on these range

-> We do not agree. We use some outlying stations to better capture events at the bounds of the catalog. Since there are no repeater found there, we would lose spatial resolution on the target region by zooming out. All station used are shown in Figure S2.

- l45 : what are the labels? what are the classes?

-> Indeed, it should read location not duration. Labels are for tectonic type, which we have taken from Muenchmeyer et al.2025. Classification describes the recurrence behavior.

- Fig1: I see many gray dots ...

-> We have removed the outlying gray dots. We will keep the topo and color map for consistency with Folesky 2025.

- Fig1: can you make the marker size larger and color code by network?

-> We have the stations in a separate plot in Figure S2. There we have added the network codes.

- Why USGS location and not the local catalog ones?

-> The local catalog is limited in time (2014 to 2024). So we would have to use different sources for the earlier large events, which we wanted to avoid. Actually, the large events may be located better in the USGS catalog, because more phase arrivals can be used for localization, as well as a better azimuthal coverage.

- Difficult to read Figure 2.

-> We intend to keep that figure, as it very well describes the occurrence of newly detected repeater groups over time and the recurrence of repeaters in existing groups. The amount of groups makes it challenging, but we believe that it very well shows the overall dynamic of the data set. We try to improve the figure as well as its caption. It is not intended to provide data for singular series, but to give an overall impression.

- lowering the cc threshold

-> No, we do not change requirements. The threshold is not lowered. This sentence is a hypothetical consideration to what happens if a close station is not available (down time). The criteria are strict in this sense. We here only explain, why we do not include more than 2 stations

- l97 magnitude conversion

-> Muenchmeyer et al. give a ML and a MA magnitude which is some what equivalent to Mw. The same method for MA estimation was applied in Sippl et al. 2023 which was the bases for Folesky et al., 2025, where we discuss the conversion from magnitude to moment. We have added a half sentence to l95ff.

Handling Editors Review

In this data paper, the authors have constructed a long-term catalog of repeating earthquakes for the Atacama segment of the Chilean subduction zone, resulting in more than 4000 repeating events from over 1000 families. The methodologies and presentation is similar to another paper published by the same group. The catalog presented in this paper can be used for further investigations later.

- Figure 2: The slip versus time for repeater families shown in Fig.2 does not allows to see the associated slip, Because many families are plotted with a small vertical offset, this graph only allows to see the time range covered by each family, but not the associated slip. The vertical axis label could be different (family index), and the color coding for the lines could be chosen in a different way to represent the actual mean slip rate for each families.

-> You are right. One cannot see individual slip. That is , however, not hte point of the figure. It shows the overall reaction of all series to large earthquakes occurrences. We would prefer leaving the figure like that, as the supplement figures S 4 – 8 have the same formatting, where one can actually recognize individual sequences better. Also, the Figure 5D and 6D are just build in the same manner, but only for a single sequence, each. Reviewer A has expressed the same concern. Please also see our answer there.

- Figure 5 C: give information about the slip contours shown in the figure legend (earthquake and reference).

-> Yes, we have included that.

- To make the comparison between both figures easier, could you indicate in both cases the earthquake slip contour and the location of both families in each plot ?

-> Actually no, because the maps do not overlap at all.

- l.95-96: Nadeau and Johnson, 1998, is one among other possible empirical slip-to-moment relation, this could be said more clearly..

-> That's correct. We include references to other possibilities of estimating slip in a new paragraph in lines 101 ff.

- l.101-103: It would be interesting to indicate in the text the percentage of events in each tectonic categories.

-> We have added the counts in l 111ff.

- l.104-111: Similarly not figure is associated with this classification. It would be be interesting to make a figure and/or to give some statistics in the text on the recurrence pattern for the RES considered.

-> We have added a corresponding Figure (S10) to the supplement.

- l. 124-125: specify where this list can be found.

-> Done.

- l. 163: at least up to 2002

-> Yes.

- L. 164: subfigures: specify the figure number here for clarity.

-> We have done that.

- l. 167: we are not able to see the slip in figure 2, as well as in most of the supplementary figures showing similar plots., just the time range: change the sentence, or add slip information (with color ?) in Fig. 2

-> Yes, that's true. We consider this figure a second overview figure besides Figure 1. It is not intended to display any single sequence recurrence pattern with this figure(s), but the overall pattern of repeater recurrence with the megathrust events. If we changed the y-axis to sequence ID, the appearance would remain almost the same.

- Figure 7: the years indicated in the top right of each plot are not clearly visible: removing the transparency in the gray box could help, and for most figure writing the text bigger.

-> We have edited this.

We hope that we have answered all your questions to your satisfaction.

Best regards
Jonas Folesky, Jörn Kummerow & Rens Hofman