Reviewer A

1. The work greatly incorporates published tools (such as RSQSim) as well as a diversity of datasets, including the geodetically derived interseismic coupling for the MHT. In that sense, I have one comment and one question:

   a. L97-98: You highlight only two coupling models, but in the literature, you could find more than Stevens and Avoac (2015) and Dal Zilio et al. (2020). This is not an exhaustive list, but you could mention others such as: Li et al., 2018 (Tectonophysics), Sreejith et al., 2018 (Scientific Reports), Yadar et al., 2012 (JGR), Ader et al., 2012 (JGR), Tabei et al., 2024 (EPS), among others. Please acknowledge the efforts from these different groups in developing interseismic coupling models along the MHT (or segments of it).

   Reply: We added the additional references in the main Manuscript, lines 104-106 and modified the sentences accordingly.

   b. The adoption of a geodetic coupling model in RSQSIM to implement the interseismic coupling factor has a strong hypothesis, which is that over 15,000 years of the seismic cycle in the MHT, the coupling maintains the same behavior. Please clarify whether you consider a time-invariant coupling (i.e, permanent areas of creeping, transition, and locked/fully locked). If so, please justify and discuss these limitations, especially in the case of MHT. Given the importance of the characteristics of the coupling model chosen to work with RSQSim, I suggest extending the discussion on how these assumptions affect not only the earthquake catalog generated but also the interpretation of considering rupture barriers through the MHT during the 10,000-year simulations (L306) in areas that we now geodetically infer as low-coupling regions.

   Reply: We agree that implementing a geodetic coupling model in RSQSim implies a strong hypothesis: the coupling distribution remains time-invariant over the 10,000–15,000-year acknowledge this assumption and its implications

   "Our approach also explicitly assumes a stationary coupling pattern over a 15,000-year simulation, whereby spatial domains inferred geodetically as creeping, transitional, or locked along the MHT are treated as persistent throughout the model run. We acknowledge that this is a simplification approach adopted in the RSQSim model, as coupling may evolve over multiple seismic cycles due to stress redistribution, variations in effective normal stress, changes in fluid pressure, or long-term rheological processes (e.g., Dresen et al 2020, Amemoutou et al 2023). Therefore, our approach should not be taken to mean that coupling remains permanently unchanged over thousand-year timescales. Instead, we use this assumption as a practical simplification that allows us to examine how the present-day, geodetically inferred coupling pattern influences long-term rupture behaviour, while keeping the frictional properties and loading conditions consistent and stable within RSQSim. Introducing time-dependent coupling into the RSQSim model in the future may provide further insights into the rupture barrier due to the low coupling zone at present."

2. Please further develop the idea or motivation stated in L138-139. What kind of new insights into seismicity can be addressed using a powerful tool, but with simpler

models of the MHT?

Reply: The new insights than can be gained from RSQSim simulations of the MHT include as the possible maximum magnitude, recurrence interval, rupture area, rupture extent, the maximum slip and along-strike rupture . This is included in the revised manuscript, line 145-146.

3. Regarding the citation of the ISC catalog, I recommend following the guidelines on their website: https://www.isc.ac.uk/iscbulletin/citing.php, adding the citation for the earthquake catalog you used. This is particularly helpful to avoid the URL link in the captions of Figures 2, 3, and 4.

Reply: Removed https://www.isc.ac.uk/iscbulletin/citing.php link and added International Seismological Centre catalogue (Storchak et al., 2015) in Figure 2, 3 and 4.

4. L161: In how many subsets does the Mw 8.9 reach? I can hardly distinguish in Figure 2c, but it seems to be a few of them if I'm not wrong.

Reply: There are two events Mw 8.9, Figure 2(c) has been improved to see it clearly. We have mentioned this in the manuscript in line 168-169.

5. L179: Based on your inspection of the five subsets of 70-year subsamples, is the comparison with the instrumental records (1950-2020) stable among them? What occurs with the rest of the 138 subsamples of 70 years when analysing the spatial distribution of earthquakes?

Reply: We now highlight that the purpose of Figure 4 is to show that RSQSim can qualitatively replicate some of the observed spatial patters of MHT seismcity over the last 70 years (Line 164-166). In addition, we note here that developing a meaningful statistical test between the observed spatial distribution of earthquakes around the MHT and our RSQSim catalog is challenging due to the former's poor depth constraints (see lines 155-157). Quantitative comparisons for earthquake MFDs between the 142x 50-year catalogue subsamples and historical seismicity are presented in Figure 2.

6. L227-229: I suggest clarifying how you compute the coefficient of variation (CV) in a new sentence to avoid confusion. Additionally, the results from both recurrence interval and CV are not the same, as shown in Table 2. For example a CV=0.8 is not seen. Please clarify.

Reply: The actual CV is between 0.2 to 0.9, there was typo error in the table which has been corrected in Table 2. We also added a sentence to clarify how CV is estimated. Line 232-235.

7. L234: Regarding your option (2) and the timing of one earthquake following another. Please refer to any evidence in the RSQSim catalogue that shows this very short period of time (approximately four months). An additional figure in the

supplementary material or the one shown in Figure 7b.

Reply: We have now added plots to the Supplementary file, Figure S9, which show these clustered events. Also mentioned in the main manuscript, line 241.

8. L237: Please further develop the concept of why the absence of SSEs in Nepal Himalaya (short-term dynamics) is consistent with case 1 (long-term dynamics).

Reply: We acknowledge that there is only weak evidence for relatively long (>500 yr) recurrence intervals on Zone 2 being promoted by the release of strain in Mw 8.5 events, and not the release of strain in SSE's. In the revised manuscript, we have therefore removed this point and acknowledge that both Case 1 and 2 at lines 238-240 are viable mechanisms for Zone 2's long recurrence intervals.

9. Explore whether Zone 3 is apparently regular in terms of their earthquake cycle and rupture extent, with a "few" small earthquakes during its cycle (Figure 7b), in contrast to other zones. For example, Zones 1 and 4 could be similar in that they have adjacent ruptures to each other, but differ in the length of each of these earthquakes. Finally, Zone 2 is highly heterogeneous. Please discuss these differences among zones in terms of the different parameters employed in the simulation.

Reply: The following discussion is added in the main manuscript in line to address this comment (lines 340 – 347).

We also note that Zone 3 exhibits a more regular earthquake cycle and a more consistent rupture extent compared to the other zones (Table 2). It has the largest area of high coupling (coupling > 0.5) and is relatively homogeneous in terms of coupling distribution. This uniform and large coupling area results in consistently high stress accumulation in the patches within the zone, promoting the accumulation of strain that is released as large-magnitude earthquakes (Mw > 8.0) at relatively regular intervals (Cv = 0.2). In contrast, Zones 1, 2, and 4 have greater heterogeneity in coupling. Consequently, these zones tend to generate irregular earthquake cycles (CV = 0.7-0.9) and rupture extent (Delogokos et al 2023). Because the frictional parameters are identical across all zones, the observed differences in earthquake extent and recurrence patterns are primarily governed by variations in coupling and the associated slip deficit rates.

10. In subsection 6.2, the comparison is only in Nepal, then I suggest adding it to the subtitle as "Comparison of MHT RSQSim catalogue-derived hazard with the classical seismic hazard in Nepal".

Reply :We have added "in Nepal" in line 269, main manuscript.

11. Add a corrected DOI/OSF link in the "Data and code availability" section after publication. For now, the link seems to be broken.

Reply: Updated the link. "https://osf.io/679jd/overview?view_only=150eff187a7342b2b4fa6a1618a40ad4"

Tables and Figures

1. Table 1: Please mention the different slip rates considered for each segment of the MHT instead of the range value; it will be more informative. Additionally, this table will benefit from a third column of reference for each value considered, which largely resumes Section 4.

Reply: Added slip rate for each zone in Table 1.

2. Generally, the Figures appear low resolution with visible image contours; sometimes, they look blurry, which is perhaps due to the formatting. Please improve the figure quality for publication.

Reply: Corrected for all figures with low resolution

3. Figure 2:

a) Please clarify for the reader that in Fig. 2b, you create the 142 subcatalogs from RSQSim, and the red line shows the average of them, same for Fig. 2c.
Reply: Added in figure caption for Fig. 2b & 2c.

b) What do the slightly noticed dashed vertical lines in the plots d, e, and f Represent?
Reply: These represent historical and instrumental seismicity rates; they have been added to the Figure 2 caption, and the lines are made thicker to enhance clarity.

c) Could you add/highlight the 16th and 84th percentiles described in L158?
Reply: We have added/restructured sentences on lines 164-166 to provide further explanation.

4. Figure 3: In this case, I would add the Coupling legend as qualitative: creeping, transition, and locked instead of the numerical values, because the uses in the manuscript are purely qualitative in those terms

Reply: Added creeping, locking and transition in Figure 3 and increased figure resolution.

5. Figure 5: Please clarify whether the circles represent the earthquake nucleation or rupture centroid.
Reply: The circle represents earthquake nucleation, Replaced Location by "Epicentre" in Figure 5 for clarity.

6. Figure 6: In this case, it is hard to read the text and labels from each earthquake. I suggest increasing the font size of the text within the figure, as well as framing their names horizontally instead of following the curvature of the MHT, as it is complicated

to read the eastern earthquakes' labels
Reply: Replaced figure with high resolution, and text is made horizontal in Figure 6.

7. Figure 8: Since it is analyzed in the following figures, please indicate the location of Central Nepal [mentioned in L259] by labelling its name, for example.
Reply: Added Central Nepal and Western Nepal labels in Figure 8 and Figure 9.

8. Figure 9: Correct the subfigures; the classical PSHA approaches are shown in (b, f, g) and not (b, d, f) as described.
Reply: corrected in Figure 9 caption.

Minor comments:

L40: Please, rephrase your sentence regarding the number of "fatalities recorded". I would recommend: "Since 1800, earthquakes in the Himalayas have caused over 150,000 documented fatalities." Or similar.

Reply: corrected as per suggestion. Line 46, main manuscript.

L46: Please add references to the sentence "high erosion rates".
Reply: Stevens et al. 2018 Reference added line 53.

L102: Please complement this information. Are the three low-coupling zones related to the limits of each historical earthquake (M>7)? Or, are you also referring to the lower seismicity recorded?

Reply: These three low-coupling zones also have lower earthquake records (Mw>5.5, 1950-2020) than the highly coupled zones. This is shown in Figure 3. We have restructured the sentence to make it clearer, lines 111-112, main manuscript.

L151: "for" is a duplicate
Reply: Removed 1 for in line 158, main manuscript.

L259: Reference needed about the expansion of hydroelectric infrastructure.
Reply: Reference Gautam et al. (2014) added in line 263.

L288: Remove parentheses in the citation Stevens et al. (2018)
Reply: Removed in line 273.

Reviewer B:

This manuscript couples earthquake rupture simulations from RSQSim with ground motion models to predict seismic hazard in the Main Himalayan Thrust. Comparisons of the simulated earthquake hazard to empirical data are presented, and comparisons of hazard with that from a traditional method are provided. The analysis approach is an important one, and the discussion of potential insights from this approach for the Main Himalayan Thrust are interesting. Limitations and potential advantages of the various models are appropriately highlighted. Overall, this is an interesting manuscript worthy of publication. I have a few small comments for the authors to consider.

The hazard comparisons are very interesting, and the commentary about potential sources of differences seem reasonable. But it would be nice to see these differences more directly, rather than just hearing author inferences. Could you provide a figure of the MFDs from RSQSim and the Stevens et al. (2018) source model? The distributions of magnitude vs depth for the two? I'm visualizing these based on the text, but would love to see them directly. Presumably the authors already have them available from internal analysis.

Reply: MFD comparison between RSQSim and Stevens et al. (2018) is now included in Figure S8. The Stevens et al. (2018) model has higher earthquake rates than RSQSim. This is also stated in the main manuscript, lines 354-355.

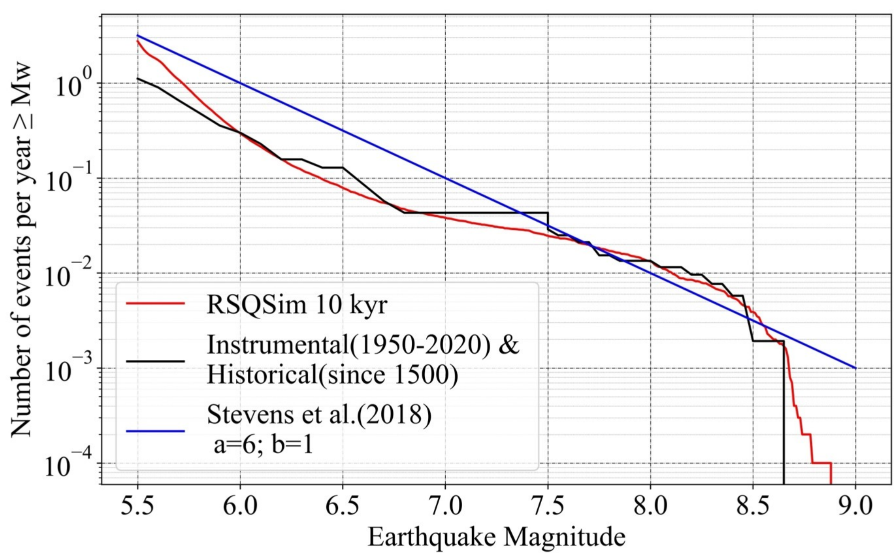

Figure S8: Comparison of MFD from RSQSim with Historical and Instrumental seismicity, and Stevens et al.(2018) model.

The depth histogram for RSQSim and instrumental earthquakes are shown in Figure S10. Depth information for historical earthquakes is not available; hence it is not included in the histogram plot.

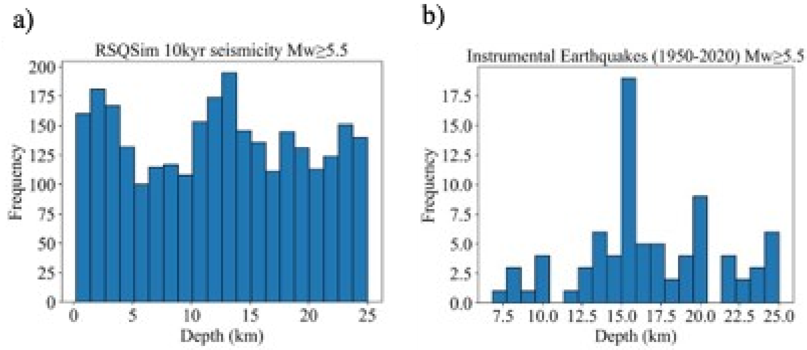

Figure S10: Depth histogram for (a) RSQSim earthquakes and (b) Instrumental earthquakes. The depths of historical earthquakes are not available; therefore, they are not included in the histogram plot.

I appreciate the numerical comparisons in the abstract. But if you're going to give differing evaluations at different exceedance rates, it would be helpful to give one more quick observation as to why you infer that is. Otherwise the multiple comparisons confuse as much as they illuminate. The reported metrics for hazard discrepancies seem rather scattered. As far as I can tell, the abstract reports "For 84% of sites, differences drop below 35% at 2% and 0.5% PoE." but these results don't show up in the paper itself, though the paper does include "at 10% PoE in 50 years level, where for 84% of sites, the RSQSim derived hazard is 60% or less of the classical model." So I do see the common 84% threshold, but no explanation of why that threshold was chosen. Additionally, those lines use a probabilistic threshold, while lines 281-283 seem to report on the extreme differences (or if those differences represent percentiles, the percentiles aren't given). The maps of differences are nice, but for the paragraph starting on line 278, and the abstract statements, it would be nice if the authors would think about how they want to summarize differences, explain their preferred metric(s), and then use them consistently for the results that follow.

Reply: Added numerical comparison in the abstract (Lines 24 to 29) and in the main manuscript as well (lines 289 to 294). Figure 10d is added in the main manuscript to illustrate % difference in RSQSim hazard with classical PSHA at 10%, 2% and 0.5% PoE in 50 years. We have added the description for 2% and 0.5% PoE in Line 295- 296). The 84% threshold is arbitrary; it was chosen because 84% corresponds to the median + 1 standard deviation.

I struggle to make a coherent mental image from Figures 2 b and c. It seems to me that the RSQSim simulations are the same and being compared to two different types of empirical catalogs. But the x axes of the two plots don't overlap, while the y axes partially overlap (and the RSQSim Mw exceeded with rate 2X10^-2 per year seems different in the two plots). It would be easier to understand this if all three data sets were just plotted on one figure, or if you need to zoom in for the two subpanels, put all three data sets on both and try to overlap the ranges a bit to provide a holistic picture.

Reply: The reviewer's comment reflects that we are comparing RSQSim to different time periods and magnitude ranges of observed MHT seismicity. In Figure 2b, we are comparing the catalog to instrumental seismicity, which is thought to be complete for 70 year time (1950-2020) period for Mw > 5.5 (Figure S3), By contrast, Figure 2c is comparing the historical record of MHT earthquakes from

Bilham et al (2019), which we consider to be complete over a longer time period than the instrumental period (i.e., since 1500 CE) but with a larger magnitude of completeness (Mw >7.5). This is described in section 5.1. Note too, it is not possible to follow the reviewer's suggestion and add these comparisons to the same plot, as doing so would require plotting the 70-year (used for the instrumental comparison) and 500-year (for the historical comparison) subsamples of the RSQSim catalog together.

Dear Editor,

We have incorporated all the reviewers’ comments into the clean version of the manuscript. Please see our responses below.

Thank you for your effort to bring the article to this stage.

Kind regards,

Govinda Niroula

Editor:

Reviewer C has agreed that his/her comments were correctly addressed. However, there are two additional suggestions (see below) that would be beneficial for the article.

On the other hand, I carefully reviewed the response to Reviewer F. Most of the comments were addressed, and I believe this improved the article's scientific contribution. However, I would like to point out two particular comments that need another revision before publication:

1. The response to reviewers refers to the supplemental material of the article. I would like to see the final version of that supplemental material. Moreover, the original supplemental material file had low-resolution figures that need to be upgraded.

Reply: Resolution of the figures in the supplemental file has been upgraded.

2. I agree with the reviewer about comparing the information in Figures 2b and 2c. The authors state that this is not possible because the time scales of the two datasets differ (completeness periods of 70 years vs 500 years). However, given that the y-axis presents the average frequency of events, there is no problem with having different periods of completeness. In fact, it is common in event databases for different magnitude ranges to be deemed complete over

different periods, and since the average annual frequency normalizes by this completeness period, it is ok to compare them in one plot. The authors are then encouraged to either plot them together in Figure 2 or to include a new Figure 3 that compares both datasets in a single figure.

Reply: We combined Figures 2b & c into one figure (2b). Now the MFD comparison is in a single plot. Necessary updates in the text have been made in Section 5.1 and the caption of Figure 2. See the updated figure below.

Figure 2.

Once these comments are addressed, I belive the article would be suitable for publication.

Reviewer A:

Dear Authors,

Thank you for your thorough response to my initial concerns during the review process. The manuscript is well written and makes a significant contribution to seismic hazard assessment of the MHT. I have no further comments on the scientific content, but wish to raise a few minor points below for your consideration:

- Figure S7 is referenced earlier (in the second paragraph of the Discussion) than Figures S5 and S6 (mentioned in the seventh paragraph). For consistency and clarity, please review the order of figure citations in the Discussion section and/or the Supp. Material.

Reply: All supplementary figures are now referred to in order in the clean version of the main manuscript.

- I recommend slightly separating Figures 10a and 10b to avoid confusion between the y-axis label of Figure 10b and the colorbar label of Figure 10a.

Reply: Space between Figure 10a & 10b is increased in the clean version of the manuscript. Please see Figure 10, below

Figure 10.

These are minor points and do not affect the overall quality of the manuscript.