Reviewers' comments:

Referee 1

1. Weaknesses and Areas for Improvement:

While the study is comprehensive, there are several areas that require improvement to enhance the manuscript's quality. Firstly, the introduction could benefit from a more detailed literature review to contextualise the current study within the broader field of seismic hazard analysis. Secondly, the methodology section, although detailed, could be more clearly structured to ensure readers can easily follow the complex modelling processes. Additionally, while the study highlights the importance of fault segmentation and multi-segment rupturing, it would benefit from a more explicit discussion of the limitations of the models used and the assumptions made during the simulations.

Thanks for your review.

1. Expand the literature review to include more recent studies on seismic hazard analysis and multi-segment rupturing to provide a comprehensive background for the research.

Thanks for your recommendation! We added the recent studies on multi-segment rupturing seismic hazard analysis in Section 3. See Line 339 in our modified version.

"Numerous studies have focused on understanding the fault's geometric and physical parameters to ascertain conditions conducive to multi-segment rupturing. Factors identified include step width (e.g., < 5 km) (Harris and Day, 1999; Lozos et al., 2012), fault structural maturity characterized by initiation age, net slip, length, and slip rate (Manighetti et al., 2007; 2021), and geometric irregularities such as fault branches and bends, significantly influenced by the pre-existing stress field (Mignan et al., 2015). Recognizing the significance of these rupture parameters in producing multi-segment

rupturing, recent studies, such as those by Chatier et al. (2019), Cheng et al. (2021), Lee et al. (2022), and Chang et al. (2023), included the possibilities and probabilities of multi-segment rupturing in seismic hazard analysis. Additionally, Dutykh et al. (2013) and Rashidi et al. (2020) employed multi-segment rupturing into models of tsunami wave generation. The concept of multi-segment rupturing was also incorporated in the UCERF3 model through their complex "Grand Inversion" methodology, which integrates data on fault slip rates, historical seismicity, and paleoseismic records (Page et al., 2014). However, for most other regional studies, collecting all the necessary input parameters remains challenging. ″

2. Clarify the methodology section by breaking down the modelling process into more distinct sub-sections, each with clear headings and explanations.

Thanks for your suggestion! We divided the methodology part into section 3.1 and section 3.2.

“3.1 Methodology” and “3.2 Scaling Relationship and Modeling Parameters”

3. Discuss the limitations of the study in greater detail, particularly the assumptions made during the modelling and their potential impact on the results.

Thanks! We added section 4.1 of “Model limitations and mitigation measures”.

“Our seismic hazard modeling for NWYR represents our current understanding of average earthquake hazards in the region based on available data. The results are affected by numerous epistemic and aleatory uncertainties inherent in seismic hazard modeling processes, including the MFD, fault geometry, fault type, slip rate, and variability in GMPEs. Mitigating the impact of these uncertainties is critical for

accurate seismic hazard assessment.

The MFD relationship, calculated from historical earthquakes, is essential for determining seismicity rate ratios across different magnitude bins. The deflection of the MFD directly influences the distribution of the modeled seismicity rates. In this study, we chose the G-R relationship over the Y-C relationship due to the regional fragmented tectonic environment. The calculated *b*-value of 0.96 aligns closely with the expected value of 1 found in seismically active regions (Pacheco et al., 1992). To derive earthquake magnitudes on fault segments, we employed rupture scaling relationships based on historical rupture parameters of earthquakes in China as proposed by Cheng et al. (2020), ensuring consistency with unique tectonic characteristics. Achieving more precise MFDs and rupture scaling laws necessitates further refinement in methodology and the use of reliable catalogs specific to the study area.

For fault geometry, type, and slip rates, we relied exclusively on recent field investigation data. In compiling fault rupture models for NWYR, we analyzed these geological data under a unified tectonic stress field, ensuring coordinated fault system movements. The variability in GMPEs is complex, influenced by factors such as earthquake rupture characteristics, seismic wave propagation, and site conditions. Consequently, we incorporated Quaternary sediment site amplification effects on PGA values. Addressing basin effects on ground motion requires dynamic simulations to achieve more precise results."

4. Include a section on future research directions, highlighting how the current study could be expanded or refined with additional data or more advanced modelling

techniques.

Thanks for your suggestion! We added the future research directions in the last paragraph in Line 737-746.

"Future seismic hazard work can be improved by utilizing geophysical data to understand fault structures where strong earthquakes are developing (Xu et al., 2017), applying geodetic data to assess energy accumulation on fault segments (e.g., Yao and Yang, 2023), using microseismicity relocation data to reveal fault asperities (Lay and Nishenko, 2022), and employing dynamic rupture simulations of single and multi-segments to enhance earthquake motion predictions (e.g., Zhang et al., 2017). These studies on fault behaviors, interactions, and multi-segment ruptures are vital for improving seismic hazard assessments. Staying vigilant and proactive in seismic risk management will better protect communities and infrastructure in the NWYR and beyond."

2. Research Gaps:

The paper identifies the lack of comprehensive seismic hazard models that integrate fault geometry and segmentation with historical seismicity rates as a significant research gap. While the study makes a substantial contribution towards filling this gap, further research is needed to validate the models used and to explore the potential for other fault systems to exhibit similar multi-segment rupturing behaviour. Additionally, the impact of climate change on landslide probabilities and seismic hazards in the region could be an important area for future investigation.

Thanks for your suggestion! We will focus on the impact of climate change on landslide probabilities and seismic hazards in the region in the next studies.

3. Missing References:

Several relevant references are missing from the current manuscript. These include recent studies on seismic hazard analysis, fault segmentation, and multi-segment rupturing. Incorporating these references would provide a more comprehensive context for the research and strengthen the validity of the study's findings.

Furthermore, I would like to kindly suggest that the authors incorporate references to a few previous studies that seem to have been overlooked. For instance, the phenomenon of multiple ruptures has been applied to the problem of tsunami generation, as demonstrated in the following article:

Dutykh, D., Mitsotakis, D., Gardeil, X., & Dias, F. (2013). On the use of the finite fault solution for tsunami generation problems. Theoretical and Computational Fluid Dynamics, 27(1–2), 177–199. https://doi.org/10.1007/s00162-011-0252-8.

Additionally, probabilistic methods have been applied to tsunami hazard assessment, as illustrated in the manuscript: Rashidi,

A., Shomali, Z. H., Dutykh, D., & Keshavarz Farajkhah, N. (2020). Tsunami hazard assessment in the Makran subduction zone. Natural Hazards, 100(2), 861–875. https://doi.org/10.1007/s11069-019-03848-1.

It would be beneficial for the authors to examine the approaches utilised in the tsunami wave community and compare them with the methodologies applied in their study of landslide hazards. Incorporating these references will not only strengthen the context of the research but also provide a broader perspective on multi-segment rupture phenomena and probabilistic hazard assessment.

Thanks! We added these studies as the reference work in Line 332 to Line 354. We also referred the works of multi-segment rupturing on tsunamic studies in Line 348 and Line 349.

4. Language and Grammar Corrections:

The manuscript contains several language and grammar errors that need correction.

Here are some identified issues:

1. Page 3, Line 45: "the Eurasia Platea" should be "the Eurasian Plate."

Modified in Line 45.

2. Page 3, Line 46: "Plateau world highest" should be "Plateau, the world's highest."

Thanks! We modified it in Line 45.

3. Page 5, Line 80: "diverse rupture behaviors contributes" should be "diverse rupture behaviors contribute."

Modified in Line 80.

4. Page 6, Line 108: "resulting in notable errors" should be "resulting in significant errors."

Thanks! We modified it. See Line 107.

5. Page 8, Line 160: "increased precision and reliability" should be "increasing precision and reliability."

Modified in Line 156.