Reviewer 2

General Comments:

The paper by Wang et al. provides a comprehensive analysis of historical and projected future runoff in the Mekong River Basin (MRB). The authors examined the runoff using four Global Climate Models (GCMs) and five Global Hydrological Models (GHMs) sourced from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) 2b. These models were applied to data from eight gauge stations across MRB, considering three Representative Concentration Pathways (RCP2.6, RCP6.0, RCP8.5). The results indicate that while the annual runoff in the basin has remained relatively stable since 1971, significant increases are projected under the various RCPs.

In general, the paper is a strong fit for the journal, and its subject matter aligns well with the journal's scope. The study's focus on runoff in the MRB is of paramount importance for the region, making the findings particularly valuable. Additionally, the methodology employed in the research is both standard and widely accepted within the field.

However, one aspect that requires improvement is the clarity regarding the paper's contribution or novelty. The authors should explicitly highlight what sets their work apart from the numerous previous studies on future runoff and streamflow projections in the MRB.

Another crucial aspect overlooked by the authors is the estimation of uncertainty associated with their future projections. In studies of this nature, accounting for uncertainty is of utmost importance and cannot be overlooked. Although the authors attempted to mitigate uncertainty by using the ensemble-average approach, it falls short in providing a comprehensive estimate of the associated uncertainty. Addressing and quantifying uncertainty in their projections would add significant value to the paper's findings and enhance the overall robustness of their research.

Response: We thank the reviewer for the thoughtful comments and suggestions which we believe are greatly helpful to improve the manuscript. In the revision, the paper's contribution/novelty has been emphasized appropriately. Meanwhile, we further quantified the uncertainty in future projections. Please kindly find below our detailed responses to each comment. Texts in blue are our responses to the comments, while those in red are revisions of the manuscript.

Specific comments:

1. Does the paper address relevant scientific questions within the scope of ESD?

Yes. The paper provides a comprehensive analysis of historical and future runoff in MRB (hydrosphere) under climate change (global change). The paper aims to quantify the impact of climate change on runoff, and thus improving our understanding of hydrological system behavior to global changes. Thus, I believe the paper aligns well with the scope of Earth System Dynamics (ESD).

Response: Thanks for your positive feedback and comment.

2. Does the paper present novel concepts, ideas, tools, or data?

No. While the results presented in the paper are undoubtedly interesting and useful, it is worth noting that there have been several previous studies conducted in the Mekong River Basin (MRB) with similar objectives. For example, https://doi.org/10.3390/w12061556 and https://doi.org/10.1016/j.eng.2021.06.026. Additionally, the data and methodology adopted by the authors is also widely used. Therefore, it is difficult to understand the novelty of the work.

Response: Thanks for your helpful comments. As mentioned in Lines 42-48 of the current manuscript, there have been previous studies on MRB runoff changes (Kingston et al., 2011; Yun et al., 2020; Wang et al., 2021; Lee et al., 2020; Liu et al., 2022). This work distinguishes from those previous studies in several important methodological perspectives. (1) Model ensemble: Previous studies generally focused on evaluating and predicting runoff simulations with a single hydrological model driven by different GCMs or various hydrological models driven by a single GCM (Kingston et al., 2011; Yun et al., 2020; Wang et al., 2021). This work is distinctive in the use of *both various GHMs runoff simulations and driven by different GCMs*. This approach allows us to systematically analyze the performance and uncertainty of different models and separate sources of uncertainty from hydrological models and climate models. By evaluating and selecting the best GCM-GHM combination, this approach is promising to increase our confidence in the projection of the future MRB runoff. (2) Validations across the river system: Previous studies analyzing future runoff projections for the MRB under different RCP scenarios usually focused on a single station/reach (Shrestha et al., 2016; Lee et al., 2020). These studies may overlook that fact that the upper and lower reaches of the MRB may have different change patterns under different RCP scenarios. For example, as the future emissions path changes from low to high (from RCP2.6 to RCP6.0 and then to RCP8.5) in the MRB, the runoff changing rate of upstream stations may increase sequentially, but that of downstream stations may first increase and then decrease. Our work provides novel insights from the whole river system perspective. (3) Testing model projections using the 2006-2020 data: ISIMIP2b projections are published before 2006 so its future projections include the period 2006−2020. Our work is unique in using this period, which now has real-time/world observations, to test model projections. This could increase the reliability of the simulation for the further future period.

Following your comments, we will provide clearer explanation on these novel points of our research that is distinctive from previous studies. For example:
On Line 48, we change the text to: "*However, these studies do not systematically analyze the runoff simulation results of long-term historical periods (including the historical period of historical scenarios and the real-time period of representative concentration pathways (RCP) scenarios, i.e. from the start simulation year of the RCPs to now pre-2023, for which observed runoff data are available.) under different GCM-GHM combinations. Such an analysis is meaningful and urgent to potentially assess and reduce the uncertainty/bias of runoff simulations introduced by both GCMs and GHMs (Kingston et al., 2011; Hoang et al., 2016).*"

On Line 60, we change to text to: "*(3) Finally, ~~we analyze the change in annual runoff and seasonal runoff under future RCP scenarios based on the best GCM-GHM combination.~~ we comprehensively analyze the future runoff change patterns (including annual runoff and seasonal runoff) in the upper, middle and lower reaches of the MRB under future RCP scenarios based on the best GCM-GHM combination.*"

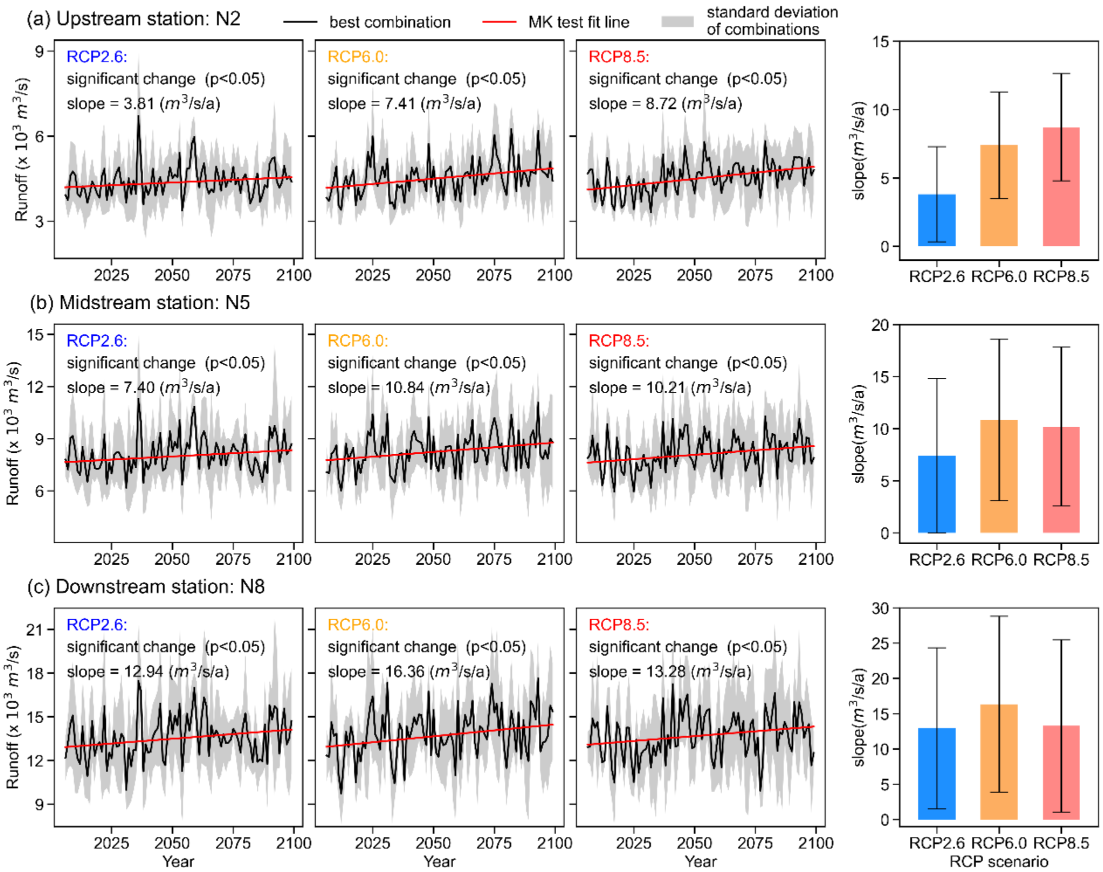
3. Are substantial conclusions reached?

Yes, based on the GHM simulation, the authors were able to reach at the conclusion that runoff in the MRB is projected to increase under climate change scenarios. However, the paper has not presented estimate of uncertainty associated with the projections.

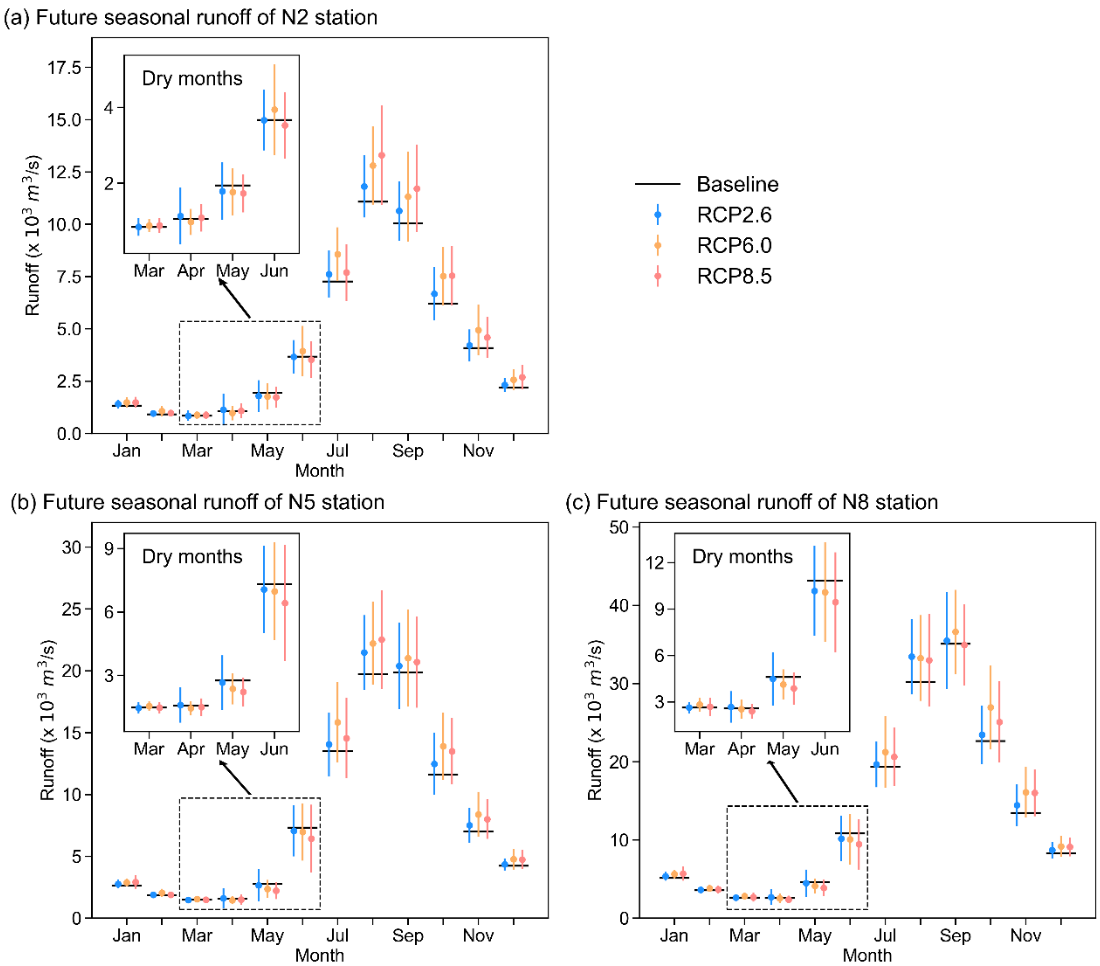
Response: Thanks for your positive feedback and helpful comment. In the revised manuscript, we have quantified the uncertainty of future projections using the standard deviation of the runoff results from GHM (e.g., WaterGAP2) under four GCMs drives. We have presented the method for quantifying uncertainty in the revised manuscript:

Section 2.3 Climate projections and hydrological models
"*All GHMs operate under the meteorological drive of the four GCMs, and the ensemble-averaged results of the GCMs are also evaluated due to the variability of the GCMs and the uncertainty of climate change. The standard deviation of the outputs of the GHM driven by four GCMs is used to quantify the uncertainty from the GCMs.*"

Furthermore, the uncertainty range has been added to Figures 6-7 and Table 4 in the revised manuscript. Meanwhile, the uncertainty range has also been marked in the text in the revised manuscript when quantifying future runoff projections.



"*Figure 6: ISIMIP projections of annual runoff for 2006-2099 under different RCP scenarios. The three rows correspond to future projections of three hydrological stations (N2, N5 and N8). In each row, three panels on the left are runoff time series for three RCP scenarios (RCP2.6, RCP6.0 and RCP8.5), while one panel on the right summarize the changing rate in annual runoff under the three RCPs. Then in the right panel, the different colored bars are for the runoff changing rate under each RCP, and the error bars are the uncertainty range.*"



“*Figure 7: Seasonal runoff changes under different RCPs scenarios at representative hydrological stations. The three panels correspond to future projections of three hydrological stations (N2, N5 and N8). In each panel, the black horizontal line is the baseline seasonal runoff, and the three colored (blue, yellow and red) dots and vertical lines are the projected seasonal runoff and its uncertainty range under the three RCPs (RCP2.6, RCP6.0 and RCP8.5).*”

Table 4: Percentage of runoff change in different months under different RCP scenarios at three representative stations.

Station	RCP	Seasonal runoff change (%)					
Chiang Khan (N2)		Jan	Feb	Mar	Apr	May	Jun
	RCP2.6	6.3±15.9	3.8±11.8	0.7±28.8	7.3±71.3	-7.8±39.1	-0.1±21.7
	RCP6.0	9.2±17.4	12.6±27.4	10.2±22.4	7.2±38.2	-8.9±32.0	6.6±32.3
	RCP8.5	8.7±19.3	1.6±12.7	6.9±23.9	1.3±33.9	-16.3±24.3	-7.3±23.1
		Jul	Aug	Sep	Oct	Nov	Dec
	RCP2.6	4.8±15.7	6.6±13.5	5.9±14.3	7.5±20.5	2.9±18.7	6.1±15.7
	RCP6.0	21.7±18.2	15.9±16.9	12.9±21.5	19.4±22.4	16.7±28.8	11.0±21.9
	RCP8.5	4.1±18.4	18.1±21.2	16.1±20.7	21.5±23.0	12.4±24.2	19.7±26.2
Mukdahan (N5)		Jan	Feb	Mar	Apr	May	Jun
	RCP2.6	4.8±13.0	1.9±11.0	-1.3±18.1	2.2±53.0	-3.4±46.6	-3.5±28.3
	RCP6.0	7.1±12.3	8.7±17.8	7.0±16.1	3.9±23.1	-11.9±27.3	-4.6±31.7
	RCP8.5	7.8±19.8	-1.0±11.7	0.2±17.9	-4.4±26.5	-23.7±23.2	-15.7±36.1
		Jul	Aug	Sep	Oct	Nov	Dec
	RCP2.6	4.1±19.2	8.9±15.4	2.6±17.6	7.4±21.7	7.3±20.3	2.8±11.5
	RCP6.0	25.3±25.7	12.7±17.0	7.1±20.0	20.4±23.7	16.3±25.3	9.2±19.2
	RCP8.5	7.9±24.1	11.4±19.8	5.8±18.9	16.7±23.3	12.8±22.4	11.4±18.3
Stung Treng (N8)		Jan	Feb	Mar	Apr	May	Jun
	RCP2.6	4.2±11.2	1.5±10.7	0.1±13.8	4.0±39.6	-2.5±37.7	-6.1±26.7
	RCP6.0	7.2±10.2	7.1±12.9	7.9±17.3	5.4±25.9	-7.5±21.8	-6.4±29.9
	RCP8.5	8.4±17.1	2.1±14.0	1.1±22.0	-9.0±18.2	-18.8±22.1	-16.8±28.4
		Jul	Aug	Sep	Oct	Nov	Dec
	RCP2.6	1.4±15.1	10.7±15.8	1.2±17.7	3.5±16.5	7.4±19.8	4.9±12.8
	RCP6.0	18.3±25.2	10.1±18.1	6.3±15.6	19.7±23.7	16.5±23.7	9.0±15.6
	RCP8.5	6.8±19.4	5.3±18.8	1.1±15.1	10.5±22.8	17.4±21.9	9.8±14.7

4. Are the scientific methods and assumptions valid and clearly outlined?

Yes, the methodology adopted in the paper is widely accepted and clearly described.

Response: Thanks for your positive feedback and comment.

5. Are the results sufficient to support the interpretations and conclusions?

Yes, but uncertainty associated with projections should also be highlighted in the conclusions to provide a clearer and more comprehensive understanding to the readers. It is allowed readers or policymakers to interpret the results in a more informed manner.

Response: Thanks for your positive feedback and helpful comment. In the revised manuscript, we have quantified the uncertainty of future projections using the standard deviation of the runoff results from GHM (e.g., WaterGAP2) under four GCMs drives. Following the above comment, the uncertainty range has been marked in the text in the revised manuscript when quantifying future runoff projections:

Abstract:

Line 12 : "*Under representative concentration pathways (RCPs, i.e., RCP2.6, RCP6.0 and RCP8.5), runoff of the MR is projected to increase significantly (p>0.05), e.g., 3.81±3.47* m^3 s^{-1} a^{-1} *(9±8% increase in 100 years) at the upstream station under RCP2.6 and 16.36±12.44* m^3 s^{-1} a^{-1} *(13±10 % increase in 100 years) at the downstream station under RCP6.0.*"

Section 3.3 ISIMIP future projections

"*For example, under the RCP2.6 scenario (see the first column of Fig. 6), the annual runoff changing rate of the upstream N2 station, midstream N5 station, and downstream N8 station increased from 3.81±3.47* m^3 s^{-1} a^{-1} *to 7.40±7.41* m^3 s^{-1} a^{-1} *and final to 12.94±11.41* m^3 s^{-1} a^{-1}*, respectively.*"

……

More about the places marked with uncertainty can be found in the revised manuscript.

6. Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)?

Yes. The methods and data used in the study are sufficiently explained, thus enabling other researchers to reproduce the results.

Response: Thanks for your positive feedback and comment.

7. Do the authors give proper credit to related work and clearly indicate their own new/original contribution?

Yes, the paper includes a substantial number of cited references. However, the authors fail to highlight how their results or approach is different from some of the similar studies conducted in the past. While they have conducted a comprehensive analysis of historical and future runoff in the Mekong River Basin, it is essential to clearly articulate the novel contributions of their work in relation to the existing literature.

Response: Thanks for your helpful comments. We apologize for the unclear elaboration of the contribution/novelty of the manuscript. Similar to our response to Specific comments #2, we have appropriately emphasized the contributions of our work in the revised manuscript. Please see our responses to your Comment #2.

8. Does the title clearly reflect the contents of the paper?

Yes.

Response: Thanks for your positive feedback and comment.

9. Does the abstract provide a concise and complete summary?

Yes.

Response: Thanks for your positive feedback and comment.

10. Is the overall presentation well-structured and clear?

Yes, the paper is well structured. However, the discussion section seems to redundantly summarize the results without delving into new insights. To enhance the paper's impact, the authors should utilize the discussion section to highlight how their results offer fresh perspectives and novel contributions concerning the future runoff of MRB beyond what has already been published. By focusing on these unique insights, the authors can provide a more substantial context for their findings.

Response: Thanks for your helpful comments and suggestions. We have made important revisions to the conclusion to emphasize our new findings and improve the conclusion section in the revised manuscript:

4 Discussion
Line 220 :“ *4 Discussion*

~~*Our results show a decreasing trend in the upstream and downstream runoff in the MRB and an increasing trend in the midstream runoff over the past 50 years. Of the 8 stations, only the N3 station reached a significant level of change. Hydropower energy development is one of the important human activities of MRB, which profoundly affects the runoff behavior of the basin. The 1990s are the early days of the establishment of the reservoirs, which significantly reduces the annual runoff. The subsequent operation*~~

~~*period of the reservoir has little impact on the interannual runoff, but mainly affects the distribution process of seasonal runoff.*~~

~~*In the MRB, the global climate models all perform well, except for the GFDL-ESM2M climate model. Moreover, GCM ensemble averaging can reduce the uncertainty of meteorological forcing. Meanwhile, based on the results of the GCM ensemble average, all GHMs have good runoff performance. Among these GHMs, WaterGAP2 performs the best, thanks to the calibration of the model (Chen et al., 2021). Overall, the runoff simulation results under the best combination are not inferior to the regional hydrological model. Under this combination, the R^2 of each station under the historical scenario (1971~2005) is about 0.75. Even in the historical simulation stage (2006~2020) under the RCPs scenario, it has the same performance. The satisfactory simulation performance of runoff enhances our confidence in future runoff analysis, and also provides a tool to understand the evolution law of future runoff.*~~

This study systematically analyzes the performance and uncertainty of runoff simulations from five GHMs driven by four GCMs within the MRB during historical periods. An interesting finding is that the variability introduced by the GCMs was similar to or even greater than that introduced by the GHMs on the runoff simulation (Figure 3 and Figure 4). For example, in Figure 3a, the median R^2 of different GHMs under the same GCM driver can differ by 0.20, but the median R^2 of the same GHM under different GCMs drivers can differ by more than 0.20. To reduce the variability of runoff simulation, on the one hand, we can obtain a well-performing GHM through comprehensive evaluation. In this study, three performance indicators are combined under eight hydrological stations, and WaterGAP2 (i.e., GHM) is found to have the best performance (highest R^2 and NSE, and lowest Pbias) under four GCM drivers in the MRB. In addition, even a good GHM has high uncertainty for future runoff projection under different GCM drivers. A feasible approach at this time should be to combine the ensemble average of runoff results from the GHM driven by different GCMs, which can help reduce the uncertainty from climate models in future projections. At the same time, the standard deviation of runoff results from the GHM driven by different GCMs can be used to quantify the uncertainty in future runoff projections.

Another point is that under different RCPs, the interannual runoff of the three representative sites has a significant ($p<0.05$) increasing trend, which is consistent with the previous relevant studies suggesting that MRB runoff would increase in the future due to climate change (Hoang et al., 2019; Liu et al., 2022). A novel finding is that the upstream, midstream and downstream stations in the MRB show different change patterns under different RCP scenarios. ~~*Among these stations, under the same RCP, the runoff increasing rate of downstream stations will be higher than that of upstream station, which is consistent with the known understanding of the routing process. Interestingly, the runoff change behaviour of the same representative station under different RCPs is not consistent.*~~ *The increase in runoff at upstream station N2 increased sequentially as the scenarios changed from RCP2.6 to RCP6.0 then to RCP8.5. The* *difference is that the downstream station N8 has the highest runoff increase under the RCP6.0 scenario, while not under the RCP8.5 scenario. This behavior is closely related to the combined effects of temperature and precipitation on runoff under different RCP scenarios. Specifically, at upstream stations, the synergistic effect of increased glacial meltwater and increased precipitation caused by warming under different scenarios is greater than the effect of increased evapotranspiration caused by warming. This results in the highest runoff increase under RCP8.5. At downstream stations, the proportion of glacier meltwater to total water volume decreased, suggesting that its impact on total runoff was also lower. Moreover, as the downstream latitude decreases, the evapotranspiration increment caused by warming also increases. Under the combined effect of these factors, the runoff increases under the RCP6.0 scenario (16.36±12.44 m^3/s/a) is higher than that under the RCP8.5 scenario (13.28±12.20 m^3/s/a). This means that the risk of future flooding in the middle and lower reaches of the MRB is still likely to remain a high level, even if we try to manage to stay on a moderate emissions path (i.e., RCP6.0). The novel change patterns of the upper, middle and lower reaches explored in the study may be able to provide a scientific basis for the future implementation of local water resource management schemes in each reach of the MRB.*"

11. Is the language fluent and precise?

Yes.

Response: Thanks for your comment.

12. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used?

Yes.

Response: Thanks for your comment.

13. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated?

Yes, as I mentioned in previous comments, the discussion section should be improved and elaborated.

Response: Thanks for your helpful comments. We have made important revisions to the conclusion to emphasize our findings and improve the conclusion section in the revised manuscript. The detailed revision of the conclusion in the revised manuscript can be found in our response to Specific comments #10.

14. Are the number and quality of references appropriate?

Yes.

Response: Thanks for your comment.

15. Is the amount and quality of supplementary material appropriate?

N/A

Response: Thanks for your comment.

References:

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