The authors are thankful to the reviewer for providing valuable comments and suggestions to improve the quality of this paper. We have incorporated all comments to the maximum extent in the revised manuscript. A point by point reply is given below:

General comments

This study investigates stratospheric QBO teleconnections with global monsoon systems based on 42 years (1979–2020) of reanalysis data. By focusing on boreal summer (JJA) and austral summer (DJF), and by excluding extreme ENSO events, the authors examine how QBO anomalies in the lower stratosphere modulate global and regional atmospheric circulations and precipitation. The results highlight significant impacts over the Northwest Pacific, North Atlantic, and Northeast Pacific, where the QBO appears to influence circulation systems such as the Walker Circulation, the Azores High, and the PNA pattern, leading to distinct precipitation anomalies.

The topic is timely and of interest, and the scientific questions are well-posed. However, in its current form the manuscript does not yet meet the standards of completeness, clarity, and rigor required for publication. In particular, the underlying mechanisms of the proposed associations are not sufficiently demonstrated, and the manuscript requires substantial technical revisions. I therefore recommend major revisions before the manuscript can be considered for publication.

Reply: Thank you for evaluating the manuscript and for your constructive feedback on the overall quality improvement of the paper. We have revised the manuscript to meet the standards of completeness, clarity, and rigor required for publication. We hope that the revised version provides a more comprehensive and coherent discussion on the underlying mechanisms. All technical errors have been corrected as per your suggestions, including additional corrections made in other relevant places.

Specific comments

Point1: Novelty of this study

It remains unclear how this study fundamentally differs from Yoden et al. (2023), and what new findings are provided. Figures 1–9 appear very similar to those in Yoden et al. (2023), with the only difference being the inclusion of an additional two years in the analysis period. Specifically, Figs. 1– 6 show the vertical profile of the QBO, followed by the climatological mean precipitation pattern and the impacts of phases 4–8 over the Northwest Pacific during JJA (Fig. 7), the impacts of phases 4–8 over the North Atlantic during DJF (Fig. 8), and the impacts of phases 5–1 over the Northeast Pacific during DJF (Fig. 9). These figures are nearly identical to those in Yoden et al. (2023). Figs. 10– 11 show additional results, but these appear insufficient to elucidate the underlying mechanisms.

Thus, the novelty of this work requires clarification. The authors should explicitly specify 'what is new or improved.' For instance, this could involve identifying the impacts of the QBO in regions not considered by Yoden et al. (2023), or providing robust evidence of mechanisms through new model experiments or analyses not previously demonstrated, as you mentioned in lines 90–93.

L90-93: "Recently Yoden et al. (2023) reported on new observational aspects of QBO modulation of the GM system, highlighting modulation of low-pressure cyclonic perturbations over the NH western Pacific during JJA and eastern Pacific during DJF. However, this study does not provide an in-depth view of the QBO association with the GM system from both a phenomenological and mechanical perspective."

Reply: Thank you for your concern. It is indeed essential to highlight the novelty of any work in comparison with the existing literature. The introduction has been revised after including the more citations. We believed that revised introduction smoothly expresses the novel aspect of this paper.

First, Yoden et al. (2023) primarily focused on presenting the long-term climatology of global monsoon systems and associated circulations during the satellite era (1979 onward) but provides only a brief overview on the QBO modulations. The analysis in the present study is substantially different from Yoden et al. (2023).

Although Figure 1 appears similar to the corresponding figure in Yoden et al. (2023), it represents an updated version covering a wider latitudinal domain (60°S–60°N) and includes wind patterns at lower the boundary layer 950 hPa. It is not emphasized as part of new results, but is used to lay the geographical context for major features of the seasonal monsoon system. Figure 2 discusses the differences in the seasonal structure of the QBO at different levels, whereas the corresponding figure in Yoden et al. (2023) illustrates the common QBO structure based on year-round data. These figures form the basis of the present analysis and hence cannot be omitted. Figures 3 and 4 present entirely new results derived from analyses of zonal-mean quantities. Figure 5 provides a new and more compact summary of Figures 7–10 in Yoden et al. (2023) for extended broader domain. Figures 6–9 present new results that were neither discussed nor included in the previous study. They constitute the main findings of this work and provide detailed phenomenological description. The limitation of Yoden et al. (2023) served as a primary motivation for the present study.

Point 2: Causality and mechanisms

The way in which zonal-mean QBO anomalies influence the regional GM system remains unclear. Why do the strongest impacts occur specifically over the Northwest Pacific, North Atlantic, and Northeast Pacific? Which atmospheric processes realize these linkages? A more concrete depiction and explanation would strengthen the manuscript. For example, time-lagged composites could demonstrate the temporal evolution of QBO-related signals and the development of circulation anomalies, or model experiments could help identify the key mechanisms in each region, even though establishing the exact causality of wave–mean flow interactions is inherently challenging.

Reply: We fully acknowledge your valuable suggestion that time-lagged composites could demonstrate the temporal evolution of QBO-related signals and the development of circulation anomalies. However, the present study was designed to provide a first-step global perspective to identify and highlight the key regions with possible mechanism where the QBO signal is most evident in the monsoon and circulation systems. The current paper is already substantial lengthy, and inclusion of further additional analysis would make the manuscript excessively long and may deviate from its primary objective of establishing the global context.

As part of our continuing research, we are conducting detailed follow-up studies focusing on individual regions to explore the underlying mechanisms in greater depth. We will test the time-lagged composites in these studies for temporal evolution of QBO-related signals.

Furthermore, the factors causing zonal-mean stratospheric signals to become zonally asymmetric in the troposphere, as well as their sensitivity to the QBO phase (50, 70 hPa), should be clarified. If these issues have already been addressed in previous studies, they should be discussed in greater detail in the Introduction.

Currently, the Introduction provides only a broad overview of the tropical, subtropical, and stratospheric QBO teleconnection routes (L51–98). As in the ENSO literature, the documented regional impacts of the QBO, particularly in the Northwest Pacific, North Atlantic, and Northeast Pacific, and the limitations of current understanding should be presented more explicitly to the reader.

Reply: The zonally symmetric QBO UTLS temperature anomalies can cause an asymmetric tropospheric response through their influence on deep convection in certain regions. The MMCs descend with time. Progressing from the 50 hPa to the 70 hPa index, the QBO thermal anomalies are lower in altitude within the UTLS and have a different effect. During JJA convection is centered over southeast Asia, off of the equator. It is not clear yet exactly why there is a big difference between using the 50 and 70 hPa indices, but the tropopause is much lower over the Maritime Continent during JJA compared to DJF, so it is more likely that the warm anomaly associated with the 70 hPa index will suppress convection over the equator. In the Northeast Pacific case both indices show reduced Bonin High and northeastward-extended South Asian High, compatible with a zonal mean cold anomaly in the subtropics, which locally enhances the spread of convection over the Northwest Pacific.

The introduction and discussion have been revised after considering the above suggestions. We believe that the revised version provides clear information on both the sensitivity to the QBO phase and the regional impacts of ENSO across the three targeted regions. Furthermore, the main text also discusses the possible factors responsible for the zonal-mean stratospheric signals becoming zonally asymmetric in the troposphere.

Point3: ENSO definition and its impact

A more detailed description of ENSO's impacts on the three target regions (Northwest Pacific, North Atlantic, Northeast Pacific) should be provided in the Introduction (L44–50). Does ENSO affect these regions independently of the QBO, or do they exert joint impacts? The rationale for excluding ENSO from the analysis should be explained more clearly to the reader.

L44-50: 'On interannual time scales, the GM system is also influenced by the El Niño Southern Oscillation (ENSO), a major driver of global teleconnections (Mooley and Parthasarathy, 1984; Shen and Lau, 1995; Krishnamurthy and Goswamy, 2000; Yu et al., 2021). The impact of ENSO can be confined to a specific monsoon system and may vary with the time scale. Recently, Yu et al. (2021) demonstrated that, at interannual time scales, the Indian summer monsoon exhibits a stronger relationship with ENSO, whereas on the decadal time scale, this relationship is weaker. Despite extensive studies on the teleconnection between GM dynamics and surface atmospheric circulations, interannual variability of GM is still unclear, and further research is needed to improve understanding.'

Reply: As mentioned in the above comment, the introduction section has been revised to include a more detailed description of ENSO's impacts on the three target regions. It also provides information on the rationale for excluding ENSO from the analysis.

In this study, only ENSO events with amplitudes greater than |1.0 K| were excluded, which implies that moderate and weak ENSO events were included. The authors state that lowering the threshold to |0.5 K| yields the same results (L471–472). However, this raises the question of why all figures were not produced using the NOAA CPC threshold of |0.5 K|. If the intention was to re-examine the new teleconnection pathway reported by Kumar et al. (2024), the ENSO-neutral threshold of 0.4 K employed in that study would seem more appropriate. Instead, the threshold of 1.0 K used in Yoden et al. (2023) was adopted. This inconsistency is likely to raise questions among readers. A sufficient explanation of the rationale behind the chosen threshold should therefore be included.

L471-472: 'Note that our analysis includes only the neutral ENSO phase, and obtained the same patterns even with a low threshold of the ENSO index (±0.5 K).'

Reply: In this study, the QBO is divided into eight 45° angular bin phases, and the sample size varies with phase and season. Some phases have a limited sample size, and lowering the threshold to 0.5K would further reduce the sample size for certain phases; therefore, we have not shown the figures for this threshold in the main text. However, in view of your concern and to maintain consistency with our previous studies (Kumar et al., 2022; 2024), we have included Fig. S3 (in the supplementary information) for the ±0.4 K cutoff case corresponding to Fig. 9 when discussing mechanisms based on Kumar et al. (2024).

Additionally, the number of El Niño cases differs from Yoden et al. (2023). Although the analysis period was extended from 1979–2018 to 1979–2020 (two additional years), the number of El Niño months decreased from 59 to 57, while neutral and La Niña months increased. One would expect the El Niño count to remain stable or increase, so this discrepancy requires clarification. (374 neutral, 59 El Niño, and 47 La Niña 395 neutral, 57 El Niño, and 52 La Niña).

Reply: Thank you very much for the in-depth study of the paper. Since ENSO events are also classified according to the QBO phases. Therefore, the phase angle plays a crucial role in counting El Niño, La Niña, and Neutral events. Additionally, a QBO state is defined using de-seasonalized zonal-mean zonal wind variations. The minor change in the climatology cycle value due to the inclusion of two additional years and the upgradation of data version (from ERA-Interim to ERA-5) induced small perturbations in the variance of the leading EOF1 and EOF2. For instance, the variances of EOF1 and EOF2 change from 59.7% and 34.9% (total 94.6%) in Yoden et al. (2023 to 58.1% and 36.7% (total 94.8%) in the current study, respectively. Consequently, there are minor changes in the QBO phase angle.

Point4: Completeness of the manuscript

4-1) Structure:

The structure of the main text should be revised. For example, Fig. 3 currently presents JJA U Difference (Fig. 3c) → JJA and DJF U (Figs. 3a, b, d, e; note there may also be a typo in the manuscript) → JJA and DJF T (Figs. 3g, h, j, k) for the thermal wind relationship → DJF U and T (Figs. 3l, f). What about Fig. 3i? Since the description mainly focuses on the differences (right panels), presenting only those panels might be enough.

Reply: We have revised both Figs. 3 and 4, per your suggestion.

In addition, the first two paragraphs of the Introduction could be merged into a single paragraph for better flow.

Reply: Done.

4-2) References

The appropriateness of the references should be carefully checked. For example, the manuscript states that increased midlatitude surface cold air outbreaks during QBO-E are reported by Kumar et al. (2022) (L61–64). However, Kumar et al. (2022) does not demonstrate surface cold air outbreaks. A more suitable reference should therefore be cited throughout the manuscript.

L61-64: 'This pathway is known as "Holton-Tan effect", or H-T effect (Holton and Tan 1980; 1982), which operates during boreal winter when westerlies exist in the polar stratosphere, QBO E favors a disrupted polar vortex, and therefore a weak Northern Annular Mode (NAM) and increased midlatitude surface cold air outbreaks (e.g., Kumar et al., 2022).'

Reply: Thanks for your in-depth review. The error in the year was typographical and has been corrected to Kumar et al. (2024), and also adding more new appropriate references to support this statement.

Minor comments

1) It seems that P5–P1 shows a peak at 20 hPa rather than at 70 hPa (Figs. 1a, e). Could the authors clarify this?

L165-167: 'this study will focus on the phases when QBO anomalies arrive in the UTLS regions, separately for JJA and DJF, with results presented for the composite difference P4 – P8 (QBO W – QBO E 50 hPa), as well as for P5 – P1 (QBO W – QBO E at 70 hPa)'.

Reply: The P5–P1 corresponds to QBO W – QBO E at 50 hPa and simultaneously opposite phase at 20 hPa with the peak magnitude. This can be more clearly seen in the revised Fig. 4 a and b. We have clarified the above point in the revised manuscript.

The STJs are not shown in the figures. Adding the climatological mean U (STJs) as contours would make the meridional shift more apparent. A similar modification is recommended for Fig. 4.

L230-231: 'Along the UTLS, this dipole favors an equatorward shift of the zonal mean STJs during QBO W at 50 hPa.'

Reply: As per your suggestion, we have added the climatological mean zonal wind (U) as contours on both Figs. 3 and 4. Thanks for nice suggestion.

2) Would 'reverse' be the correct term?

L464: 'The reverse scenario during can be seen during the QBO E phase.'

Reply: We have revised the sentence as "The opposite effects can be seen during the QBO E phase."

3) Are the years used to define QBO 50 hPa and QBO 70 hPa the same?
L20: 'As QBO phase progress,'

Reply: The same range of years was used, but the particular months chosen for W or E binning depend on the level. But the word "progresses" was misleading. We have omitted the "phase progress" in the revised manuscript.

Technical corrections

There are numerous typographical errors, ranging from minor issues to those that may lead to misinterpretation of the results. These reduce the readability of the manuscript. Below I list only a subset. The authors are strongly advised to thoroughly proofread the entire manuscript to correct these errors and enhance clarity.

Reply: Thank you for the critical reading and valuable suggestions to improve the quality of the paper. We have carefully proofread the entire manuscript to remove numerous typographical and minor errors.

L585: The abstract and main text state that the analysis period is from 1979 to 2020. However, the conclusions section refers to the period from 1979 to 2022.

Reply: The analysis period, 1979–2020, has been corrected in relevant places.

L148: profile of P1-P5 is different above 0.3 hPa →0.3?

Reply: Typographical error, and corrected 3 hPa.

L465: Consistent with previous results (section 5.2 & 5.4) → this sentence is written in section 5.4

Reply: Again, the typographical error; the reference has been corrected to "sections 5.2 & 5.3".

5.4. L489:190°W and 260°W'→190-260E.
L14: coincide with → coincides with
L15: Northen Hemisphere → Northern Hemisphere
L15: for same QBO W → for the same QBO W
L20: QBO phase progress → QBO phase progresses
L67: synoptic and 'and' planetary-scale → remove 'and'
L101: neither El Niño or La Niña → neither El Niño nor La Niña
L102: ESNO → ENSO
L233: Fig.s → Figs. L239: (Figs., 3 f)

Reply: Thank you. All the above noted errors have been corrected in the revised manuscript.

L265: P5 (hereinafter QBO W at 70h Pa) and P1 (hereinafter QBO W at 70 hPa)

Reply: The text inside the parentheses associated with P1 has been corrected as "(hereinafter QBO E at 70 hPa)".

L497: Brunt–väisälä frequency → Brunt–Väisälä frequency
L505: Zhou at el → et al.
L581: annualar mode → annular mode

Reply: Thank you, Corrected

L613-614: As a result, strengthens the anticyclonic circulations → incomplete sentence.

Reply: We have revised the sentence as "QBO W at 70 hPa promotes a positive PNA phase, which intensifies the mid-latitude northeastward flow over the Pacific Ocean".