Review of the manuscript "QBOi El Nino Southern Oscillation experiments
Part I: Overview of experiment design and ENSO modulation of the QBO" by Kawatani et al.

Summary

The manuscript presents an overview of the experimental design from the new SPARC QBOi project and examines the modulation of the QBO by ENSO using nine climate models. The findings indicate that the QBO period is longer during La Niña compared to El Niño across all models, consistent with observations. However, changes in the QBO amplitude remain inconclusive. Overall, I find the experiment intriguing, the manuscript well-written, and the results clearly explained. Most of my comments are minor and focus on improving consistency between different parts of the manuscript and aligning the figures with the text.

One major comment, however, concerns the lack of deeper insights into ENSO modulation of the QBO. The authors attribute this to the simplicity of the analyses and the limited availability of model output data, which they suggest prevents a full explanation of the quantitative differences in QBO between El Niño and La Niña. While future studies are mentioned as a potential avenue to address this, I argue that if a more detailed analysis is feasible, it should be included in this paper, as it was the primary motivation for the experiment and study.

Major Comments

1) Lack of additional insight into the mechanisms of ENSO modulation of the QBO

My primary concern is whether this paper and the associated experiments provide any additional insight into the mechanisms by which ENSO modulates the QBO. At the start of the paper, I had hoped—likely in line with the motivation behind designing and implementing these experiments—that this study would offer a deeper understanding of these mechanisms. However, the study appears to be an extension of Kawatani et al. (2019), with potentially more models included beyond MIROC, yet missing important analyses due to data limitations.

There are repeated statements such as: "Further investigation of these models is hampered by the incomplete model variables in the available data sets", "This simple analysis with limited model output data cannot fully explain quantitative differences in QBO periods between El Niño and La Niña", and "Detailed zonal-time spectral analyses of model fields, like those performed in Kawatani et al. (2019), remain a subject for future study."

If such analyses are indeed possible, this paper is the appropriate venue to present them, rather than postponing them to future studies. For example, as the authors mentioned, detailed spectral analyses of the EP flux, gravity wave parameterization fluxes, precipitation, or momentum

budgets based on the TEM framework could offer crucial insights into the intermodel spread of QBO period and amplitude.

To provide further context on my disappointment, Kawatani et al. (2019) noted: “It would be interesting to analyze the ENSO modulation of the three-dimensional wave forcing as well as tropical upwelling, which must show large differences between El Niño and La Niña. This may be investigated in a future study”. Now, five years later, this study states: “A detailed investigation of the three-dimensional distributions of parameterized wave fluxes modulated by ENSO, including model dependence, would be of interest and remains a topic for future research.”

It feels like an opportunity has been missed to address these outstanding questions. If there is a way to conduct these analyses, I strongly encourage the authors to include them in this paper.

2) Lack of use of recent data and citations of recent studies

Some aspects of the study, including citations and the data used, feel somewhat outdated. For instance, the use of ERA-I instead of ERA5. Additionally, the study only uses observed data up to 2012. If this limitation is due to avoiding the QBO disruptions, there are still several years of data available between 2012 and the end of 2015, as well as between 2020 and 2024. While including these additional years may not change the main conclusions of the paper, it would enhance the robustness of the analysis, particularly for slowly evolving phenomena like ENSO and QBO, where even a few more samples could provide valuable insights. Moreover, the citations miss some relevant and recent studies, such as Zhou et al. (2024), and a few others noted in my review.

Minor comments

L47-49: It can also be mentioned that “all models simulate stronger equatorial tropical upwelling in El Niño compared to La Niña up to ~10 hPa”.

L85: Small-scale gravity waves also contribute significantly to the forcing of the QBO westerly (e.g., Pahlavan et al. (2021))

L95: As a good reference on this you can cite Coy et al. (2020).

In general, the figures can be significantly improved by reducing redundancy, which would allow for larger, clearer panels. For instance, in Figure 2, use “El Niño” as the title for the left column and “La Niña” for the right, rather than repeating them for each panel. Similarly, list model names only on the left side of the figure and show the y-axis (0–20) only on the bottom

panels, instead of repeating it in every panel. These changes can enhance readability and apply to other figures as well.

The other general issue with the figures is the presence of too many contours, which reduces readability. In particular, in Figures 4, 8, 9, 10, and 13, the contours over the shadings can be removed, similar to Figure 12, to improve clarity.

Figure 3: Have you analyzed each phase of the QBO separately? For example, do both phases of the QBO become shorter during El Niño?

Figure 3: Have you considered using a Fourier Transform to determine the period instead of relying on zero wind line crossing (e.g., as done in Lee et al. (2024))? While it likely won't change the conclusions, it might be a better option, particularly when the QBO becomes more irregular/unrealistic, as seen during El Niño in ECHAM.

L412: Will the cooler anomaly around 60°N–90°N in ERA-I, which is not observed in the models, change if more data is included, such as using ERA-5 from 1940 to 2024?

For Figures 10, 11, 13, and 14, you could consider including results from reanalysis (e.g., ERA5) as a reference, similar to what is done in Figures 8 and 9.

Figure 12: Could you add the total flux for El Niño and La Niña (i.e., averaged over 10°S–10°N and all longitudes) to the bottom panels? If so, is it consistently larger during El Niño?

Editorial comments

L84: “respectively” seems redundant.

L107: You can cite (Richter et al., 2020) again to avoid ambiguity.

L108: SST is not yet defined.

L140: “QBO-resolved” -> “QBO-resolving”

L164: GWP is already defined.

L165: What is experiment 2?

L165: SST needs to be defined at L108.

L198: The model name “CESM15-110L” is mentioned here, while “WACCM5-110L” is used in the results (figures and tables). I suggest selecting one naming convention for consistency.

L200: Using the concise version of model names is a great choice, but it would be helpful to maintain this approach consistently in the results (figures and tables) as well. Currently, there is a discrepancy where the text uses concise names while the results use the full model names, making it harder to follow.

L198: “CESM15-110L” is mentioned here but in the results (figures and tables) “WACCM5-110L” is used. I suggest choosing one for consistency.

L200: It is great to use the more concise version of the model names but it would be great to use the concise version in the results as well (figures and tables) to make it easier to follow. Now, there is this discrepancy between the text and results, the former using the concise version, and the latter the full name of the models.

L220: Palmerio et al. (2022) is not in the bibliography.

L238: TEM is already defined.

Table 2: what is “5-1115” in front of GISS.

L284: “larger” -> “longer”(?)

L295: “with” -> “for”

L375: ITCZ not defined yet.

L378: “(left-top)” -> “(center-top)”

L392: Any reference for this statement?

Figure 7: “PRCP” not defined.

L427: BDC is already defined.

L431: “(left-top)” -> “(center-top)”

L442: A point after 4 is missing. "In El Niño and La Niña from QBOi models" is redundant. Also, capitalize the first letter to maintain consistency with the other titles.

L443: “eddy forcing” -> “wave forcing”, to be consistent with the other sections.

L443: “mean zonal” -> “zonal mean”

L444: TEM is already defined.

L445: “eddies” -> “waves”

L566-567: “WACCM” -> CESM1

L577: ITCZ should be defined earlier at L375.

L620: “below” should be removed.

L621: “below” -> “above” (?)

L639: “Fig. 14” -> “Fig. 13”

Caption of Fig. 14: “eddy” -> “wave”. “resolved motions” -> “resolved forcing”.

References

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