

**Authors' response to Editor's comments on "QBOi El Niño Southern Oscillation experiments: Overview of experiment design and ENSO modulation of the QBO"**  
**by Y. Kawatani et al.**

We very much appreciate the Editor's extensive efforts in carefully reading of the revised manuscript and making suggestions for improvement. Our responses to each of the Editor's comments are included below. For clarity, we have included the Editor's comments in *blue italics* and our responses in regular font.

*Thank you for the considerable work you and your coauthors have done to revise your paper. I was very happy to see that you addressed almost all of the issues raised by the two anonymous reviewers, with which I concurred. In particular, including the quantitative analysis of the sensitivity of the QBO period and amplitude to the phase of ENSO adds substantively to the manuscript. My decision on the revised manuscript is "publish subject to minor revisions", after which I will make a final decision to accept the paper for publication.*

We appreciate the Editor's positive assessment of our revised manuscript. We carefully considered each of the remaining comments and revised the manuscript where appropriate.

*i) Edit to bring the abstract more in line with the results of the paper; and remove extraneous information. Suggest the following change on lines 55-56: "...simulated La Nina periods tend to be longer than those observed during El Nino, although in most models the differences are small compared to that observed." This wording is more in line with the summary of the results in the text (e.g., line 345-6 "Only three of the nine models ...simulate La Nina- El Nino differences in the QBO period that approach this observed sensitivity, even under the amplified ENSO forcing used in this study.", and the text on lines 917-919 "It is noted ... the QBO period.")*

We have revised the sentence in the abstract to follow the Editor's suggestion, but slightly modified it as follows: *"The simulated QBO periods during La Niña tend to be longer than those during El Niño, although in most models the differences are small compared to that observed"*.

*ii) Also in the Abstract, delete the sentence on lines 59-61 ("The models capture... wind and temperature."). As I said in my review of the original manuscript, all models capture the equatorial tropospheric anomalies associated with ENSO for at least the past 35 years. So this statement adds nothing to the manuscript (other than prompting the reader to ask "why are they surprised at this result?").*

We have deleted the sentence in the abstract as suggested.

*iii) Adsf*

We assume this was a typographical error.

*iv) A reference is required on the statement that ends on line 155.*

We agree and have added references to Kawatani et al. (2010b) and Kawatani et al. (2019) here.

*v) Line 216: "... representing the upper end of past variability..." refers to a vertical coordinate on "end". Change this to read "...representing the extreme of past variability."*

We have revised the sentence as suggested.

*vi) Delete the paragraph starting on line 365. This point is made more succinctly by appending a short qualifier to line 365: "as seen in Fig. 2. For further information on how model formulation and boundary conditions influence the simulated QBO, see Bushell et al 2020."*

As suggested, we have deleted the paragraph and added the recommended sentence here.

*vii) Line 458, the word "uniform" is vague. Please elaborate.*

We have revised the sentence to clarify the intended meaning as follows:

*"These results highlight that, unlike the relatively consistent ENSO-related changes in QBO period, in which all models simulate longer periods during La Niña than during El Niño, the QBO amplitude exhibits more model-dependent and phase-dependent variations."*

viii) *In reference to Fig. 11 (the original Fig. 12), Reviewer 2 asked about the total EP flux in the El Nino and La Nina simulations. You indicated in response to the reviewer that a (nicely worded) new paragraph was added to the revised text (“When averaged over ... the total ... is significantly larger during El Nino only in CESM1. In contrast, ... between El Nino and La Nina conditions.”). I couldn’t find this text. If it isn’t in the paper, please add it.*

We thank the Editor for pointing this out. Indeed we had intended to include the sentence mentioned in our response to Reviewer 2, but it was inadvertently omitted. We have now inserted the following sentence into the discussion of Fig. 11 as follows:

*“In addition to these spatial patterns, when averaged over 10°S–10°N and all longitudes, the total (eastward plus westward) momentum flux at 100 hPa is significantly larger during El Niño only in CESM1, which uses variable non-orographic gravity wave sources. In contrast, the other three models with Hines-type schemes and fixed wave sources (ECHAM, MIROC-ESM, and MRI) do not show significant differences in total flux between El Niño and La Niña conditions”*

ix) *Lines 715-end of paragraph. It should be noted that, unlike in all of the models, observations show that the easterly acceleration in the QBO is by resolved ( $K \leq 20$ ) waves. See Fig. 12 of Pahlavan et al.*

We respectfully note that this interpretation of Pahlavan et al. (2023) may reflect a misunderstanding. As shown in their Fig. 12 and described in the text, the easterly (westward) acceleration in the QBO is primarily driven by small-scale gravity (SSG) waves with zonal wavenumbers greater than 20, while contributions from larger-scale waves ( $K \leq 20$ ), including Kelvin, MRG, and IG modes, are relatively minor. This conclusion is consistent with findings from other observational and modeling studies, and is now widely accepted in the QBO literature.

x) *Delete the gratuitous one-sentence paragraph on lines 831-832; it doesn’t add any specific information.*

We have deleted this sentence as suggested.

*xi) Move the text on lines 917-919 to line 853, so line 853 reads “... basic agreement with observations. However, only three of the nine models (ECEARTH, LMDz, and ECHAM) simulate La Niña–El Niño differences in QBO period that approach the observed sensitivity (~27 %), even under the amplified ENSO forcing. The remaining six models exhibit more modest ENSO modulation 920 of the QBO period.”*

We have moved the text as suggested.

*xii) Finally, in several places in the text, the results may be reported with too many significant digits. For example, one line 428. Let’s say there are perhaps 40 QBO cycles in a 100-year simulation. The mean period will have some uncertainty, compounded by taking the difference in the period. I can’t imagine there are more than two significant digits in the result, but please check. Similar comments apply to the quoted numbers on lines 222, 340-341*

We changed all percentage values in the main text to integers (e.g., 28% instead of 27.9%). For QBO periods in months, we now use one decimal place (e.g.,  $25.3 \pm 2.1$  mon). In Figure 3, we originally showed values to two decimal places, but changed them to one decimal place for consistency. We kept this level of detail to allow reasonable comparison across models, especially where standard deviations are included.