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Interactive comment on "Role of equatorial planetary and gravity waves in the 2015–16 quasi-biennial oscillation disruption" *by* Min-Jee Kang et al.

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General Comment:

The authors investigated the relative contribution of each resolved wave and parameterized waves to the QBO disruption in 2015-2016. They have shown that MRG and westward IG weakened the QBO and then led to extratropical Rossby breaking at the QBO jet core at 40 hPa. They also investigated the roles of CGWs obtained from an offline CGW parameterization that author's group has developed and showed the importance of variable wave sources. There have been several studies to investigate the mechanism of the 2015-2016 QBO disruption. I think this paper is the most compre-

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Discussion paper

hensive study among them. I believe this paper is suitable for the publication in ACP. My recommendation is published after very minor revision. I have a few comments added below.

Response: First of all, we would like to thank the reviewer for the time spent on reviewing our long manuscript. All reviews have been beneficial and made us aware of important points which had to be addressed. We, the authors, are therefore thankful for the reviewer's contribution to improve the manuscript. We carefully addressed all comments and tried our best to improve the manuscript based on the suggestions and comments.

Comments:

1. MRG are confined to the range |k|<=20 and omega <0.75 cpd in the symmetric spectrum. I think zonal |k|<=20 is a little wide for the MRG. Presumably |k|<=∼10 would be better. Westward IGWs should be included in this definition. How much do the results depend on the ranges of |k|? I guess the relative contribution of MRG, shown in Table 1 and Figure 4, would be changed. One good point to answer this concern is to mention the dominant zonal wavenumber ranges for the MRG to force the QBO. I guess 3 < k < 6, but am not sure. I would suggest authors at least to mention the dependence of |k| selection to the quantitative results.

Response: Thank you for your comment! The MRG waves are confined to the spectral range where the signs of Fz1 and Fz2 are the opposite within $|k| \leq 20$ and $0.1 \leq \omega \leq 0.5$ cpd in the anti-symmetric spectrum (Kim and Chun 2015, JGR). Here, the Fz1 and Fz2 represent the first and second terms of the vertical EPF (Fz). This range is basically within $|k| \leq 10$ as seen in the example of the MRG wave spectrum in Figure A4, which is similar to what the reviewer expected. During the revision process, we performed a sensitivity test on the EPD for the MRG waves by changing the spectral boundary of the MRG waves as $|k| \leq 10$ and $0.1 \leq \omega \leq 0.5$ cpd in the anti-symmetric spectrum. It is found that the EPDs of the MRG waves in October and November 2015 are -0.437 and

-0.5883 m/s/mon (originally: -0.433 and -0.5876 m/s/mon), respectively, implying that the difference is within 1%. The dominant zonal wavenumber ranges for MRG waves are mentioned in the revised manuscript. [p.5, L144–145]

2. L216: “The required wave forcing term (REQ) is calculated as a residual by subtracting the advection terms from the zonal wind tendency in the TEM equation” When calculating REQ, do the authors consider the first term on the left of Eq. (1), that is meridional advection term, which is normally very small near the equator? In my experiences, the meridional advection term has also some values off the equator even at $\sim$5 degrees, which cannot be sometimes negligible.

Response: Yes, we also consider the meridional advection term, so the REQ is calculated as a residual by subtracting both the meridional and vertical advection terms from the zonal wind tendency. It is clarified in the revised manuscript. [p.8, L239]

3. L258: “although the magnitudes of the REQ and wave forcing (vertical advection) in ERA-I is generally stronger (weaker) than that in MERRA-2” I guess one possible reason for this is the different values of w* between MERRA-2 and ERA-I. As you know, the representation of BDC is quite different quantitatively among reanalyses as the S-RIP project has indicated.

Response: We agree with you. As the reviewer mentioned, w* value in the reanalysis is well known for its large spread. In addition to the differences in w*, a large spread in the vertical wind shear, which is generally related to the vertical resolution of the data, is also a possible reason for the discrepancy in the vertical advection term, which is supported by Figure 5 of Kim and Chun (2015, ACP). The related discussion is included in the revised manuscript. [p.10, L285–286]

4. I would suggest to refer the paper by Dunkerton (2016, GRL, https://doi.org/10.1002/2016GL070921). Dunkerton’s paper, published just after the QBO disruption, discussed some presumable mechanisms, which would be now useful for the current study.

Response: Thank you for suggesting a paper. The paper by Dunkerton (2016) is now included in the revised manuscript. [p.2, L44]

5. Figure 4(c): The explanation lines of Rossby-Y & Rossby-Z are hard to see. Please expand the lines.

Response: Thank you for pointing this out! The explanation lines in Figure 4c are expanded in the revised manuscript. [Fig. 4]

References

Kim, Y.-H., and H.-Y. Chun: Momentum forcing of the quasi-biennial oscillation by equatorial waves in recent reanalyses. Atmos. Chem. Phys., 15, 6577–6587, doi:10.5194/acp-15-6577-2015, 2015.

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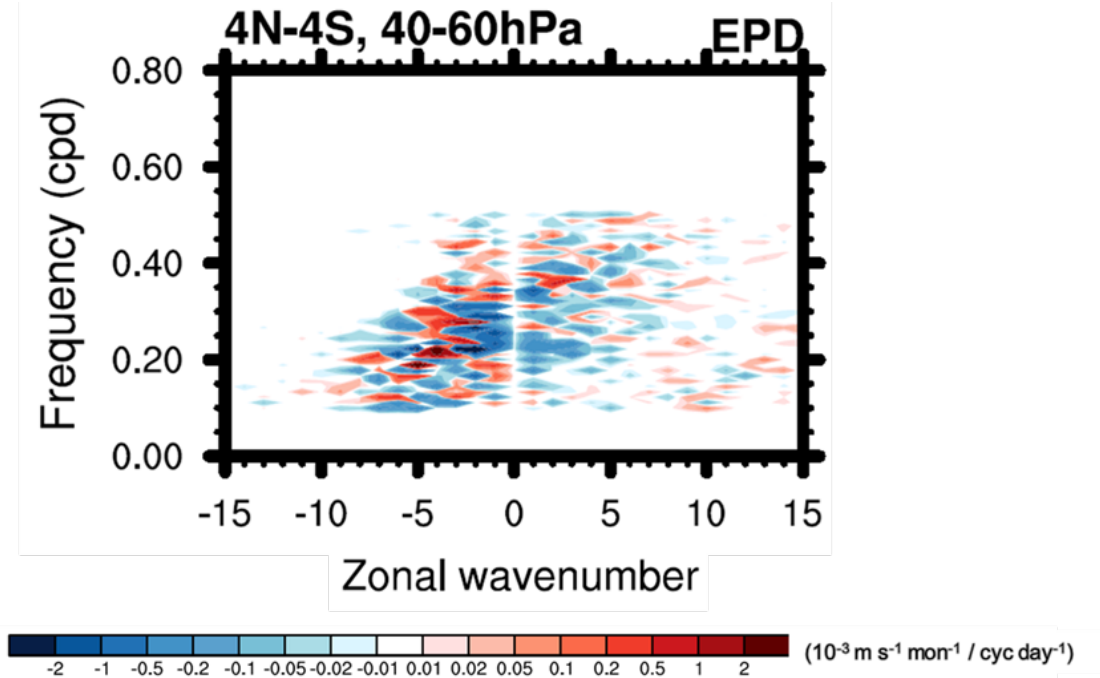

Fig. 1. Figure A4. Spectral density of the EPD for the MRG waves averaged over 4°N–4°S at 40–60 hPa in November 2015.