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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.

Anonymous Referee #2

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This paper gives a comprehensive overview of the different wave forcings that act during the 2016 QBO disruption. The paper discusses the effect of wave forcing by extratropical Rossby waves, equatorial waves, and small scale convective gravity waves, and is therefore the most complete description of the QBO disruption so far. The paper is very well written and fits well into the scope of ACP. The paper is recommended for publication after addressing my minor comments as detailed below.

Main comments:

(1) For the spectral analysis time segments of 90 days are used after applying sine and cosine windows at the first and last 30 days. According to Parseval's theorem, this will

lead to an underestimation of spectral amplitudes, and, on average, EPF and EPD will be ∼30% underestimated. This relatively small effect will not affect the basic results of the paper, but it should be mentioned.

(2) I am not sure whether the preconditioning of the QBO disruption by MRG EPD and IG EPD in October 2015 is a reliable result. Firstly, the magnitude of EPD is quite small, secondly, the EPD in October 2015 looks different in ERA-Interim, as can be seen in the supplement.

Specific comments:

p2, l33: You may want to include more recent work on the effect of the QBO on surface weather and climate, for example Kidston et al. (2015), or Gray et al. (2018).

Kidston, J., A. A. Scaife, S. C. Hardiman, D. M. Mitchell, N. Butchart, M. P. Baldwin, and L. J. Gray (2015), Stratospheric influence on tropospheric jet streams, storm tracks and surface weather, Nat. Geosci., 8, 433-440.

Gray, L. J., J. A. Anstey, Y. Kawatani, H. Lu, S. Osprey, and V. Schenzinger (2018), Surface impacts of the Quasi Biennial Oscillation, Atmos. Chem. Phys., 18, 8227-8247.

p3, l73: The reference Evan et al., JAS, 2012 does not fit here. Evan et al., JAS, 2012 discuss intermediate-scale tropical inertia-gravity waves of horizontal wavelengths in the 5000km range, and not the effect of small scale gravity waves.

This reference should be replaced by Evan et al., JGR, 2012 which is a WRF simulation of the QBO forcing by small scale gravity waves of horizontal wavelengths >270km. In addition to the listed model studies you should also include observational evidence of the effect of small scale gravity waves, for example Ern et al., JGR, 2014.

Evan, S., M. J. Alexander, and J. Dudhia (2012), WRF simulations of convectively generated gravity waves in opposite QBO phases, J. Geophys. Res., 117, D12117, doi:10.1029/2011JD017302.

Ern, M., F. Ploeger, P. Preusse, J. C. Gille, L. J. Gray, S. Kalisch, M. G. Mlynczak, J. M. Russell III, and M. Riese (2014), Interaction of gravity waves with the QBO: A satellite perspective, J. Geophys. Res. Atmos., 119, 2329-2355, doi:10.1002/2013JD020731.

p3, l88: "All" gravity waves is not correct! As stated in l.82/83, this paper discusses only small scale gravity waves of horizontal wavelengths <100-200km. However, there is also considerable QBO forcing by small scale gravity waves of horizontal wavelengths >200km, as can be seen from Evan et al., JGR, 2012.

p4, l106: On the selection of WQBO cases: Please state more clearly that the definition of the WQBO as used in this paper focuses on QBO situations that are comparable to that of the 2016 QBO disruption. Generally, there should be WQBO periods or WQBO onsets also in other months.

p5, l134/135: As EPF is obtained by summing in the spectral space (l.142), applying cosine windows will lead to an underestimation of spectral amplitudes, and also of EPF, and EPD. See Main Comment (1).

p9, l253/254: I am not sure whether it is a reliable result that IG and MRG would act as a preconditioning at 40hPa in October 2015 before Rossby waves can take effect! Please note that Fig.4b (for MERRA2) and Fig.S5 in the supplement (for ERA-Interim) look quite different! The preconditioning effect that you suggest seems to be much weaker than the differences between the two reanalyses.

p10, l281-285: Another reason for this difference could be the part of the gravity wave spectrum that is neither covered by the CGW scheme, nor resolved or parameterized in MERRA2. It should be emphasized that MERRA2 is not a free-running model! There will be model imbalances that are caused by data assimilation. Data assimilation can therefore correct misrepresentations of the gravity wave forcing by the nonorographic GWD parameterization.

Fig.6: Here you identify source regions of Rossby waves by positive EPD coinciding

with upward directed EPF. At 15N around 150hPa EPF is directed downward coinciding with negative EPD. Do you think this is another source region of Rossby waves? As EPF is directed downward, it looks like these waves cannot propagate into the stratosphere.

p11, l327: that the positive EPD region is a source region of the westward-propagating waves. -> that the positive EPD region should be a source region of westward-and-upward propagating waves.

p12, l370: It should be mentioned that Eq.(3) includes both barotropic and baroclinic instability. Did you check which term is stronger - the barotropic term (meridional gradients), or the baroclinic term (vertical gradients)? Coy et al., 2017 claimed that barotropic instability would be stronger. In your Fig.8, this does not fit the title and the figure caption saying "baroclinic instability".

p17, l513: barotropic instability -> barotropic and/or baroclinic instability

Technical comments:

p5, l124: the parameter \hat{f} is not used in Eq.(1)

p6, l175: is lower than 700 hPa -> is at altitudes lower than 700 hPa

Fig.1: colorbar should be m/s, but is m/s/month

Fig.3: one of the colorbars should refer to the wind in m/s, but both colorbars give tendencies in m/s/month

p8, l222: (Fig. 3a) -> (Fig. 3c)

p9, l256/257: Figure S4 is the same figure with Fig. 3 but using ERA-I data. -> Figure S4 shows the same as Fig. 3 but using ERA-I data.

p9, l264: (Fig. 4c) -> (Fig. 4a, dotted line)

caption of Fig.7, l795: (c) January 2016, -> (c) December 2015,

caption of Fig.7, l799: where the EPD is smaller than -> where the EPD is stronger than

p13, l390: affects -> affect

caption of Fig.9, p35, l814: January 2016, and (b) -> January 2016, and (d)

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