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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Momentum forcing of the QBO by equatorial waves in recent reanalyses" *by* Y.-H. Kim and H.-Y. Chun

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The authors thank the referee #2 for his/her valuable comments. Following the comments, we will append a discussion on the wave forcing estimates averaged over 10°N–10°S in the final revised paper, and provide the figures for the estimates over 10°N–10°S as a supplementary material. We will also include the results at 50 hPa. The responses to each of the referee's comments are listed below.

Comment 1: *The relative roles of equatorial waves and large, medium, small-scale gravity waves depend on height as well as easterly/westerly shears (e.g. Kawatani et al. 2010). In the introduction and main results in this paper, the authors discussed*

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the wave forcing only at 30 hPa and 10hPa. I believe the author should include more detailed discussion at 50 hPa and/or 70 hPa, which must be very useful information and required for the QBO community, since climate models failed to simulate the realistic amplitude of the QBO in the lower stratosphere.

Response: Following the referee's suggestion, we will include the analysis of the wave forcing at 50 hPa in the revised paper.

Comment 2: *In addition, I believe that including other reanalysis datasets, such as ERA40 (although data available until August 2002), JRA-25, NCEP-1 and NCEP-2, must make this paper much more interesting and useful, for example, for the S-RIP (SPARC reanalysis Intercomparison project) activity.*

Response: We plan to calculate the estimates using the other reanalysis datasets that the referee mentioned, as we are involved in the S-RIP activity. However, the inclusion of the results from these datasets to this paper is not possible during the process of the paper, because download of the datasets takes too long time (several months). In this study, we discussed that the equatorial wave amplitude is damped in the p level datasets of the reanalyses, and the damping rate depends on the vertical resolution of the native models. The models of the old reanalyses have coarser vertical resolutions than those of the four most recent datasets used in this study. Thus, the wave forcing from the old datasets would be more underestimated than that from the recent datasets. We will include this discussion in the revised paper.

Comment 3: *Another concern is to include the CFSR reanalysis in this paper. The previous CFSR model failed to simulate the QBO, and ERA-40 stratospheric wind profiles were used as bogus observations in CFSR data, at least from 1981 to 1998. I am not sure the latest CFSR model quality, but the authors should check this point.*

Response: As the referee commented, the early CFSR assimilation failed to capture

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the QBO in its streams 2 and 3, and the ERA-40 stratospheric wind profiles were used as bogus observations for the period of 1981–1998 to include a reasonable QBO signature (Saha et al., 2010). As a result, the QBO in the zonal mean zonal wind is successfully captured in the CFSR. There does not exist enough information about the quality of the CFSR in terms of the equatorial wave perturbations. Somehow the CFSR exhibits some interesting features: for example, in Fig. 2, it is shown that the IG wave forcing in the E–W phase in CFSR is always larger than that in the other datasets. We include these CFSR results in the paper, taking into consideration the uncertainty of this reanalysis.

Comment 4: *Other major points are the latitudinal width (5S-5N) the authors discuss about wave forcing relevant to the QBO. As shown in your recent paper (Kim and Chun 2015, JGR), EP-flux divergences of equatorial waves and gravity waves distribute much wider latitudinal width. For example, E-MRG show eastward (small westward) wave forcing around 10 degree (over the equator), and W-MRG show westward (eastward) forcing over (off) the equator. The 5S-5N average is the reason why MRG show westward forcing both in easterly and westerly shear phase of the QBO (Fig. 1). Because the amplitude of the QBO is approximately Gaussian about the equator with a 12 degree half width (Baldwin et al. 2001), 5S-5N average is too narrow, at least for contents of this paper. The author should show results averaged in 10S-10N, for example. Related with this comment, how the authors treat n=0 eastward waves (eastward MRG) in this paper? Please clarify in the manuscript.*

Response: We calculate the wave forcing estimates over 5°S–5°N because 1) the wave forcing at higher latitudes (e.g., 10° or 15°) induces residual meridional circulation (v^*), and thus, is partly compensated by the Coriolis force (e.g., Haynes, 1998), and 2) the Coriolis force and meridional advection induced by v^* can be another source of uncertainty in the reanalyses. Over 5°S–5°N, these terms are small and can be ignored. Thus, we keep the estimates for 5°S–5°N in the manuscript. However,

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we also agree the referee's comment that the wave forcing is distributed in a wider latitudinal band. We will provide the figures for the equatorial wave forcing and X averaged over 10°S–10°N as a supplementary material, and discuss them at the end of the result section in the revised paper. Regarding the $n = 0$ eastward waves, we will clarify that the MRG wave in this paper includes the $n = 0$ eastward waves.

Reference:

Haynes, P. H.: The latitudinal structure of the quasi-biennial oscillation, Q. J. R. Meteorol. Soc., 124, 2645–2670, 1998.

Saha, S., Moorthi, S., Pan, H.-L., Wu, X., Wang, J., Nadiga, S., Tripp, P., Kistler, R., Woollen, J., Behringer, D., Liu, H., Stokes, D., Grumbine, R., Gayno, G., Hou, Y.-T., Chuang, H., Juang, H.-M. H., Sela, J., Iredell, M., Treadon, R., Kleist, D., Delst, P. V., Keyser, D., Derber, J., Ek, M., Meng, J., Wei, H., Yang, R., Lord, S., van den Dool, H., Kumar, A., Wang, W., Long, C., Chelliah, M., Xue, Y., Huang, B., Schemm, J.-K., Ebisuzaki, W., Lin, R., Xie, P., Chen, M., Zhou, S., Higgins, W., Zou, C.-Z., Liu, Q., Chen, Y., Han, Y., Cucurull, L., Reynolds, R. W., Rutledge, G., and Goldberg, M.: The NCEP climate forecast system reanalysis, Bull. Am. Meteor. Soc., 91, 1015–1057, 2010.

Interactive comment on Atmos. Chem. Phys. Discuss., 15, 5175, 2015.