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Interactive comment on "Comparison of equatorial wave activity in the tropical tropopause layer and stratosphere represented in reanalyses" *by* Young-Ha Kim et al.

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Review of "Comparison of equatorial wave activity in the tropical tropopause layer and stratosphere represented in reanalyses"

by Y.-H. Kim et al.

Recommendation: minor revision

This is a well-written, comprehensive comparison of Kelvin and Rossby-gravity waves and wave activity as represented in six reanalysis datasets. The comparison is thorough and the interpretation of the results is reasonable, as far as it goes. However, I

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Discussion paper

believe there are two areas where the paper could be improved. The first (required) is the choice of latitude range over which results are averaged for Eliassen-Palm (EP) flux and EP flux divergence comparisons. Garcia and Richter (JAS, 2019) have recently shown that averaging beyond $\pm 5^{\circ}$ can be misleading in the case of Rossby-gravity waves because their EP flux divergence pattern changes sing within a narrow neighborhood of the Equator, such that broader latitude averaging leads to cancellation. The second (optional) would be a more thorough examination of the impact of the quasi-biennial oscillation (QBO) on the behavior of EP fluxes and wave spectra (at present, there is only one figureâĂŤFig. 11âĂŤand a short discussion thereof).

Otherwise, the paper is an important contribution to the literature on tropical waves, and includes a very useful discussion of the impact of new satellite observations on the reanalysis products. I believe the paper is suitable for publication once the general comments above and the specific comments listed below are addressed.

Specific comments (page, line):

(4, 15) “the EP flux formulation”: The reference cited does not explain how the flux is calculated; it just gives the standard definition of EP flux. A brief description of how you go from spectral components of velocity and temperature to F(omega,k) would be helpful. Also, do you average F in latitude? Over what range? See also comment at (10,14).

(5,4) “JRA-55 and JRA-55C show . . . less power below 20 hPa”: Does this have anything to do with vertical resolution? Slower Kelvin waves would be prevalent in the lower stratosphere; these waves have short vertical wavelengths whose accurate representation depends on having sufficient vertical resolution. It would be useful to include in Table 1 information on the horizontal and vertical resolution of each reanalysis.

(5,6) “thin purple” Thin purple what? Are you referring to the thin purple lines in the figure?

(5,15) “MRG generated in the region. . .”: How do you know where the waves are generated?

(5,17) “Fig. 2, dashed”: Figure 2 has many dashed lines. Do you mean the longer-dashed lines in the panels for 100 hPa?

(5,22) “more intense than those at lower frequencies with |k| > 4, as the altitude increases”: I am not sure what this means. There are local maxima at the (omega,k) mentioned in the text at 50 and 20 hPa. At 20 hPa, these maxima are larger than any other spectral components, although this is not the case at 50 hPa. Is that what you have in mind? I am not sure why the remark about |k|>4 is needed here.

(6,14) “MRG . . . wavepacket travels eastward”: While this is evident from the zero-background wind dispersion relation, it may not be obvious to many readers, who are conditioned to think of RG wavepackets propagating westward in the tropical troposphere (“African waves”). You may want to further explain the role of background wind, which is important for westward RG waves since they have small intrinsic group velocity. By the way, insofar as the zonal propagation of these RG wavepackets is sensitive to the background wind, it is not clear to what extent the very slight eastward displacement with altitude of their Vs variance maximum (Fig. 3b) can be interpreted simply in terms of eastward group velocity, since the winds at altitudes above 100 hPa alternate between easterly and westerly depending on the phase of the QBO. Examination of this behavior stratified by the phase of the QBO would have been helpful.

(8,4) “MRG . . . localized wave packets”: Could you speculate as to why the RG waves are found only over the Atlantic and easternmost Pacific?

(8,8) “CFSR . . . has a zonally broader signal”: Consistent with the spectrum shown in Fig. 2.

(8,18) “due to the data availability”: I think you mean “due to the lack of ML data” for MERRA.

(8,25) “annual time series”: “time series of annually-averaged data” might be clearer.

(8,32) “A similar systematic change . . . at 10 and 5 hPa”: On the other hand, at 50 hPa there is no change. Any idea why? Even if you do not know, this should be pointed out.

(9,16) “the rate of change . . . is 17%”: 17% is not a "rate of change"; it is the change between two periods expressed in percentage terms (note also similar, imprecise usage on line 18).

(10,11) “if duration of westerly QBO phases . . . are shorter in P2 than in P1”: So, are they shorter or not? Regardless of statistical robustness, if you are going to bring this up as an explanation you should at least checkâĂŤand tell the readerâĂŤwhether the conjecture is true even qualitatively.

(11,14) Fz (Figs. 9 and 10. . .): The implicit assumption here is that div(F) is dominated by d(Fz)/dz. This need not be the case, especially for RG waves. In addition, you neglect stating whether the EP flux was averaged in latitude. It appears that it is, since later on (12,12) you write that Fz is averaged over $\pm 15^{\circ}$. Such broad averaging can complicate the interpretation of the results; Garcia and Richter (2019) showed that averaging over a range of latitude wider than $\pm 5^{\circ}$ yields misleading results for the RG waves found in their simulation of the QBO.

(11,24) “while for the Kelvin waves . . . interdependence”: I do not understand what this means. Could you clarify?

(11,33) “apparently”: Why apparently?

(12,12) Figure 11 . . . 15N-15S averaged”: This broad latitude averaging could be problematic. See comment at (11,14).

(12,12) “Fz as function of phase speed”: Note that Fz may not be the best quantity for characterizing the EP flux of RG waves. The conceptual framework assumed here appears to be that wave activity propagates from the lower to the upper stratosphere, as in a "classic" 1D model of the QBO. That is a limited perspective that might not apply to the behavior of RG waves in the real world.

(12,30) “Kelvin wave forcing integrated. . .”: What does the color bar at the bottom of the figure (labeled month-1) represent? How does one get, even approximately, the values quoted in this sentence from Fig. 11 plus the color bar?

(13,5) “MRG waves dissipate mainly in the lower stratosphere . . . zonal wind is easterly at 70 hPa”: Yes, but where does the negative forcing in the descending westerly phase at 20 hPa (Fig. 11, top two rows) come from? It appears unconnected to anything below.

(13,6) “only up to 1 m s-1 month-1”: This is less than a quarter of the magnitude quoted earlier for Kelvin waves. The large asymmetry in magnitude might be due to averaging over $\pm 15^{\circ}$. As noted earlier, Garcia and Richter (2019) showed that averaging RG wave EP flux beyond $\pm 5^{\circ}$ reduces its magnitude substantially.

(13,16) “gravity waves . . . may play a more important role”: Garcia and Richter (2019) concluded that RG EP flux divergence is much larger when averaged over a narrower range of latitude; and yet this EP flux divergence does not drive the QBO in their model but is instead a result of instability of the QBO westerlies. The implication is, indeed, that the easterly forcing must come in large part from smaller scale gravity waves.

(14,4) “suggestive of in situ wave generation”: What is the generation mechanism? The idea that RG waves might be generated in situ has been proposed by Garcia and Richter (2019), who associated it with instability of the QBO westerly jet and showed that similar behavior is present in other models and in observations. However, the waves identified here do not appear to be the same as those documented by Garcia and Richter, since the latter always occur in close connection with regions where the westerly jet curvature is large, such that the barotropic vorticity gradient reverses sign. On the other hand, whatever these waves are, they might be excited by the same instability mechanism that excites the RG waves documented by Garcia and Richter. I agree that these waves merit a closer examination.

(15,2) “polarization relationships”: What does this mean? Are you referring to the dispersion curves?

(15,3) “exhibit remarkably similar patterns”: Perhaps you should add “in the lower stratosphere”, since you showed EOF results for 50 hPa only.

(15,10) “significant changes after the late 1990s”: But no changes at 50 hPa, if I am interpreting Figure 7 correctly. I have no idea why this is, but it ought to be mentioned.

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