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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

Anonymous Referee #1

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General Comments

The paper by Kim and Chun is a very nice study investigating the forcing of the QBO by equatorial waves in four of the most important reanalysis data sets (ERA-Interim, MERRA, CFSR, and JRA-55). In addition, for each of the data sets the net forcing by mesoscale gravity waves is estimated from the residual of the zonal wind tendency equation.
A special merit of this study is that uncertainties in the wave forcing estimates are discussed. In particular, the importance of using native model levels instead of data interpolated, for example, on fixed pressure levels is pointed out. This very insightful discussion is of great importance for current efforts of improving the QBO in climate

models, because reanalyses are frequently used as a reference.

The paper is very well written and contains important information for the readership of ACP. There are only a few very minor comments that should be addressed before publication in ACP.

Minor Comments

(1) p.5176, l.4ff: Zonal wind tendencies are generally given in m/s/month. Because calendar months can have varying numbers of days, the unit m/s/day is more commonly used.
It should therefore be clarified once in the text that "month" in this context refers to a fixed number of 30 days, for example on p.5181, l.18. Once this has been clarified, numbers can easily be converted.

(2) p.5177, l.26: suggestion: inertio-gravity waves → gravity waves

For inertio-gravity waves, it is usually assumed that $\hat{\omega} \sim f$. Satellite observations, however, cover a larger range of intrinsic frequencies. As shown in Alexander et al., QJRMS, 2010, their Fig. 8b, satellites can observe gravity waves with intrinsic periods as short as ∼1–2 hours, much shorter than the intrinsic period given by the Coriolis parameter.

Reference:

Alexander, M. J., et al.: Recent developments in gravity-wave effects in climate models and the global distribution of gravity-wave momentum flux from observations and models, Q. J. R. Meteorol. Soc., 136, 1103–1124, doi:10.1002/qj.637, 2010.

(3) p.5179, l.20: It should be mentioned that comparison with observations shows that the ECMWF model strongly underestimates temperature fluctuations of mesoscale gravity waves (for example, Schroeder et al., 2009). Therefore reanalyses based on the ECMWF model, as well as other reanalyses, are also expected to generally underestimate such small-scale fluctuations.

Citation;

Schroeder, S., Preusse, P., Ern, M., and Riese, M.: Gravity waves resolved in ECMWF and measured by SABER, Geophys. Res. Lett., 36, L10805, doi:10.1029/2008GL037054, 2009.

(4) p.5179: Not all parameters in equations (1)–(3) are defined in the text. Instead, it is referred to Andrews et al. (1987).
Omitting these definitions is comprehensible because this is textbook knowledge. Including all these definitions would considerably lengthen this section and reduce legibility. Further, I suppose that most readers interested in the topic of this study will be familiar with this notation. Therefore, I leave it to the authors whether the parameters should be explained here again, or not.

(5) Fig.1: The text in the lower left of each panel describing the different wave types is not easy to recognize.

Suggestion: Either use a different color for this text, maybe red, or move this text to the left of the panels.

(6a) p.5180, ll.3/4: Here, all zonal wavenumbers $|k| \leq 20$ are attributed to RGW waves. Usually, however, only $k < 0$ waves are attributed to the RGW wave band.

By combining all $|k| \leq 20$, the wave bands of westward propagating RGW waves, and of eastward propagating n=0 inertia-gravity waves are mixed.

It is not clear whether:
(a) RGW waves and n=0 inertia-gravity waves are summarized in one contribution
This could be justified by the fact that the combined spectral band of RGW

and n=0 inertia-gravity waves runs continuously from negative to positive zonal wavenumbers.
or:
(b) The further restriction of $F^{(z,H)}F^{(z,M)} < 0$ suppresses most or all contributions of n=0 inertia-gravity waves.

(6b) p.5180, ll.9/10: This comment is related to (6a). On p.5180, ll.9/10 it is stated that all remaining non-Kelvin and non-RGW waves with $|k| \leq 20$ are assumed to be Rossby waves, if $\omega < 0.4$ cycle/day.

This, however, includes also eastward propagating waves that are no Rossby waves, for example n=0 inertia-gravity waves, if they have not been classified as RGW waves before.

On the other hand, the contribution of n=0 inertia-gravity waves may be negligible compared to the RGW or to the Rossby waves, and therefore would not be relevant for the exact definition of wave types.

Please clarify!

(7) p.5180, l.18: It should be mentioned that in all figures the x-axis ticks correspond to 1st of January of the given year.

(8) p.5182, l.26: It should be mentioned that the net resolved wave forcing obtained for ERA-I_ml is similar to previous ERA-I estimates by Ern et al. (2014). Somewhat lower values in Ern et al. (2014) may arise from the larger latitude range of 10S–10N in their study.

(9) p.5184, l.16:
zonal wind shear → vertical shear of the zonal wind

(10) p.5184, l.26: SD → standard deviation (SD)

(11) p.5184, l.26/27: Suggested rewording:
This represents the magnitude of $\overline{u}_z$ alternating → These values are governed by the magnitude of $\overline{u}_z$ that alternates

(12) p.5185, l.9: It should be pointed out more clearly that relative differences of ADVz between ERA-I and ERA-I_ml in Fig.4b may appear small. However, these differences of 2–4 m/s/month can still be an important effect when calculating the residual drag from the tendency equation, which has typical values of $\sim$10 m/s/month.

(13) p.5186, l.1: It should be more clearly mentioned that all terms in the curly brackets are from ERA-I_ml. Only the EP flux divergence of the resolved waves is from the other respective reanalysis.

(14) p.5186, ll.6/7: It should be mentioned that these values of $\overline{X}^*$ are similar to estimates by Ern et al. (2014). Somewhat higher values in Ern et al. (2014) may arise from a larger latitude range in their study.

(15) p.5186, ll.9/10: Some care has to be taken with this statement. Kelvin wave forcing is not a net forcing, while $\overline{X}^*$ is a net forcing. However, I have the impression that not only the Kelvin wave forcing, but also positive values of the ERA-I_ml net resolved forcing in Fig. 3 show somewhat stronger peak values than $\overline{X}^*$.

For clarification, I would suggest to just add the word “net”:

the mesoscale gravity wave forcing → the net mesoscale gravity wave forcing

(16) p.5187, l.18: the mesoscale gravity wave forcing → the net mesoscale gravity wave forcing

(17) p.5187, l.26: (2–4Δ_V) → (2Δ_V–4Δ_V)

(18) p.5191, ll.16–19: Reference Kobayashi et al., 2015 should be updated. The final version of this article is now available at J. Meteorol. Soc. Jpn.

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