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Interactive Comment

Interactive comment on "On the presence of equatorial waves in the lower stratosphere of a general circulation model" *by* P. Maury and F. Lott

Anonymous Referee #1

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General Comment

In their paper the authors investigate the characteristics of Kelvin waves (KWs) and Rossby-gravity waves (RGWs) in the LMDz GCM and compare with ERA Interim (ERAI) reanalyses. One main finding is that dynamical filtering is very important for the spectrum of waves that is seen in the stratosphere. Other findings concern the source mechanisms of KWs and RGWs. In LMDz there is strong activity of Kelvin waves, comparable to ERA Interim under similar meteorological conditions, although precipitation in LMDz is much less organized in convectively coupled equatorial waves than in observed precipitation from GPCP. It is shown that in the LMDz model Kelvin waves in the tropics could be induced by EP flux originating from the subtropics and midlatitudes during the winter season. For Rossby-gravity waves there is some evidence that, in addition to the accepted theory that they propagate upward from tropospheric sources, also downward propagation from higher altitudes may become important if propagation conditions from the troposphere into the stratosphere become unfavorable.

Overall, this is a very interesting study, and of broad interest to the readership of ACP. Publication of this article is therefore recommended after addressing the minor and technical comments, as detailed below.

Main comments are:

(A) Some more discussion should be added about the EP flux from midlatitudes into the tropics in LMDz

(B) Some more discussion should be added about the finding that RGW packets can also propagate downward

(C) Some more information should be given how the wave composites are constructed

For details see the Detailed Comments below.

Detailed Comments

(1) p.22609, l.5: About the QBO forcing: In addition to the relatively unspecific references Holton/Lindzen (theory) and Baldwin et al. (an overview) also more spe-

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cific references giving numbers should be included here, for example, Tindall et al., QJRMS, 2006 and Ern and Preusse, ACP, 2009:

citations:

Tindall, J. C., Thuburn, J, and Highwood, E. J.: Equatorial waves in the lower stratosphere. II: Annual and interannual variability, Q. J. Roy. Meteor. Soc., 132, 195–212, doi:10.1256/qj.04.153, 2006.

Ern, M. and Preusse, P.: Wave fluxes of equatorial Kelvin waves and QBO zonal wind forcing derived from SABER and ECMWF temperature space-time spectra, Atmos. Chem. Phys., 9, 3957–3986, doi:10.5194/acp-9-3957-2009, 2009.

(2) p.22609, l.19: It should be mentioned that much of the variation of Kelvin wave variances in the stratosphere can be explained by assuming a fixed source in the troposphere and wind filtering alone (for example, Ern et al., ACP, 2009).

citation:

Ern, M., Cho, H.-K., Preusse, P., and Eckermann, S. D.: Properties of the average distribution of equatorial Kelvin waves investigated with the GROGRAT ray tracer, Atmos. Chem. Phys., 9, 7973–7995, doi:10.5194/acp-9-7973-2009, 2009.

(3) p.22616, ll.3-6: this sentence is difficult to understand:
"This shift to higher equivalent depths in the stratosphere means that the vertical wavenumber of KWs decreases when the equivalent depth h increases and the corresponding KWs are less attenuated (see Eq. 4)."
suggest to rewrite, as follows:
"This shift to higher equivalent depths in the stratosphere means that in the stratosphere KWs on average have higher equivalent depths and larger vertical wavelengths (cf. Eq.(4)). The reason for this shift is that KWs with shorter vertical wavelengths/lower equivalent depths have lower phase speeds and are more strongly affected by dissipation processes and critical wind levels."

(4) p.22617, l.16: It should be mentioned that daily fields of temperature perturbations due to KWs or RGWs are reconstructed from the spectra, and that the composites are built around the longitude of the temperature maxima that were found. Therefore in Figs.6–9 the maximum temperature deviation in the composites is always at 0 deg longitude.

(4) p.22617, l.21: How do you make sure that not all KW findings are from only a short time period in one single year?
Would it be a problem if this happens?

(6) p.22618, l.14: The wavenumber range 4–6 covers the maximum in the ERAI spectrum, but for LMDz the RGW spectrum has high values also at lower zonal wavenumbers. Perhaps it would be better to include also s=3.
Of course, using lower zonal wavenumbers might introduce even shorter vertical wavelengths that may be even more problematic to resolve for the model.

(7) p.22620, ll.4-16: Please be more explicit and add some more discussion!
(a) Please clarify: The EP flux is calculated from only the fluctuations in the KW spectral band used for building the composites?
(b) If this is the case, the following should be stated more clearly:
EP fluxes in the KW spectral band are also seen in the extratropics of LMDz, but not so in ERAI. More clearly, in LMDz (during winter) there are eastward traveling planetary waves in the subtropical jet and in the polar jet that are not present or not so strong in ERAI.

Question:
Could the presence of these planetary waves be somehow related to the background winds in LMDz? Are there significant differences to ERAI?

(8) p.22620, ll.15/16: "...southern subtropics, e.g. where the mid-latitudes synoptic variability is the strongest."

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In this sentence subtropics and mid-latitudes are mixed. This somehow does not fit. Please clarify!

Do you think that synoptic scale variability plays an important role? I am not sure. Please note that the EP fluxes due to KWs are of planetary scale!

Instead, I would assume that planetary-scale variability from the strong wind jets in the SH extends into the tropics. Obviously, midlatitudes and the tropics in LMDz are less dynamically separated than in ERAI.

(9) p.22622, l.4: "...stratospheric KWs sometimes accompany the life-cycle of CCKWs in the troposphere."

This statement is a little too unspecific. Of course, if present, CCKWs can propagate vertically if propagation conditions are favorable. Under these conditions they can reach the stratosphere. In the real atmosphere this predominantly happens during QBO easterly phase. Since in LMDz winds in the lower stratosphere are usually easterly, this should happen even more often.
In addition, there are also excitation mechanisms for stratospheric equatorial waves that involve less-organized convection (see, for example, Holton, JAS, 1973). These excitation mechanisms should also be somehow related to, for example, seasonal or shorter-term variations in the overall convective activity.

(10) About the downward propagation of RGW packets in Fig.11: More discussion should be added, addressing also the relative importance of this process!
Here are some thoughts that could be added if you think that this is plausible:
Fig.11 shows that under certain conditions (wind filtering layer below) RGWs in the stratosphere can be observed that have eastward tilted phase fronts, propagate downward, and are therefore probably not generated by convection.
If there is NO wind filtering layer below, the situation is however different: in Figs.7, 8 and 9 in both ERAI and LMDz RGW phase fronts are tilted westward, as would be expected for forcing from below.

$\Rightarrow$ also in LMDz the waves usually come from below!
$\Rightarrow$ in LMDz the RGWs are either forced by convection, or the forcing is similar to the forcing of Kelvin waves as described in section 6.1 (wave flux from midlatitudes at low levels, then upward propagation of waves in the tropics)
$\Rightarrow$ the "stratospheric reloading" with downward propagating wave packets can be dominant under certain conditions (wind reversal below), but is probably not the main process responsible for most of the wave activity seen in the tropics of LMDz or ERAI.

(11) p.22633ff: From the shape of the wave fronts in Figs.7c, 8c, 9c, and 11c, it looks like values are given only on the pressure levels 100, 70, 50, 30, 20, and 10 hPa, and not on every level of LMDz or ERAI.
Please clarify, and add this information in the manuscript!

Technical Comments

- p.22608, ll.20/21: suggestion:
  ...where here are large Rossby-gravity waves in the middle stratosphere, and for dates when the stratosphere is dynamically separated...
  $\rightarrow$
  ...with large Rossby-gravity waves in the middle stratosphere for dates when the stratosphere is dynamically separated...
- p.22609, l.23: Randell $\rightarrow$ Randel
- p.22610, l.8: intra-seasonnal $\rightarrow$ intra-seasonal
- p.22612, ll.16/17: For a given X field ... $\rightarrow$ For a given field X(λ, d, y, Φ) ...

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- p.22612, l.20: Please add the information that λ is longitude, Φ is latitude, d is the day, and y the year!
- p.22612, l.20, in Eqs.(1) and (2): 10°N $\rightarrow$ 10°
- p.22613, l.11: equatorial averaged $\rightarrow$ equatorially averaged
- p.22613, l.21: This should be clear to most readers, but please also explain the parameters N, g and H in Eq.(4)
- p.22614, l.19: shows $\rightarrow$ show
- p.22614, l.27: in $\rightarrow$ into
- p.22615, l.16: simulate. $\rightarrow$ simulated.
- p.22616, ll.1/2: KWs packets. $\rightarrow$ KW packets.
- p.22616, l.11: negative $\rightarrow$ negative (=westward)
- p.22616, l.13: in observations. $\rightarrow$ in observations because of the QBO.
- p.22616, l.15: positive $\rightarrow$ positive (=eastward)
- p.22617, l.3: RGWs $\rightarrow$ RGW
- p.22617, l.7: LMDZ-E $\rightarrow$ LMDz-E
- p.22617, l.16: KWs $\rightarrow$ KW
- p.22617, l.18: temperature $\rightarrow$ temperature absolute values ???
- p.22617, l.25: KWs $\rightarrow$ KW
- p.22618, l.24: indicates $\rightarrow$ indicate

- p.22620, l.11: outside from → outside of
- p.22620, l.13: since this refers to the LMDz model results only (?):
  to build Fig.10 → to build Figs.10b and 10c
- p.22621, l.2: that, during → that during
- p.22621, l.7: on Fig. → in Fig.
- p.22623, l.5: Feedbacks. → feedback.
- p.22623, reference Boville and Randel
  page range looks strange
  Randell → Randel
- p.22625, l.10: freeze-dryingby opticallt → freeze-drying by optically (??)
- p.22625, l.13: title of reference Liebmann and Hartman, 1982 looks strange! Please check!
- p.22625, l.28: an impact → and impact (?)
- pp.22627ff: units should be added to the color bars in all figures.
- p.22627, Fig.1:
  in the caption:
  (a-d) → (a, d)
  (b-e) → (b, e)
  (c-f) → (c, f)
- p.22627, Fig.1: there are inconsistencies in the definition of the two time periods, please check!
  In the caption, it reads MAMJJA and SONDJF, while in the Figure the title says: MJJASO and NDJFMA

- p.22628, Fig.2, caption: latitudes 10°S and 10°N → latitude range 10°S to 10°N
- p.22628, Fig.2, caption: I do not understand the following sentence:
  "The interval between the thin solid lines is two times smaller than between the shaded areas."

  Is this what you mean?
  "Contour lines are given every 0.01 mm^2 day^{-2} Cy day^{-1}, corresponding to the color scale. In addition, another contour line is given for 0.005 mm^2 day^{-2} Cy day^{-1}."
- p.22630, Fig.4, caption: latitudes 10°S and 10°N → latitude range 10°S to 10°N
- p.22630, Fig.4, caption: "The interval between..." same as for Fig.2
- p.22631, Fig.5, caption: latitudes 10°S and 10°N → latitude range 10°S to 10°N
- p.22631, Fig.5, caption: "The interval between..." same as for Fig.2
- p.22632, Fig.6: The color bar is plotted on top of the wind arrow given as figure legend. I suppose this arrow is the same as in (a) and (b), and can therefore be removed.
- p.22633, Fig.7:
  y-axis legend in (b) is too close to the axis, same in Figs.8, 9 and 11
  6 m/s wind arrow given as legend is too close to the heading of (b), same in Figs.8, 9 and 11
  "a)", "b)", and "c)" should be moved closer to their corresponding panels so that they can be attributed more clearly to the respective panel, same in Figs.8, 9 and 11

  caption: Shaded area → Shaded areas

  caption: for meridional → of the meridional

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- p.22637, Fig.11:
  caption: of the RGWs $\rightarrow$ of the RGWs in ERAI

  it should be mentioned that the composite is for the meridional wind v.

- p.22635, p.22637: in Figs.9 and 11 the heading of (a) says "T(CI=0.1K)..." However, I suppose that the color shading represents meridional wind, like in Figs.7 and 8. Please correct, if required!

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 22607, 2013.

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