The authors would like to thank the anonymous Referee 1 for her/his careful reading, and for finding it interesting and adapted to ACP. Her/His comments clearly helped to improve our manuscript. We have considered most of the changes suggested, and all the scientific remarks have been taken into account. The details of our response follow.

The Main comments are:
(A) Some more discussion should be added about the EP flux from mid-latitudes into the tropics in LMDz
More discussion about the EP flux has been added to the manuscript. Details follow in the order given in the referee letter (therefore see the responses to the comments (7) and (8) below).

(B) Some more discussion should be added about the finding that RGW packets can also propagate downward
See responses to comment (10) below.

(C) Some more information should be given how the wave composites are constructed
See responses to comments (3)-(5)-(6) below.

1. <u>Detailed Comments (1)-(2) & (3)</u>

- **<u>(1) p.22609, l.5:</u> About the QBO forcing: In addition to the relatively unspecific references Holton/Lindzen (theory) and Baldwin et al. (an overview) also more specific references giving numbers should be included here, for example, Tindall et al., QJRMS, 2006 and Ern and Preusse, ACP, 2009:**

Thank you. The additional references to Tindall et al. (2006) and Ern and Preusse (2009) have been included in the introduction. **(l. 27)**

- **<u>(2) p.22609, l.19:</u> 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).**

To consider Ern et al. 2009 paper, we have added in the introduction the following sentence:

« An example is provided in Ern et al. (2009), which shows that a large part of the variations in Kelvin wave variances in the stratosphere can be explained by the wind filtering acting over a fixed tropospheric source. » **(l. 196-199)**

- **<u>(3) p.22616, ll.3-6:</u> 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."

We have corrected the sentence as following:

"This shift to higher equivalent depths means that on average KWs have larger vertical wavelengths (cf. Eq. 4) in the stratosphere than in the troposphere. The KWs with shorter vertical

*wavelengths, having lower phase speeds, are more strongly affected by dissipation processes and critical wind levels."***(l. 41-43)**

2. Main comment (C) and Detailed Comments (4) – (5) & (6)

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

- **(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.**

- **(5) 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?**

In order to clarify the composite method and to answer to Referee 1 detailed comments (4) & (5), a description of the composite method has been added at the beginning of Section 5 « Composite analysis » :

*"To characterize the spatial structure and the life cycle of the SEWs, we follow Lott et al (2009) and make a composite analysis of band-pass filtered fields. For the Kelvin waves, the band-pass filter operates in the frequency-wavenumber Fourier space, by multiplying the Fourier components of all fields by a transfer function that largely contains the broadband spectral maxima associated with Kelvin waves (Fig.4), and guarantees that the filtered fields include them well. To finalize the filtering we then return to physical space. To diagnose when a Kelvin wave is present at 50hPa, we evaluate an index whose value equals the maximum of the filtered Temperature averaged between 10°S-10°N, and identify the longitude λ_m at which this maximum occurs. The composites are then built from averages over dates when maxima of this index exceeds a given threshold and shifting the maps selected by λ_m . We also average the dates at various lag before and after the central dates, so our composite are 41-day long. In each dataset the threshold is chosen so that the number of cases selected equals the number of years in the dataset. We choose here to select a rather low number of events to guarantee independence between the selected wave packets, bearing in mind that each wave packet can have a life cycle that lasts near a month. To ensure that the same wave cannot be selected twice, no day within 20 days after a case event can be selected. Finally, we have tested that none of our results are affected by moderate changes in the thresholds or in the filters (for instance, including more horizontal wavenumbers)***.** *In the following, the composite of a filtered dynamical fields X is note* $\widetilde{X}^C$ *"* **(l. 226-245)**

- ***p.22617, l.18: temperature → temperature absolute values ???***

The index reports the temperature maxima, and we also identify the associated longitude. All the description of the method has been changed, we hope this is now clearer.

- *(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.*

There was an error in the manuscript that is now corrected **(l. 266)**. The wavenumber range chosen for the filter is 4-8 and not 4-6, which partly takes into account Referee 1 remark since the broadband maxima in the spectra are better captured. Nevertheless, it is true that we could extend it down to s=3, and even s=2.

In fact, we have done this test, and our results are not very sensitive to this change (the composite waves being slightly larger, as shown below). Yet, it was lengthy to discuss this type of sensitivity, and we tried to shorten the description of our filters in the spectral domain. Our RGW filter considers in part the s=3 wavenumber, giving to it a weight half smaller than the weight gave to the wavenumbers s=4, 5,...8.

Also, we have extended the filter in the spectral domain to wavenumbers s=2 to s=9 and the results do not change significantly. To illustrate this point, we present in Fig. 1 a composite of RGWs for the LMDz-E simulation with a filter including the wavenumbers s=2 to s=9 (right panel). The resulting composites (Fig. 1, right panels) do not present significant differences as compared to those using a s=4-8 filter (Fig. 1, left panels) presented in Fig. 8 .

Accordingly, we have added a sentence referring to these sensitivity tests in the description of the composite method:

"Finally, we have verified that none of our results are affected by moderate changes in the thresholds, and also to moderate change in the filters, for instance by including few more horizontal wavenumbers." **(l. 240-242)**

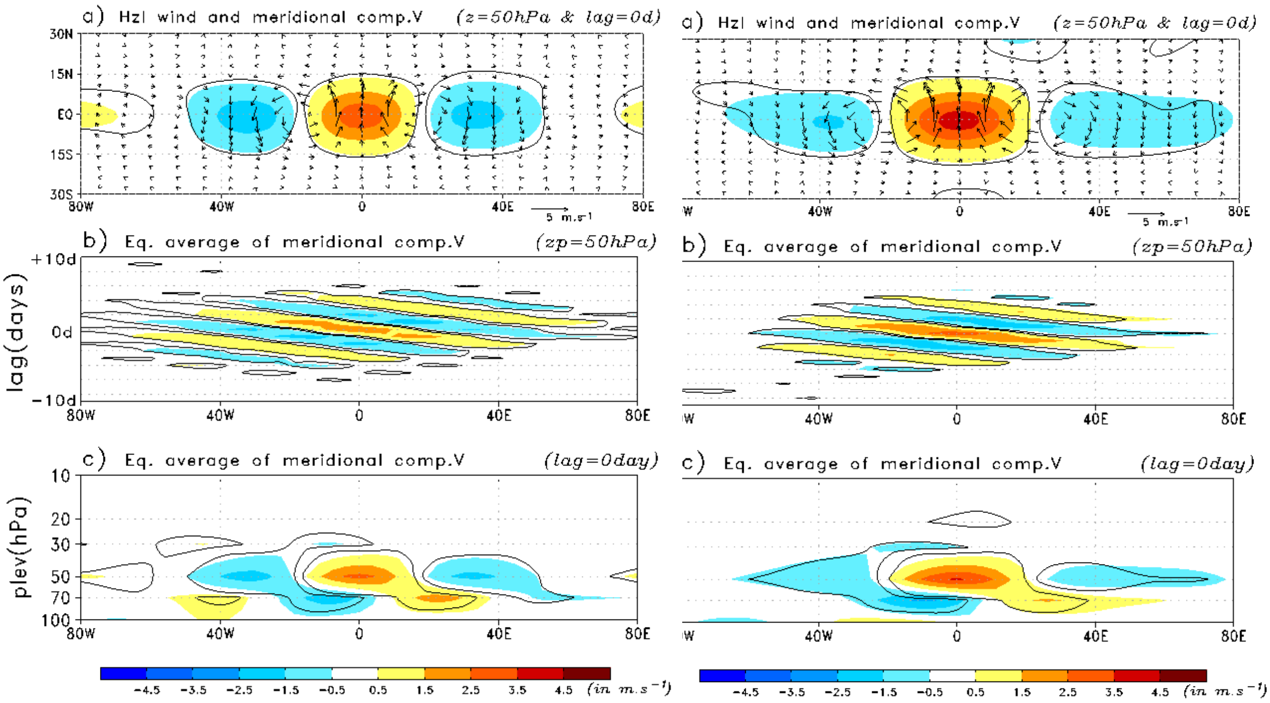

Fig 1: **LMDz-E: RGWs composites calculated with a s=4-8 filter (left panels) and a s=2-9 filter (right panels):**
a) Meridional wind *v* (shading) and horizontal wind *(u,v)* (arrows) z_p*=50* hPa and *l=0 day* lag.
b) Hovmöller diagram of the meridional wind v at z_p*=50 hPa.*
c) Longitude--altitude cross section of the meridional wind *v* averaged over the equatorial band.
Shaded areas of meridional wind values are in red (blue) for positive (negative) *(in m.s*$^{-1}$*).*
The black lines delimit the 99% significant regions according to a Student *t* test on the meridional wind.

3. Main comment (A) and Detailed Comments (7) & (8)

- **(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?**

The EP fluxes presented in the manuscript are calculated from the composite of the KWs. To clarify this point, we modify the beginning of Section 6.1 as follows :

“To locate the sources for the KWs, we next evaluate the EP-flux (Eliassen and Palm, 1961) of the KW composites presented in Fig. 6, and adapting Andrews et al. (1989):

$$\overline{F^{\phi}} = \rho_0 a \cos\phi \left(\overline{u}_z \frac{\overline{v^C \theta^C}}{\overline{\theta}_z} - \overline{u^C v^C} \right) \quad , \qquad (5)$$

$$\overline{F^{z}} = \rho_0 a \cos\phi \left(\left(f - \frac{(\overline{u}\cos\phi)_\phi}{a\cos\phi} \right) \frac{\overline{v^C \theta^C}}{\overline{\theta}_z} \right) - \overline{u^C w^C} \quad . \qquad (6)$$

Here $\overline{u}$ and $\overline{\theta}$ refer to the zonal mean composite of the unfiltered zonal wind and potential temperature respectively. In our context, the composite fields $\tilde{u}^C$, $\tilde{v}^C$, $\tilde{w}^C$ and $\tilde{\theta}^C$ are used as disturbances, which is justified for the filtered fields because none of our band-pass filters keeps the s=0 component.” **(l. 301-307)**

  - **(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 extra-tropics 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 back-ground winds in LMDz? Are there significant differences to ERAI?**

We do not believe that the differences between the waves origin relate to an error in LMDz mid-latitudes and tropics. In fact, these regions are well simulated (in mean and variability, as shown by Lott et al. (2005)). When the convective tropospheric sources are underestimated, we think that these regions play a role and become dominant. In LMDz, these kind of sources become dominant and substantial enough to compensate for the lack of equatorial sources. The same behavior appears in the ERAI reanalysis when we study stratospheric waves in situation where the stratosphere is dynamically separated from the troposphere. In this case, the highlighted stratospheric reloading explains the presence of waves in the stratosphere for situations where we consider that the convective tropospheric sources are not responsible.

- **(8) p.22620, ll.15/16: “...southern subtropics, e.g. where the mid-latitudes synoptic variability is the strongest.” 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, mid-latitudes and the tropics in LMDz are less dynamically separated than in ERAI.

We agree with Referee 1. We did not think about the synoptic variability but the entire variability. Thank you. The passage has been modified for clarity, and without refering to the synoptic variability.

"The interpretation that convection is not the main driver in LMDz is supported by the fact that the dates used to build the Fig.10 are selected during the boreal summer, e.g. when the convection is stronger in the northern hemisphere subtropics (cf. Fig.1a, b and c), whereas the KWs seem to come from the southern subtropics." **(l. 317-320)**

4. Main comment (B) and Detailed Comments (10)

- ***(B) Some more discussion should be added about the finding that RGW packets can also propagate downward***
- ***(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, propa-gate 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.***

We have considered Referee 1 comment about the eastward tilt of the RGW composite, and also think that the interpretation is not straightforward. Nevertheless, we prefer not to speculate much about this because the tilt is due to a very small signal at 20hPa compared to the one at 50hPa level where the RGW packet is present. Accordingly we have written the sentence :

"Finally, the vertical structure of the composite in Fig.11c shows that the RGWs in this scenario tend to stay confined above 50hPa, which corroborates that they do not come from lower levels in the equatorial troposphere." **(l. 339-341)**

We would like to point out that one result of this paper is that the subtropical sources can become dominant in a model with insufficient tropospheric equatorial sources. In this sense, we agree with the Referee 1 on the fact that the extra-tropical forcing – like the « stratospheric reloading » – is probably not the main process responsible for most of the wave activity seen in the tropics of ERAI or LMDz. We rather consider that this forcing can explain a good part of the RGWs in the LMDz stratosphere. Thus we added a paragraph to the conclusion :

"An important point of the present paper is that subtropical and mid-latitudes sources are significant to produce SEWs. Then, in a model where the tropospheric sources are underestimated, these subtropical and mid-latitudes sources can become dominant. In this sense, the highlighted «stratospheric realoading» is not only important to explain the presence of RGWs above westward QBO winds, it also reveals the significance of these alternative sources in the re-analysis products. These alternative sources explain the presence of SEWs in a model despite its underestimation of various aspects of the convection." **(l. 384-390)**

5. Detailed Comments (9) & (11)

- **(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.

We have tried to be more specific in the discussion, by including references to Holton (1973). We added the following paragraph to the conclusion:

"We recall here that the planetary large scale organisation of the convection allows to add more variability at long spatial-scale and at short time-scales at the same time. According to Holton (1973) for instance, it appears that this organisation may not be so significant. Note nevertheless that when convection is organised in a GCM, it probably better represents the heating vertical profiles, a factor which is also essential to efficiently force SEWs." **(l. 365-368)**

- **<u>(11) p.22633ff:</u> 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!**

A sentence has been added to the manuscript:

"Note that in the present study the daily fields from LMDz and ERAI are interpolated at the six pressure levels in the stratosphere: 100, 70, 50, 30, 20 and 10hPa." **(l. 97-98)**

6. <u>Technical Comments</u>

• <u>p.22608, ll.20/21:</u> *suggestion*:
...where here are large Rossby-gravity waves in the middle stratosphere, and for dates when the stratosphere is dynamically separated... → ...with large Rossby-gravity waves in the middle stratosphere for dates when the stratosphere is dynamically separated...

Thank you for the suggestion. We have changed the end of the abstract:

"We show that non-equatorial sources are also significant in re-analysis datasets as they explain the presence of the Rossby-gravity waves in the stratosphere. To illustrate this point, we identify situations with large Rossby-gravity waves in the reanalysis middle stratosphere for dates selected when the stratosphere is dynamically separated from the equatorial troposphere." **(l. 15-19)**

We considered all the technical comments listed below by Referee 1:

- **p.22609, l.23: Randell → Randel**
- **p.22610, l.8: intra-seasonnal → intra-seasonal**
- **p.22612, ll.16/17: For a given X field ... → For a given field X(λ, ϕ, d, y) …**
- **p.22612, l.20, in Eqs.(1) and (2): 10◦ N → 10◦**
- **p.22613, l.11: equatorial averaged → equatorially averaged**
- **p.22614, l.19: shows → show**
- **p.22614, l.27: in → into**
- **p.22615, l.16: simulate. → simulated.**

- **p.22616, ll.1/2: KWs packets. → KW packets.**
- **p.22616, l.11: negative → negative (=westward)**
- **p.22616, l.13: in observations. → in observations because of the QBO.**
- **p.22616, l.15: positive → positive (=eastward)**
- **p.22617, l.3: RGWs → RGW**
- **p.22617, l.7: LMDZ-E → LMDz-E**
- **p.22617, l.16: KWs → KW**
- **p.22617, l.25: KWs → KW**
- **p.22618, l.24: indicates → 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.22612, l.20: Please add the information that λ is longitude, Φ is latitude, d is the day, and y the year!
• p.22613, l.21: This should be clear to most readers, but please also explain the parameters N, g and H in Eq.(4)

These precisions have been included into the manuscript.

"... where the terms λ, ϕ, d and y correspond to the longitude, the latitude, the day and the year respectively." **(l. 124)**

"... where N is the Brunt-Väisälä frequency and H is the scale height of the atmosphere" **(l. 144)**

7. *Technical notes in the references*

• 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 (?)

Thank you for noticing the typing errors in the bibliography. All of them have been corrected.

8. Technical notes in the figures

We also considered all the technical notes concerning the figures and their captions.
The units have been added to all colorbars in figures. More precisely :

Fig1
• p.22627, Fig.1: in the caption:
(a-d) → (a, d)
(b-e) → (b, e)
(c-f) → (c, f) We replaced the letters in the caption as suggested.
• 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

The mistake has been fixed.

Fig2, 4 &5

• <u>p.22628, Fig.2,</u> caption: latitudes 10◦ S and 10◦ N → latitude range 10◦ S to 10◦ N

• <u>p.22628, Fig.2,</u> caption: I do not understand the following sentence: "The interval between the thin solid lines is two times smaller than between the shaded areas."

This sentence has been rewritten as follows:

« Contour interval are 0.01 mm2 day−2 Cy day−1 for the shaded areas and 0.005 mm2 day−2 Cy day−1 for the thin solid lines. »

Fig. 4 and 5 captions have been modified accordingly.

Fig6

• <u>p.22632, Fig.6:</u> 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.

We modified the figure accordingly.

Fig7-8-9-11

• <u>p.22633, Fig.7:</u>

-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

For each figure,

- we moved the y-axis legend
- the « a) b) and c)» are moved closer to the title of their corresponding panels
- Mistakes in the captions were also corrected.

• <u>p.22637, Fig.11:</u>

-caption: of the RGWs → of the RGWs in ERAI

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

These informations have been added in the caption.

• *<u>p.22635, p.22637:</u>* 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!

The mistake has been fixed.