Anonymous Referee #1
Received and published: 23 November 2016

This paper analyzes an intradecadal spectrum of the stratosphere using a reanalysis and compares it with model simulations. One of the main differences in the intradecadal
variability between the reanalysis and model results is associated with the QBO in the tropics. The authors assessed simulated equatorial waves in intraseasonal spectra of the middle stratosphere, and attributed the defect in simulating the QBO to underrepresentation
of the equatorial waves in the models.

We want to thank referee #1 for the valuable comments and the detailed review.
We have to admit, that we missed referring our work to some of the recent, relevant studies (i.e. Krismer and Giorgetta 2014). In a revised version we will change this accordingly. In particular our conclusion would benefit from considering their results.

Major comments :
The above findings, however, have been well known by previous studies, as the authors also mentioned in the paper. The authors did not extend their analysis further, and thus the paper does not seem to provide concrete ideas that can support or add on our understanding on this topic.

Indeed, the finding of a threshold for a vertical resolution is well known. However, the discussion of underlying reasons and mechanisms is still highly topical, which you also indicated by your given references. For example gravity wave parameterization with respect to vertical resolution (Jadwiga et al. (2014) and Anstey et al. 2016) or the very detailed study of Krismer and Giorgetta (2014) about the analysis of resolved wave (in particular Kelvin wave) forcing of the QBO in their model system .
Furthermore, to our knowledge this is the first time that the relevance of the QBO has been addressed by power spectral analysis for the intra decadal time scale.

Based on the Introduction section, this paper seems motivated by the potential impacts of model-representation of the stratospheric variability
upon the (intra) decadal predictability. I agree that this is very interesting topic. However, it might be not easy to address/assess the potential impacts of the stratospheric variability using this relatively short-term (20 years) climate simulation.

Fair comment! The introduction could suggest that this study has a specific focus on the decadal prediction. However, the decdal time scale is our main motivation. We demonstrate that on the decadal time scale, globally the QBO plays an important role. This is shown by our decadal power spectral analysis, where a great fraction of the power can be find near the 24 months period in the tropics. In a revised version we will certainly rephrase our introduction.

Further, in our opinion a 20 years climate simulation are a good time range to investigate processes of the intra decadal (<10 years). In particular we could demonstrated that our signals derived from the decadal power spectral analysis are robust and statistically significant.

In addition,
by estimating the typical vertical scales of the equatorial waves presented in the reanalysis, the authors discussed the model vertical resolution that is required to simulate

the QBO (< 1 km).
Regarding this, readers may expect more contents than those presented here (e.g., actual spatiotemporal structures of waves and their propagation in simulations using different stratospheric resolutions) because many recent papers have demonstrated this point even in more details (e.g., Krismer and Giorgetta, 2014; Richter et al., 2014; Anstey et al., 2016).

We agree, that the reader could, as always, expect more content in particular aspects. However, in our opinion this study is self-contained. May we briefly explain this. First of all, we started with the analysis of the intra decadal power spectrum. We show differences between reanalysis data and our model simulation with different vertical resolutions. The QBO signal only could be reproduced by the model with high vertical resolution. To analyse the causes we applied the Wheeler and Kiladis (1999) method. We compared the wave spectra of our two model simualtions to reanalysis data. We can point out that a low vertical resolution of the model lacks of representing the anti-symmetric wave spectra, in particular the power of the MRG waves were under represented. The analysis of anti-symmetric wave spectra of the reanalysis data narrows the range of the equivalent depth relevant for the QBO. This narrowed range of equivalent depth we use as input for our calculation for the vertical wavelengths of MRG waves. With this calculation we can show that the relevant wave spectra of MRG waves needs at least to resolve waves with a vertical wave length of 2 km, which means that the vertical model discretisation need to be less than 1 km. These aspects of MRG waves, the approach which lead to this finding is new and so far not documented.

So in simple words, we came from the intra decadal time scale, detected the relevance of the QBO and found model problems representing the QBO. Compared to reanalysis majorly the MRG waves are underestimated. We could pin point this problem to insufficient vertical model resolution. Therefore, we think this study is self-contained.

Considering the contents of the paper, I would not recommend to publish this manuscript in ACP.

We do not agree with this conclusion. As written above, we demonstrated new aspects in analysing the QBO. In particular the relevance of vertical resolution for MRG waves are pointed out. Further, the relevance of the QBO for the intra decadal timescale is shown. Nonetheless, for a revised version we must refer in more detail to the references, provided by the reviewer #1

L100-101: This is an ordinary way to get the variances. Please delete this sentence.
We did this for clarification. We think this is necessary, because we also found different definitions with respect to term variance.

L102: If you would sum over all wavelengths, you did not have to perform the 2-dimensional FFT for the decadal time series.
The 2D FFT for this approach would be unnecessary. However, our code use 2D FFT since, for other application 2D FFT is necessary, in oder to analyse characteristic bandwidths. So this is only the correct description of the process of our calculation.

L115 and L259: I suspect that the paper by Lindzen and Holton (1968) might be not a proper reference here. I guess that you intended to refer to Lindzen and Matsuno (1968). Please confirm these.
will be revised

L120: “n = 1” ! “n = -1”
will be revised

L121: “number is” ! “number we consider is”
will be revised

L130-137: This description does not seem really necessary.
L140 and Fig. 1 caption: The log of any variables cannot have a unit (unless you specifically define the quantity with a reference power, like decibel [dB]).
will be revised

L140-141: So obvious statement. Please remove it.
will be revised

L142: “variability” ! “power”
will be revised

L143: Delete “in particular”.
will be revised

L145: Please rephrase “polar vortex contribution to the variability” to clarify the meaning.
will be revised

L147: Include “for periods shorter than 6 months” after “latitudes”
will be revised

L154: “provide”
will be revised

L153-158: This fact is very well known. The authors could just add some references here rather than describe this in detail. In addition, Fig. 2 does not address more than what we know.
Fig. 2 does provide new aspects! It is shown that the spectra around the 24 months period is one of the mayor contributions of the intra decadal time scale and clearly can be distinguished from back ground noise.

L165: “... hemisphere high latitudes”
will be revised

L166: “intra-annual and intra-seasonal”: What are the difference?
>12 months; >3 months

L172: “The QBO comes close to exhibiting ...”: Please make the sentence clear.
will be revised

L173: Delete “about the equator”.
will be revised

L188-189: Please move this sentence to Section 2.
will be revised

L189: Delete “this”.
will be revised

L199: Synoptic waves may have zonal wavenumber larger than 4 (k = 4 corresponds to the wavelength of 10000 km in the tropics). Please delete “and synoptic”.
will be revised

L208: “0.1” ! “0.03”

will be revised

L230: Delete “pattern and” unless the “pattern” here has a different meaning from the “shape” and you will describe both.
will be revised

L239-241: I could not understand this sentence. Please rewrite it.
will be revised

L244: “30” ! “3” (or 2 days?)
will be revised

L258: “linear equatorial wave theory was”
will be revised

L266: Note that the equation for N_2 written here is correct only if H is defined as RT/g, where T is a mean temperature that actually represents the temperature in the tropics at this altitude (Eq. 1.1.13 on p6 in Andrews et al., 1987).
We use this only for a crude estimation.

L269: “Figure 6”
will be revised

L269: How did you obtain the climatological mean of the vertical wavelengths of MRG waves? It is spectral-power-weighted mean?
Please read section 2 from line 265 on.

L280: “corresponding” ! “those of”
will be revised

L285-286: Please rephrase the sentence.
will be revised

L289: “to” ! “and”
will be revised

L300: “simulations appear.”
will be revised

L304: “frequency-wavenumber”
will be revised

L318: Please delete “(which are the main drivers)” because it is believed that the IG and mesoscale gravity waves may also provide large momentum, as well as the Kelvin waves.
We totally agree with the referee with respect to a general statement regarding the QBO. However, in our analysis we refer to lower stratospheric altitudes. IG and mesocale g-waves interacts in general in higher altitudes. We will revised this accordingly.

L331: I do not agree that this paper shows it.
Will be revised. The QBO is important for the intra decadal time scale and therefore will have great potential for the decadal prediction.

L336-338: This is a rather unexpected statement because there was no discussion regarding the gravity wave parameterization before this.
Will be revised and further information will be included.