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Interactive comment on "Tropical temperature variability and Kelvin wave activity in the UTLS from GPS RO measurements" *by* Barbara Scherllin-Pirscher et al.

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We thank the reviewer for the review and his/her helpful and constructive comments which we fully took into account in the revision of the paper. Please see our detailed response below (the original remarks of the referee are in italics).

Major comments

1. *My major concern is their definition of Kelvin waves. Although their definition of Kelvin waves (zonal wavenumber 1–2 and frequency 7–30 days from the zonal*

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space and time FFT) looks reasonable based on previous studies, I am not sure if the simple FFT filtering properly captures Kelvin wave variability quantitatively near the tropopause because amplitudes of tropopause waves strongly vary at different tropical regions. I agree that the inverse FFT of a filtered spectrum is a useful tool to construct characteristics of general zonal and vertical structure of Kelvin waves. This method, however, might not be a best way to quantify temperature variance associated with Kelvin waves, particularly for localized ones. If waves are nearly equally distributed over the tropics, the simple FFT should be sufficient to calculate time series of Kelvin wave variance.

We thank the referee for highlighting this important issue. We reassessed the definition of atmospheric Kelvin waves and decided to filter Kelvin waves with wavenumbers $k = +1$ to +6 and periods from 4 to 30 days. These filter widths are determined by our sampling strategy as well as by the spatial resolution of our daily-mean fields. Furthermore, we will follow Kim and Son (2012) and filter Kelvin waves between 8 m and 240 m equivalent depths.

Our new method is now able to also capture local enhancements of Kelvin wave power in the tropical tropopause layer. We will replot Fig. 1 (where we will include equivalent depths of 8 m and 240 m) as well as Fig. 2b, Fig. 5c, and Fig. 6 to Fig. 10.

In the manuscript, we will add the following sentence in Sect. 2.3:

We isolate Kelvin wave activity by selecting wavenumbers $k = +1$ to $+6$, periods from 4 to 30 days, and equivalent depths from 8 m to 240 m.

2. *My second concern is the use of a fixed altitude range for the tropopause layer. The tropopause is not a fixed level and varies with a seasonal cycle, QBO, etc. A fixed range includes mostly tropospheric characteristics when the tropopause is high. When the tropopause is low, the fixed range more represents the stratosphere. Since temperature variability greatly changes from the troposphere to*

stratosphere, the variance calculation could be significantly affected by varying tropopause heights. It will be more reasonable to use a moving tropopause layer to calculate variance.

In order to investigate the sensitivity of Kelvin wave activity in the tropical tropopause region on different coordinate systems, we calculated and compared Kelvin wave activity in fixed-altitude and in cold-point tropopause coordinates. We find that temporal variability of Kelvin wave variance at the cold-point tropopause is in very good agreement with variability at 17 km. Furthermore, Kelvin wave variance 2 km above the cold-point tropopause is very similar to Kelvin wave variance at 19 km. We will include both these plots as new Fig. 9 in the manuscript and add a discussion in Sect. 3.3:

To assess whether this temporal variability should be attributed to temporal variations of the tropopause rather than to Kelvin wave activity itself, we calculated Kelvin wave variance in cold-point tropopause coordinates. Figure 9 shows results at the cold-point tropopause and two kilometers above. Comparison to Fig. 8 shows very similar temporal evolutions. The time series at the tropopause and 2 km above (Fig. 9) are virtually similar to those at 17 km and 19 km in altitude coordinate (Fig. 8), respectively. Again, no clear periodicity of Kelvin wave activity can be found.

Minor comments

1. *Term of "high-frequency": This term is not appropriate for disturbances shorter than 100 days. "Sub-seasonal" could be a replacement.*

   We agree with the reviewer. We will replace "high-frequency variability" by "sub-seasonal variability" in the entire manuscript (text and figures).

2. *P4 L3: Add latitude resolution of gridded data*

   We averaged over all high-quality profiles within 10°S and 10°N and performed our analysis for this tropical band (with 20° width). Therefore, our gridded fields are not latitudinally resolved. To make this more clear we will rewrite this sentence. It will read:

   Tropical (10°S to 10°N) temperature profiles from GPS RO are gridded in longitude, altitude, and time (no further latitudinal gridding).

3. *P4 L4: Add a statement like "This gridded data can only resolve waves with zonal wavenumbers up to 6." Also state the limitation of vertical scales that the dataset can resolve.*

   Thank you for this suggestion. We will include this statement in the manuscript.

   The vertical resolution of GPS RO temperature profiles ranges from about 100 m in the troposphere to about 1.5 km in the stratosphere. This is mentioned in Section 2.1 in the manuscript and implies that individual levels of our analysis are not independent from each other. We will add

   Since underlying GPS RO profiles have a vertical resolution of 0.1–1.5 km (see Sect. 2.1), adjacent vertical levels are not fully independent of each other.

4. *P4 L18: Gaussian filter filter → Gaussian filter*

   done

5. *P4 L29: I assume only positive wavenumbers were included. To clarify this I suggest: "by selecting wavenumbers k=1 and 2 . . . " → "by selecting wavenumbers k=+1 and +2. . . " or explain only eastward signals were included. Alternatively a small box for Kelvin waves can be added in Figure 1.*

   Good point. We will add the plus sign in the text (the entire sentence is given in reply to major comment 1).

6. *P6 L21: "... larger temperature variability before 2006 compared to after 2006." I think this implies that sub-grid scale variability ($<$1 day, $<$60 degrees) is significant. Mention that.*

   We agree with the reviewer that sub-grid scale variability is significant. We already mentioned that in the manuscript, P6, L26/27, which reads:

   This can be explained by noting that much of sub-seasonal variance is related to sub-grid-scale (smaller than 30°) variation (as shown in Randel and Wu, 2005), which is under-sampled by one satellite.

7. *Figure 1: The spectrum is too discrete between 10–50 days at zonal wavenumber 1. If my understanding is right, the whole time record was put to calculate the spectrum. Then, I think the spectrum will be more continuous than Figure 1. Why does the spectrum have separate peaks along the vertical axis?*

   It is correct that the spectrum is based on the entire RO record. Please note, however, the very small contour line interval (only 0.0002 K^2). In some cases, this small, linear contour interval can produce separate peaks in the spectrum.

   Figure 1 shows that most power is concentrated at low frequencies (annual cycle and inter-annual variability). To better show the general picture of spectral power, we will replot this figures using logarithmic contour interval using contour lines of (0.0001, 0.00025, 0.0005, 0.001,..., 10, 25, 50) K^2.

8. *"zonal anomalies": The term is a bit confusing. I will rather use "anomalies", and describe the definition of anomalies. I presume anomalies are deviation from the time-mean zonal-mean.*

   In Fig. 2 and 3, zonal temperature anomalies are obtained from subtracting the daily-mean zonal-mean profile. To clarify how these zonal anomalies were obtained, we will write in the text:

Strongest amplitudes are observed near the tropopause, where the magnitude of zonal anomalies (i.e., anomalies relative to the daily-mean zonal-mean) exceeds 5 K and that of Kelvin waves exceeds 2 K.

Figure 3 shows temporal evolution of zonal temperature anomalies (relative to daily-mean zonal-mean) from November 2009 to February 2011 at 18 km.

Figure 4b and 4c show low-frequency temperature anomalies averaged over DJF and JJA, respectively. We will remove "zonal" in these plot titles and rather write "DJF: Seasonal mean anomalies" and "JJA: Seasonal mean anomalies".

9. *Figure 10: Green, red, and blue lines are distracting. Those color lines seem subjective. If they are objectively decided, explain them. Otherwise I suggest deleting the color lines. Also Kelvin wave filters are for 7–30 days in (a), but OLR variance is for $<$100 days in (b). Explain why they use different filter ranges.*

   Yes, different colors were chosen subjectively. We will remove red and blue lines but indicate peaks in Kelvin wave variance outside of one standard deviation with green lines.

   We tested the hypothesis whether sub-seasonal fluctuations in convection (including different types of waves) could explain irregularly distributed peaks in Kelvin wave variance. We did not use OLR variance using the very same filter width because Kelvin waves at and above the tropical tropopause are not convectively coupled waves anymore. Kelvin waves in OLR data are of smaller scale and faster periods compared to our Kelvin waves close to the tropical tropopause (Wheeler and Kiladis 1999). Furthermore we found that these waves contribute very little variance and are also included in these high-pass filtered waves.

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