Reply to the comments on the manuscript

"Ground-based observations of periodic temperature fluctuations in the mesopause region with periods larger than 2 days"

by Christoph Kalicinsky, Robert Reisch, and Peter Knieling

We thank the reviewers for their helpful comments and recommendations. In the following, we discuss the issues addressed by the reviewers and explain our opinions and the modifications of our manuscript.
We enumerate the comments and repeat them in bold face. The modifications of the manuscript are displayed in the marked-up manuscript version as coloured text. Deleted parts are shown in red and new or modified text parts in blue.

1 Comments Reviewer 1

The paper "Ground-based observations of periodic temperature fluctuations in the mesopause region with periods larger than 2 days" by C Kalicinsky et al., utilized more than 30 years of mesospheric temperature observations to study the oscillations and their long-term variations. Lomb-Scargle periodogram (LSP) is used to identify the periods of these oscillations. Fluctuations with periods of 5/6 days, 8-12 days, 15 days and 28 days were identified and related to Rossby waves. Most of the activities occurred during the winter season for longer period waves, while the short period waves peaked during equinoxes. The authors claim that long-term variations of the wave activity showed a quasi-bidecadal signature. This is a very valuable study and could provide crucial information about planetary waves and their long-term behavior. However, I have some concerns that need to be addressed.

Major concerns:

1. **I can't agree with the way the authors counting wave events. By doing this, it makes the results in Figure 3 misleading and hard to understand. I could not tell how many times the waves in each bin had happened during this >30 years period. For example, the 28 day wave event claimed to be the most popular one, it has the same count as the 45-60 day waves, 350. What does it mean? Which one occurred more often by how many times? By looking at the duration of the 28 day wave in Figure 7 (∼70 days), does it mean only ∼5 times this wave occurred during the >30 years of observation? From the spectrum results of Figure 2 and Figure 7, one can see that within one year, there were not a lot of wave events identified which is totally normal.**

   It is more reasonable to count each event as one which will clearly show how many times each wave happened throughout this very long data set.
   We agree that the way we count the wave events can be improved. We added a second version of the histogram. The first one is kept as before. The second one is now a histogram where the counted significant days are normalized by the period in the corresponding bin. This was suggested by reviewer 2. Thus, the new statistic measures the importance of a wave type in terms of cycles and it is now independent of the period

of the wave itself. As a consequence the increase of the values in the histogram with increasing period is removed and the peaks at smaller periods are enhanced showing the relative importance of these wave types. We believe that this way to count the events is slightly better as it still takes into account the difference between short and long events and does treat them in the same way even if one event includes one cycle and the other several cycles.
However, we still keep the former version with the significant days as it also contains information on the importance of the different waves with respect to the total time period in which they were observed. In total, it is clearly visible that the 28 day wave is the most important one, as it is observed at the largest number of days and it is also the wave event where the most cycles have been observed. Additionally, at a period of about 2 days another type of wave has a somehow larger peak in the histogram with the normalized bins. We added all new information to the corresponding paragraphs.´

General comments:

1. **The period range in Figure 4 is confusing with each subset inclusive of the others. In the top row, the difference between period >10 days and period >20 days are small, which indicates the waves with periods between 10 and 20 days, does not occur a lot. Does this mean the quasi-16 day waves only show up in your data very occasionally? Again, the counting mechanism make it hard to understand the seasonal variations of the detected wave events. Independent spectrum range would help with the results.**
We updated the plot and removed 4 of 6 subfigures. Finally, we only kept the results showing the seasonal variation of the significant days for periods smaller than 20 days and larger or equal than 20 days. Thus, we divided the results in two parts only. The waves with larger periods clearly show the largest number of counts in winter whereas the waves with smaller periods show maxima at equinoxes. Thereby, the waves with periods below 10 days account for the major part of observations in summer and around equinoxes. We rephrased the corresponding parts of the text to explain such details.
Indeed, the quasi-16 day wave plays only a minor role as can be seen in the new plot where the histogram values are normalized by the periods of the corresponding bins (See major concerns bullet 1). In the new figure 4 we kept the counting mechanism as we think that the number of days at which significant events occur during the year clearly shows the differences between summer and winter for the different periods. When only the number of events would be counted a e.g. 10-day event in summer would have the same weight as a 45-day event in winter.

2. **Section 3.2 focused more on the similarities and differences among the 3 quantities. It is not clear how introducing the 2 new proxies, especially the later one would help in drawing a clear conclusion. In Figure 6b, only the ∼20 year variation was mentioned, what about the shorter periods with even stronger power? How significant of this 20 year period oscillation? What is the confidence level for this result?**
In the former study by Höppner and Bittner (2007) the standard deviation was used as proxy for the wave activity. This has the drawback that all kind of fluctuations are included in this quantity and not only the significant ones. Because of this, we introduced the mean amplitude of the significant events as a new proxy. This also

has a small drawback, because it does not include the length of the events, only the strength. Thus, we also introduced a third proxy which is the amplitude weighted sum of significant days. As all of the three proxies have similarities and also differences the comparison of the individual LSPs can help to gain information on the importance of the length and the strength of the wave events on certain periodic behaviours. As the standard deviation mainly depends on the amplitude the LSPs of the standard deviation and the mean amplitude look quite similar. This means that the long-periodic fluctuation at about 20 years is likely caused by events with larger amplitudes in some years and smaller amplitudes in other years instead of longer or shorter events. In the case of the 4-year oscillation this is different. This oscillation is seen in all proxies but the largest power is seen for the weighted sum of days. This would suggest that the length of significant events shows a quasi-quadrennial oscillation.
The two main peaks of the LSP for the standard deviation at about 20 years and 4 years are not significant at a 95% confidence level with respect to the complete analysed period range (FAP). This is a common problem with this rather conservative approach in the case when several similar large peaks occur in a periodogram, which means that a larger number of oscillations shares the almost total variance of the complete time series, and does not mean that the oscillations are not real. With respect to the single frequency the significant level for the peak at 20 years is almost 95%, i.e. it is rather uncertain that a peak with that height occurs at exactly this period just by chance. As we are searching for a peak at a period of 20 years because of the former study by Höppner and Bittner (2007), this second way is valid in our study here.

3. **The LSP results for 28 day waves in Figure 7b does not make sense comparing with the data in Figure 7a. During the event of the 28 day wave, the spectrum results showed a very broad peak (period extended from 25 to nearly 50 days) while the data (Figure 7a) showed a highly defined wave period which would be a narrow horizontal maximum in Figure 7b. With such a broad peak, how the period of 28 days is concluded? The other thing of this 28 day wave event is it happened in July and August, which is summer for the northern hemisphere which is contradict to what the authors conclusion (line 240).**
First, there is a mistake in the caption of the figure. Both subfigures a and b show the time period from July 1st to June 30th and, thus, they show the same event that took place in winter. We rephrased the caption.
At the beginning the peak is very broad and the period of the maximum lies slightly above 30 days, but after this short time period the maximum lies in the region between 25 to 30 days. The mean period of the fit shown with the red curve in Fig 7a is about 26 days. Therefore, the majority of the observations will be counted in the maximum bin from about 25 to 30 days (compare Fig. 3) and we denoted it as a quasi-28 day wave event.
We rephrased the corresponding parts of the text and added more details.

4. **In general, observations from one ground-based site are not enough for planetary wave mode identification. Section 4.1 tried to relate the observed periods of oscillations to known Rossby waves of certain mode. The Rossby mode has certain latitudinal and longitudinal structures. Relating waves ob-**

served from different latitudes can lead to wrong conclusions. Also, for the waves of 4-6 days, 16 days, most of the studies cited were using observations of the mesospheric wind. The normal modes of winds are quite different from the ones for temperatures.

We agree that you need additional data to identify the wave modes. We rephrased our statements according to this in Section 4.1.

Minor comments:

We changed the manuscript according to the minor comments where still necessary.