

Reply to the comments on the manuscript

”Simultaneous ground-based observations of a large quasi 26-day wave from three different measurement sites in northern mid-latitudes ”

by Christoph Kalicinsky, Sandra Wallis, Lukas Depenthal, Christoph G. Hoffmann, Anna Lange, and Christian von Savigny

We thank the reviewer for his helpful comments and recommendations. In the following, we discuss the issues addressed by the reviewer 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.

Comments Reviewer 1

Summary:

Kalicinsky et al. have identified a strong, large-scale wave perturbing the temperature field of the mesopause region in the northern hemisphere winter 2016/2017. The disturbance was observed with ground-based OH-spectrometers located at three different sites in Germany: Greifswald, Wuppertal, and Hohenpeißenberg. By combining these measurements with satellite observations supplied by SABER on the TIMED satellite and MLS on the Aura satellite, Kalicinsky et al. argue that the observed disturbance agrees well with the expected behaviour of a propagating Rossby (1,4) normal mode wave. Bringing together the different observations, they support their hypothesis in a clear and concise way. The article is well-written, and I would recommend publication after a few questions are addressed and some improvements are considered.

Comments:

1. Lines 19-21

To emphasise that atmospheric quantities are modified at a wide range of periodicities some previous studies are mentioned. It might ultimately come down to preference, but including almost 4 lines of previous publications is perhaps touching on some upper limit? An alternative might be to point the reader in the direction of a handful of illustrative examples.

We reduced the references to about the half. We still kept a number of references to show the variety of measurements and observed periods.

2. 2.1 OH*(3,1) rotational temperature observations

The ground stations are introduced in detail. For interpretation of the studied event, the placement of the stations is relevant and it would be of interest for the reader if a map illustrating the placement of the stations, and perhaps the distances between them would be supplied.

We included a map with the positions of all three instruments.

3. **2.2 SABER observations**

The SABER observations were not compared to the station at Hohenpeißenberg, but there is no explanation why.

The instrument at Hohenpeißenberg had the worst time resolution of all three instruments, which led to more data gaps in the time series because of weather conditions. It is more likely for a single spectrum to be influenced in partly cloudy condition when the measurement time is longer. Thus, the two other time series have more data in the time interval of interest and we selected them for comparison to SABER and restricted the SABER region around these two stations. Additionally, we think that a comparison of the time series to SABER would be more or less redundant and does not lead to further results. In all other comparisons of results from the ground-based stations with the satellite observations the station in Hohenpeißenberg is included.

4. **2.3 MLS observations**

In general, this part is not as well written as the descriptions of the other observing systems. First, the bias with respect to SABER is described using pressure as a vertical coordinate, and while this is reasonable, a pointer at some approximate geometric altitude (km) would connect this better to the previous segments. Secondly, the data selection described with Lines 87-91 could perhaps be motivated more clearly. Concepts such as “status field” and “convergence field” are not explained. An explanation of positive precision requirement, and a motivation of the ice-water content criteria would be useful.

An approximate geometric altitude z for each pressure level mentioned in the MLS-SABER comparison was added using the US Standard atmosphere (NOAA, 1976). We included a short explanation about the status field (a quality metric provided for every profile containing a variety of flags), the convergence field (describing how the fit of the radiances by the retrieval algorithm compares to the expected fit), the requirement for a positive precision (to exclude data that is strongly impacted by the a priori information) and the use of ice-water content as a criteria (to reduce the interference of clouds).

Reference: NOAA, 1976: U.S. Standard Atmosphere, 1976. National Oceanic and Atmospheric Administration, https://www.ngdc.noaa.gov/stp/space-weather/online-publications/miscellaneous/us-standard-atmosphere-1976/us-standard-atmosphere_st76-1562_noaa.pdf.

5. **Figure 2**

The statement “compare red curve in Fig. 1”? is not clear. Some words may be missing. Also “plus minus” as “plus-minus” or “ $\pm$ ”.

We added additional information to the figure caption.

6. **Lines 99-100**

An idea is to emphasise the black lines as the temperature residuals $\rightarrow$ “See black lines of Fig. 1). Later in the text, lines 114-115, the reader is told to focus on the red lines.

The black lines show the residuals and the red curves show the sinusoidal fits with constant amplitude. One can already observe the fluctuations in the raw data (black lines)

and then even clearer in the fits (red curves). We changed the text order in this paragraph to improve the readability.

7. Lines 105-106

I am wondering if the larger amplitude at Greifswald is more fitting, rather than increased? Also, the “increased temporal coverage of the data due to weather conditions” should be explained as this is new information. Did the other stations have less observations in the considered time period?

You are right, the term “larger amplitude” is much better. The data gaps depend on weather conditions and also on the time resolution of the measurements themselves. As explained above, it is more likely for a single spectrum to be influenced in partly cloudy conditions if the integration time is longer. Thus, the instrument in Greifswald has the most data points in the time interval of interest. We added this information.

8. Line 118

“... of the unusual dynamical situation during winter 2016/2017”; is it the wave event that we are discussing that is the unusual situation?

We are talking about the wave event causing this unusual situation. We rephrased the text.

9. Lines 121-123

I don’t think there was any explanation why the running mean of specifically 41 days was selected? What was the motivation behind this?

It is a subjective choice here. The 41 days are chosen as this is long enough for the mean to not follow show the short period fluctuations any more but short enough to follow the changes of the seasonal variations like the annual, semi-annual, and ter-annual cycle. We added this information to the corresponding paragraph.

10. Line 134

The seasonal fit described by Eq (1)?

Yes. We added this information.

11. Figure 3 To simplify interpretation I would suggest adding a zero-line. Consider making the lines thinner (or adjusting the alphas) so that they can be more easily distinguished. Finally, the abbreviations HGW and WUP in the legend do not match anything mentioned in the article

We added the changes mentioned by the reviewer.

12. Line 154

The study of the meridional structure is largely based on sinusoidal fits performed in the longitude range 0E to 30E and at the specific altitude of 84 km. Could you comment on this. Is there a span of altitudes that give similar results or is it specifically this altitude? Can the expected vertical structure of the Rossby (1,4) be observed in this component?

The altitude and longitude range was chosen because of the best agreement to the ground-based data. Adjacent altitudes show similar results and it is not restricted to 84 km as can be seen in the vertical cuts. The vertical structure is shown in Fig. 4.

13. **Lines 155-158**

A few things regarding the phase analysis could be clarified.

Could the phase be expressed as a number between 0 and the period, for simplified interpretation? It would be easier to interpret the results and see that there is approximately half a period between the two groups. “The phase, expressed as DOY of the first positive maximum after DOY 365 ..” is there a reason for this reference?

A sign difference in the amplitude with antiphase signals, is that not two sides of the same coin, i.e. a negative amplitude and “372 DOY phase”, is the same as positive amplitude and “385 DOY phase”? This could be better explained, maybe with an equation? I presume it is related to phases being “assigned” negative/positive amplitudes.

The phase can be shifted to be zero at DOY 365 and then it would be more or less between zero and the period. We chose a reference day within the event itself as small differences can sum up in calculations when the reference date is far away. The determined values, especially the phase, may not visually show the situation perfectly in a figure then.

Your explanation is fully correct. We took all amplitudes as positive in the first step and then assigned them negative and positive due to their phase. We rephrased the text part to clarify this.

14. **Figure 8**

See comment on Figure 3.

We improved the figure.

Technical corrections:

We addressed all technical corrections.