Ann. Geophys. Discuss.,
https://doi.org/10.5194/angeo-2019-117-RC2, 2019


Annales Geophysicae Discussions
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# *Interactive comment on* "Local Stratopause Temperature Variabilities and their Embedding in the Global Context" *by* Ronald Eixmann et al.

**Anonymous Referee #2**

Received and published: 11 October 2019

The study by Eixmann et al. is an interesting work that investigates stratopause temperature enhancements (STEs) that occur at mid and high latitudes in the Northern Hemisphere during winter. The paper focuses on two locations, Kühlungsborn and Andenes, where lidar data are available. It is found that the characteristics of STEs seen in lidar data are similar to those found in MERRA-2 reanalysis data, and it is concluded that the mechanism that causes STEs can be investigated using MERRA-2 data.

For further analysis, planetary waves 1-3 are determined from MERRA-2 data, and local temperature anomalies caused by those waves and their superposition are calculated for the two selected locations. This is a novel approach that helps to interpret measurements at fixed locations. It is found that almost all STEs in MERRA-2 can be explained by the variability of planetary waves with wavenumber 1, 2, and 3, which is



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Discussion paper

an interesting and new result.

The paper is well written and of interest for the readership of Annales Geophysicae. Publication of the paper is therefore recommended after minor revisions.

Main comments:

(1) It is quite encouraging to find that many STEs can be explained already by superposition of planetary waves. However, there is a remaining difference in STE occurrence rates between lidars and MERRA-2 that is not explained. Therefore possible effects of smaller scale dynamics, likely gravity waves, should be discussed in more detail.

Reviewer 1 suggested to calculate the local contribution of MERRA-2 planetary waves at the times and locations of the lidar profiles to estimate the contribution of breaking gravity waves and higher wavenumber planetary waves from the observations. In this way, it could be determined for the lidar observational record how many STEs would be expected by superposition of planetary waves 1-3. The difference between this number and the total lidar STE occurrence rate could then be used as an estimate for the effect of smaller scale dynamics. It could then also be checked whether this difference is in agreement with the difference between lidar STE occurrence rates and the MERRA-2 occurrence rates based on more years.

(2) As also mentioned by Reviewer 1, it would be desirable to have better constrained reanalysis data in the stratopause region. Starting with the year 2004 MERRA-2 assimilates MLS data. For this later period MERRA-2 should be one of the best freely available reanalysis data sets in the stratopause region. Therefore it would be interesting to additionally perform the MERRA-2 analysis only for the period starting with winter 2004/2005 to find out whether there is an effect on the MERRA-2 results, and whether the agreement between lidar and MERRA-2 climatologies changes and perhaps even improves.

Specific comments:

(1) p.2, l.2: The reference Hitchman et al. (1989) should be mentioned also here because this is the earlier work.

(2) p.2, l.5/6: Did you mean the variability of the stratopause, here? Or the mean state? Or both?

(3) p.4, l.5-10: Please add the information that, different from most other reanalyses, MERRA-2 assimilates MLS satellite soundings in the stratosphere and the mesosphere, starting with 2004. Therefore stratopause temperatures in MERRA-2 should be more reliable after that.

(4) p.4, l.23: As averages as short as 3 hours are used for the lidar data also long period gravity waves may not completely average out. This may add some noise to the lidar STE statistics.

(5) Fig.2 seems to be in disorder: Firstly, the panels are not labeled (a) ... (d). Secondly, the caption is not correct: All nighttime measurements are displayed in gray, not blue, and their mean in blue, not red. Thirdly, it looks like the same average STE curve (in red) is used for both Andenes and Kühlungsborn. This does not make much sense because there are temperature offsets between both stations. Fourthly, the legend in (a) and (b) it should read "single soundings", not "single STE". Fifthly, please use English titles for the different panels.

(6) p.5, l.13-16: Please note that in Fig.2 the same red curve is by mistake used in all panels. Therefore please check numbers after correction!

(7) p.6 after l.22: You should add some discussion on the differences between MERRA-2 and lidar STE occurrence rates.

The STE occurrence rate of MERRA-2 at the two locations is 14% and 17%, while for lidar these rates are 41/134=31% and 20/71=28%, about twice as high.

This difference is quite remarkable and shows that large scale dynamics like planetary waves that are well represented in MERRA-2 explain about 50% of the STEs, which is

an encouraging result, but are likely not the only mechanism causing STEs. Obviously, also smaller scale dynamics like gravity waves contribute to the lidar STE statistics.

(8) p.6, l.27: Here you write: "Figure 4 shows the original time series at one location at 2 hPa (blue line), ..." In the caption of Fig.4 it is mentioned that the blue line would be the "temperature deviation from the climatological daily mean". This information should also be given in the text of the manuscript. It should also be mentioned in the text that MERRA-2 data are shown.

(9) p.8, l.21/22: As has been shown in Fig.4, most of the temporal evolution of temperature anomalies can be described by a superposition of planetary waves, including the STE events.

This sparks the question whether "localized momentum forcing resulting in a synoptic ageostrophic circulation" is needed to explain the STEs. It seems that STEs can be caused already by superposition of conservatively evolving planetary waves.

(10) p.8/p.9: In the Discussion and the Summary it should be mentioned that the STE occurrence rates derived from lidar are twice as high as for MERRA-2 which indicates that dynamics at smaller scales can also lead to STEs.

Other comments:

(1) p.1, l.1: During winter the circulation -> During winter the circulation at mid and high latitudes

(2) p.2, l.17: in the northern hemisphere winter -> in the northern hemisphere during the winter season

(3) p.2, l.33: The word "whereby" does not fit here. Suggest to start new sentence:

(54N, 11E) whereby Andenes... -> (54N, 11E). Andenes...

(4) p.3, l.1: winter -> winters

(5) p.3, l.1: structure -> structured

(6) p.4, l.9: winter -> winters

(7) p.4, l.18: measuerement -> measurement

(8) p.4, l.32: in phase of the wave. -> in phase of the wave is taken into account.

(9) p.4, l.32/33: suggested rewording for the sake of comprehensibility:

For example, the amplitude of a PW remains the same but changes in phase and thus can change the value of the local displacement at Andenes. -> For example, the amplitude of a PW could remain the same, but changes in phase still can change the value of the local displacement at a given location.

(10) p.5, l.12: (red line) -> (blue line)

(11) p.5, l.19: the climatology -> the temperature climatology

(12) p.5, l.19: winter -> winters

(13) caption of Fig.3: the long-term mean is subtracted. -> the long-term mean (blue line) is subtracted.

(14) p.8, l.5: polar stratopause -> polar winter stratopause

(15) caption of Fig.3: Külungsborn -> Kühlungsborn

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