Atmospheric Chemistry and Physics Discussions

Atmos. Chem. Phys. Discuss., referee comment RC3
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Reply on AC1

Anonymous Referee #1

Referee comment on "Ozone–gravity wave interaction in the upper stratosphere/lower mesosphere" by Axel Gabriel, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-1066-RC3, 2022

Comment on public reply:

General Comment:

The reviewer appreciates the quick response to the raised concerns. However, the replies also caused further concerns on the manuscript and require clarification. The reviewer takes the freedom to rephrase the comments a bit to reduce the ambiguity.

HAMMONIA (minor comment):

In the acknowledgments, there is a statement about computational resources. If there were no computational resources used why acknowledge.

Day and night differences (major concern/ very critical):

The submitted paper points at Lidar observations conducted at the Antarctic and mid-latitudes. These measurements are essential to motivate the main narrative of the paper, but also to justify the results to be relevant. Thus, the paper should present a careful discussion of the observations in the context of this work. The shown GWPED in both publications includes all types of waves, viz. tides, planetary waves, and gravity waves. The different filtering approaches underline this aspect (Erhard et al., 2015, Baumgarten et al., 2017). There is a concern to generalize and attribute the observed GWPED only to a specific gravity wave with defined properties. The observational uncertainties are supposed to be mentioned and discussed here as well.

There is another major concern when generalizing the polar day-night differences, which are, in fact, summer-winter seasonal differences and cannot be linked to the mid-latitude day-night difference. These are entirely different physical aspects due to critical level filtering, source variability, and gravity wave propagations conditions.

Looking at Figures 2 and 3 in Baumgarten et al., 2017 does not indicate any local time dependence of the gravity wave activity. Only monthly averaged GWPED results show a day-night difference. Baumgarten et al., 2017 even discussed the day-night differences as part of the analysis bias concerning tides. This was later confirmed by Baumgarten et al., 2019 when the day-to-day variability was analyzed combining spatial and temporal filters into one multi-dimensional retrieval. This is also an aspect for planetary waves and lidar observation as demonstrated by Eixmann et al., 2020 (AG), which is relevant for summer–winter comparison at the Arctic/Antarctic.

Critical level filtering:

The reviewer strongly disagrees with the statement in the replies that “Critical level filtering occurs during strong westerlies between April and October (see Figure 7 of Kaifler et al., 2015)”. Critical level filtering is present at all times and during all seasons, however, depending on the sign of the stratospheric winds different gravity waves encounter the critical level depending on their propagation direction and phase speed. This is directly related to the source questions and multi-step-vertical coupling processes.

Tidal amplitudes and gravity wave amplitudes:

Tidal amplitudes (semidiurnal or diurnal) can reach up to 8-15K (stratosphere/lower mesosphere) and occasionally 20 K (mesosphere) at the middle atmosphere between 30-80 km (e.g., from MERRA2). However, the amplitudes of tides are altitude-dependent and undergo the same exponential growth as gravity waves. The reviewer does not agree and has not seen observational evidence for an order of magnitude difference between tidal and gravity wave amplitudes (in a statistical sense) at the stratosphere and mesosphere. None of the lidar observations that are presented in the motivation are even close to the Rocky Mountains.

Sinusoidal approximation of gravity wave:

The reply draws an analogy between a gravity wave and a pendulum. This approximation seems to be by far too idealized as it skips key properties of a wave for real atmosphere application as they are found in observations. Gravity waves have a 3-dimensional wave vector and an intrinsic period and often occur not as an isolated plane wave but in wave packages. These packages have an envelope function, which is often assumed/approximated to be Gaussian. Depending on the background flow and the properties of the wave trains in the package cancelation effects are likely as updraft and downdraft phases can mix for a fixed observer on the ground in the Eulerian frame of reference. A pure vertical 1 D approximation is fine as a theoretical approach, but hard to be generalized in a real environment.

In summary:

The reviewer values the theoretical approach presented in the manuscript but has serious concerns about the motivation and justification of its importance. A revision of this manuscript either requires dealing with all the observations in more detail, including atmospheric tides and other dynamical effects as well as their biases, or skipping the observations to a large extent and just presenting the results as an idealized theoretical approach that requires observational justification. The way how the amplitude growth is well-founded between theory and observations is not appropriate. However, a justification could be also achieved by performing ICON model runs with high resolution to investigate the presented approach with resolved gravity waves in more detail. In principle, this is also possible with HIAMCM. Gravity wave resolving models permit a less ambiguous wave characterization. Such model runs will certainly strengthen the presented conclusions if confirmed. However, the reviewer understands that the model runs are a lot of work and might be postponed to future work.