

Ann. Geophys. Discuss., referee comment RC2
<https://doi.org/10.5194/angeo-2021-48-RC2>, 2021
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Comment on angeo-2021-48

Anonymous Referee #2

Referee comment on "A case study of a ducted gravity wave event over northern Germany using simultaneous airglow imaging and wind-field observations" by Sumanta Sarkhel et al., Ann. Geophys. Discuss., <https://doi.org/10.5194/angeo-2021-48-RC2>, 2021

Overview

This paper is about multi-wavelength airglow observations of a gravity wave event above northern Germany. The peculiar finding is a strong wave signature visible in the O(¹S) (97 km altitude) and O₂ (94 km altitude) bands, a fainter signature in the Na band (91 km altitude), and no wave signature in the OH band (86 km altitude). Auxiliary data used in the study are wind measurements by a meteor radar network and temperature profiles acquired by the SABER instrument on the TIMED satellite. To my knowledge, this is the first report on such a wave event with co-located local measurements of horizontal wind. Information on horizontal wind is of particular importance for the estimation of intrinsic wave parameters. Using the available measurements, the authors derive a vertical wavenumber profile from the gravity wave dispersion relation and conclude that a thermal duct is responsible for the non-detection of wave signatures in the OH band.

The paper is well written and presents some novel results. I recommend it for publication in Annales Geophysicae subject to the authors addressing the comments below. My main concern is the lack of a plausible explanation for the non-detection of wave signatures in the OH band (see major comment below). Without an explanation, the paper is merely a compilation of observations. Although the uniqueness of the presented observations may justify their publication (I leave this to the editor), a proper description, discussion and evaluation of potential mechanisms responsible for the diminishing modulation in OH airglow brightness will greatly increase the scientific value of this paper.

Major comment

I am surprised that the authors did not use Fig. 6 to estimate the vertical wavelength. From the slopes of the dashed lines I get values ranging between 8 and 12 km. On the other hand, $m^2 = 0.5$ (taken from Fig. 7e) leads to $\lambda_z = 8.8$ km. This value is consistent with the previous estimate and thus increases confidence in the derived vertical wavelengths. Also, from Fig. 7e I estimate the width of the duct $h=5.5$ km. According to $\lambda_z = 2h/n$ (see e.g., Dong et al. 2021; reference id given below) we can conclude that the wave propagating within the duct is likely of 0th order ($n=1$) assuming that the vertical wavelength inside the duct is approximately the same as above the duct. Indeed, based on Fig. 7e, m^2 values at 88 km (center of the duct) and at 95 km (above the duct) are similar. However, the 0th mode is a symmetric mode and, because the center of the duct (~ 88 km) is approximately aligned with the center of the OH layer (~ 86 km), the ducted wave should result in detectable modulations in airglow brightness. Some pieces of the explanation of the non-detection of wave signatures in OH airglow are clearly missing here. On the other hand, the authors provide no explanation either. In my opinion the sentence "The coincidental appearance of the duct layer caused the wave amplitudes to diminish" (l.327) is unsupported speculation. Before making such a statement, the authors should at least discuss conditions which *can* result in cancellation of wave signatures in OH airglow due to the viewing geometry or otherwise.

Minor comments

l. 50: It would be helpful if you could define "large-scale waves"

l. 55: "Instabilities present in the atmosphere do not support free propagation of GWs." This sentence is not clear to me. The assertion implies that instabilities are a property of the (background) atmosphere. However, the question whether an instability arises also very much depends on the properties of a particular wave propagating through the atmosphere. For instance, depending on the wind profile, an eastward propagating wave may propagate freely whereas a westward propagating wave is filtered due to a critical level.

l. 56: This may be a discussion about terminology, but it is my understanding that wave breaking is a process during which a wave breaks down and energy is transferred to smaller eddies. I wouldn't call these eddies waves because the word 'waves' implies some form of coherent structure. The generation of secondary waves is a separate process.

l. 65: Please explain "inhomogeneities in the background medium". Do you mean variations in density?

I. 75: "according to whether m^2 arises". I believe you meant "imaginary m^2 "?

I. 124: What is the horizontal averaging of the SABER measurements?

I. 142: What window sizes did you use?

Equation 1: What are the values used for H and k_x ?

I. 185: What are the time offsets between acquisitions with different filters?

I. 185: "mean phase velocities". Are these observed phase velocities?

I. 216: "there will not be any significant differences in the temperature". Well, I agree that significant differences between the SABER measurement and the temperature one hour later are not very likely, but the possibility can't be ruled out.

I. 255: "In fact, clear signatures of wave activities were observed on other nights in OH airglow images over northern Germany." What about before and after the event you described in this paper? Was there any coherent structure observable in all four airglow bands?

I. 264: "The SABER measurements indicated that the centroid height of OH airglow emission occurred near 87 km." Can you also provide estimates of the thickness of the OH layer (and potentially shape)? Because the vertical wavelength of the gravity wave is likely comparable to the thickness of the OH layer, even small changes in the thickness may have a large impact on the observability of the wave in OH airglow.

I. 273: "We believe that the perturbation wave amplitude will finally decide whether the structure observed in the OH airglow image is faint or not." Please explain. Are you arguing that the strength of the OH airglow emission ("faint or not") solely depends on the amplitude of the gravity wave?

I. 294: conductive

I 302: "It is well-known that the MIL tends to be quite stable within a few hours' time scale." Well, it depends on how you define "a few hours' time scale". For instance, tides can have a huge impact on the MLT *within a period of few hours*. Depending on the phase of the tide, mountain waves may propagate well into to the OH airglow layer or experience critical levels below.

I. 309: delete "that" -> indicates the existence

I. 311: delete first "of" -> some energy

I. 341: Please check the grammar of this and the following sentences.

Literature

Dong, W., Hickey, M. P., & Zhang, S. (2021). A numerical study of gravity waves propagation characteristics in the mesospheric Doppler duct. *Journal of Geophysical Research: Atmospheres*, 126, e2021JD034680. <https://doi.org/10.1029/2021JD034680>