Atmospheric Chemistry and Physics Discussions

Atmos. Chem. Phys. Discuss., author comment AC2
https://doi.org/10.5194/acp-2020-1289-AC2, 2021

Reply on RC2

Markus Geldenhuys et al.

Author comment on "Orographically induced spontaneous imbalance within the jet causing a large-scale gravity wave event" by Markus Geldenhuys et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2020-1289-AC2, 2021

Change to manuscript unrelated to the reviewers' comments
A minor addition have been made in Section 4.3 (CTL-run vs. T21-run: What causes the difference?). A new insight into Uccelini and Koch (1987) Eq. 9 has sparked the change. This change do not change the content nor the conclusions of the manuscript, however, the article would be more complete with this there-in.

Response to Anonymous Referee 2
We would like to thank the anonymous referee for reviewing our manuscript. The comments were valuable and improved the work significantly. The reviewers comment is indicated by italics and the response follows this.

Response to Major point
The authors have access in the simulations to all variables. The wave they are describing is a low frequency wave, as discussed for instance in the comments of the hodograph. A very good variable for capturing the signature and life cycle of this wave in the simulations would be the divergence of the horizontal velocity field. The signature of balanced motions is weak in this field, and waves with short vertical wavelengths come out conspicuously. The investigation of the divergence could in particular bring insights on the generation of the wave (in complement to the ray-tracing), and also importantly on whether traces of an analogous wave are present in the T21 run.

The divergence field highlights the GWs upstream of the Greenland coastline and has been included in Figure 10 in the text. The divergence field did not highlight any stronger wave feature in the T21-run.

Response to Specific comments
l26 Earths -> Earth's

This has been addressed

l30 for fronts, rather than a reference to a study of the parameterization of waves from fronts, reference to a study or to studies of the process itself, ie of emission by fronts, would be more appropriate. Here are some suggestions

References for Snyder et al. (1993) and Ralph et al. (1999) have been added.

l50-56: De la Camara et al 2016 also obtained improvements after modifications of their NOGWD scheme. It is mentionned at the end of Garcia et al 2017 that the improvement can be obtained by enhancing the NOGD too.

As suggested, text from de la Camara et al. (2016) and Garcia et al. (2017) has been included in the paragraph.

l76: is the acronym PGGS explained somewhere? Is there a reference describing it?

The acronym PGGS is explained in line 76 (first submission). We have updated the text to make this clearer.

l113-115: does the irregular grid have disadvantages? It is indicated that it allows to reduce the computation time. How important is this? Naively, one imagines that such calculation is done just once, so that computational expensiveness may be secondary, so long as it remains within reasonable bounds.

Compared to previously used techniques, the approach used here showed no significant disadvantages to the other implementation Krasauskas et al. (2018). Large 3D retrievals like the one presented in this paper require the use of supercomputers. Because of the nature of the problem, the calculation is done iteratively (and not only once). A typical tomographic retrieval will have 5 to 10 iterations. The run for this manuscript used ~ 1 000 000 points, this takes about 80 CPU hours with 6 processes and 2 threads. In practice, one needs dozens of these retrievals for a publication-quality 3D retrieval. Any computational cost savings are therefore relevant.

l113-115: It is pointed out that this is the very first irregular grid retrieval. Is it possibel to quantify error bounds relative to the retrieval used usually?

This submitted manuscript was the very first Limited Angle Tomography (LAT) Delauney method retrieval. Krasauskas et al. (2020) recently submitted a full-angle tomography Delaunay method retrieval. (Our newly submitted article will reflect the addition of LAT as opposed to the one submitted first.)

Regarding the comparison of the new retrieval methods to the old one: The publication Krasauskas et al. (2018) performed a detailed comparison of the new regularisation and Delaunay triangulation techniques with the previously used methods. Comparison of the new methods against the old ones are evaluated using synthetic data retrievals (Figure 3 in Krasauskas et al. (2018), compare rows A and D) and error bar comparison is shown in Figure 5, rows B and D. To summarise the paper, they found that the new method compared to the old method show similar structures within the tangent point area (high trust region).

Some of uncertainties are discussed in lines 122-125; this is interesting. Perhaps a figure illustrating the sensitivity of retrievals to different choices could be shown in an appendix or as a supplementary material, so the interested reader may have an idea of the more robust features and the less reliable features of the retrieval.

Robust features are indicated by the black line in Figure 3 of the manuscript. The black line indicate the volume with a high number of tangent points. Tangent points are the lowest point along the viewing trajectory, meaning its the densest and carries the most signal. The tangent point region has been found to be robust during tomography (Krisch et al. (2017) and Krisch et al. (2018)). However the tangent point volume is rather thin during limited-angle tomography (as compared to full-angle tomography) and the surroundings are much less stable. Most of the retrieval experiments dealt in reducing obvious artefacts in the boundary regions outside the tangent point region. Reducing the artefacts make the cross-sections more visually pleasing and reduces the small, but given, impact on the tangent point volume. We use only data from this tangent point volume in the associated vertical cross-section plot and to the determine wave features in Table 1 of the manuscript. Meaning we only use the robust features. To avoid duplication the interested reader is directed to Krisch et al. (2018) for an in-depth discussion on the strengths and weaknesses of limited-angle tomography and the resultant effect on the reliability of features.

l138: 'groundbased is too long for a subscript; a suggestion would be to write omega_gd and explain in the text that this corresponds to 'ground-based'.
l138 Place the footnote after the word 'density' rather than after the parentheses which contains a mathematical formulation; there is no ambiguity because it would not really make sense to consider the fifth power of the expression... but still, it would be simpler to have the footnote after a word.

Both of these were addressed.

l139: 'taken into account': given the uncertainties on the damping due to turbulence or to the dissipation of waves in general, it would be worthwhile describing the assumptions used to account for these processes. Sensitivity to the choices made there could also be welcome, when results are presented.

A reference is now provided which describes the damping in full.

l142: what other indications of potential sources are there? Reaching the ground... For waves emanating from couvective regions, is the WKB condition violated?

Within the raytracer, there are no other (other than the WKB parameter) indications that can be used to diagnose sources. GROGRAT relies on the interpretation of the user to realise the potential sources at hand and test each source. Very similar to what was done in the rest of the manuscript. In the near future, it is the hope to implement more diagnostic tools to help with the source identification.

At this point in the manuscript, it is too early to discuss whether the WKB parameter was violated or not. This is discussed (and shown) later on in the manuscript (see Figure 6 and related discussions).

l163: it would be useful to include a standard reference on the Savitsky-Golay filter, even if it seems classical.

The classical paper that first introduced this filter has been added to the text.

l173: the footnote is not well placed

This was addressed.

l182-183: 'the divergence of the jet': what exactly does this designate? This is ambiguous.

The sentence was updated to be more specific. Now it reads: "However, the divergence of the winds within the jet remains ..."

l190: the waves observed have a wavelength ~2 km. Should this read 'wavelengths < 4km'rather than '> 4km'? The following sentence causes confusion.

Thanks for pointing to the typo. The typo was vertical wavelength (is now changed to horizontal wavelength).

l219: 'despite the expected increase': on such short vertical scales the increase is not expected to appear clearly, relative to all other causes of variation; the observations do not scan a range much larger than the vertical wavelength...

The "despite the expected increase of amplitude with a decrease in density" has been removed.

l224-225: could this assertion be more physically justified? What foes this criterion correspond to, and what are the other possible causes?

We elaborate more on this now by referring to Equation 4 in the manuscript.

l275: the beginning of the section could use a sentence of paragraph explaining the purpose of the simulations.

The following 2 sentences were added to Section 4 to introduce the reason for the numerical experiment.
"Originally designed as an attempt to entirely rule out topography as a source, a numerical experiment with strongly reduced topography was designed. This yielded unexpected results implicating topography as a major contributor."

Figure 11: more informative than the wind barbs given that the panels are small and that only a limited number of wind barbs can fit, the authors should consider plotting geopotential; the pressure level to which this corresponds should be indicated in the caption.

The wind barbs have been replaced by pressure isolines at the respective level.

About the summary: the summary is a bit abrupt, and acronyms (GLORIA, GROGRAT) are used directly. It depends on the editorial instructions, but it may be worth reintroducing them for hasty readers.

We completely agree. The summary has been updated to be more 'standalone' to make more sense to hasty readers.

l367: the horizontal phase speed is an important quantity, and the range given is very wide. The uncertainty in the estimate of this important quantity is worth a comment.

The range given is not an uncertainty range, these are the values for rays 0 to 2 between 7.5 to 12.3 km. Because of the ray and altitude range, a range in the phase speed is obtained. The article has been updated to make it clear that these values are over a range of altitudes.
The large changes in the phase speed with altitude is a result of the large changes in wind speed.

l372-373: this is an important issue currently; reference to previous work highlighting this issue would be relevant, eg Sato et al (2012)

Four references were added as an example.

l380: 'For coherency'? Perhaps state explicitly the goal of the simulations, the hypothesis that is tested with these simulations.

This has been addressed.

l392: 'the jet, which depends heavily on the orography': the formulation is ambiguous...

the dynamic of the jet is influenced by the orography?

This has been clarified in the text.

References

A. de la Cámara, F. Lott, V. Jewtoukoff, R. Plougonven and A. Hertzog, 2016: On the gravity wave forcing during the southern stratospheric final warming in LMDZ, Journal of Atmospheric Sciences, Vol 73, pp. 3213-3226, 10.1175/JAS-D-15-0377.1

R. R. Garcia, A. K. Smith, D. E. Kinnison, A. de la Camara and D. J. Murphy, 2017: Modification of the Gravity Wave Parameterization in the Whole Atmosphere Community Climate Model: Motivation and Results, Journal of Atmospheric Sciences, Vol 74, pp. 275-291, 10.1175/JAS-D-16-0104.1

L. Krasauskas, J. Ungermann, S. Ensmann, I. Krisch, E. Kretschmer, P. Preusse, and M. Riese, 2019: 3-D tomographic limb sounder retrieval techniques: Irregular grids and Laplacian regularisation, Atmospheric Measurement Techniques, Vol 12, pp. 853-872, 10.5194/amt-12-853-2019

L. Krasauskas, J. Ungermann, P. Preusse, F. Friedl-Vallon, A. Zahn, H. Ziereis, C. Rolf, F. Ploeger, P. Kanopka, B. Vogel and M. Riese, 2020: 3-D tomographic observations of Rossby wave breaking over the Northern Atlantic during the WISE aircraft campaign in 2017, Atmospheric Chemistry and Physics Discussions, 10.5194/acp-2020-1053

I. Krisch, P. Preusse, and J. Ungermann, A. Dörnbrack, S.D. Eckermann, M. Ern, F. Friedl-Vallon, M. Kaufmann, H. Oelhaf, M. Rapp, C. Strube and M. Riese, 2017: First tomographic observations of gravity waves by the infrared limb imager GLORIA, Atmospheric Chemistry and Physics, Vol 17, 14937-14953, 10.5194/acp-17-14937-2017

I. Krisch, J. Ungermann, P. Preusse, E. Kretschmer and M. Riese, 2018: Limited angle tomography of mesoscale gravity waves by the infrared limb-sounder GLORIA, Atmospheric Measurement Techniques, Vol 11, pp. 4327-4344, 10.5194/amt-11-4327-2018

F. Ralph, and P. Neiman, and T. Keller, 1999: Deep-tropospheric gravity waves created by leeside cold fronts, Journal of Atmospheric Sciences, Vol 56, pp. 2986-3009, 10.1175/1520-0469(1999)056<2986:DTGWCB>2.0.CO;2

C. Snyder, W. Skamarock and R. Rotunno, 1993: Frontal dynamics near and following frontal collapse, Journal of Atmospheric Sciences, Vol 50, pp. 3194-3211, 10.1175/1520-0469(1993)050<3194:FDNAFF>2.0.CO;2

L. W. Uccellini and S. E. Koch, 1987: The Synoptic Setting and Possible Energy Sources for Mesoscale Wave Disturbances, Monthly Weather Review, Vol 115, pp. 721-729, 10.1175/1520-0493(1987)115<0721:TSSAPE>2.0.CO;2