Answer to the comments of referee 3 (RC 1):

We would like to thank the anonymous reviewer for his / her valuable comments and additional information. I found them very helpful and changed the manuscript accordingly in most cases.

Two further remarks: when I read the manuscript, I found three further minor issues, which I corrected:

- In table 1, I changed the unit of the variable “alt” to from “M” to “m”. Furthermore, I replaced “RD7” in row 4 of this table by “ADM-Aeolus Level-2B Algorithm Theoretical Baseline Document“
- p.14, l. 295: I changed “section 5.1” to “section 5”. This was a relict of a previous version.

I tried to avoid page and line numbers but where I used them I refer to the new version with accepted changes.

RC1: 'Comment on amt-2024-18', Anonymous Referee #3, 10 Apr 2024 reply

In their paper "Gravity waves above the Northern Atlantic and Europe during streamer events using ADM-Aeolus" the authors use ADM Aeolus data to derive the kinetic energy density (Ekin) of gravity waves over the Northern Atlantic and Europe during periods of streamer events. During these events enhanced gravity wave energy densities would be expected. One major problem is the high noise level of Aeolus which complicates the derivation of gravity wave signals. Therefore, the authors average over a larger region to reduce the uncertainty of time series of daily averages for relating them to the streamer occurrences. Indeed, minor enhancements of Ekin are found that may be related to the streamers. Horizontal distributions of Ekin show enhancements that may be related also to other gravity wave sources.

Overall, the paper is an interesting study, fits into the scope of AMT, and the results are of interest for the community of atmospheric dynamics and people who intend to derive gravity wave distributions from Aeolus soundings.

The paper is therefore recommended for publication in AMT after addressing my minor, but important comments.

MAIN COMMENTS are:

(1) The expression "Ekin,low" is somewhat misleading and should be avoided! This expression as is suggests to be a lower estimate of the gravity wave kinetic energy density. However, Aeolus Ekin estimates should be significantly high-biased because of the high Aeolus noise level.

Therefore it should be stated more clearly in the manuscript that Ekin derived from Aeolus should not necessarily be a lower estimate!

Using a better statistics will reduce the "uncertainty" of Ekin, but will not remove the bias introduced by Aeolus noise. Of course, a better statistics will help to obtain more reliable relative variations of Ekin assuming that the noise produces a constant Ekin offset.

Removed expression Ekin,low from whole manuscript including figures, re-formulated abstract

(2) Gravity waves found in the region of interest are not necessarily excited in the same region by the streamer events. It has been shown before by, for example Krisch et al. (2017) that gravity waves can travel large distances horizontally until where they are observed. This information should be added in the discussion.

Done

SPECIFIC COMMENTS:

(1) l.15 and l.21: Later in the manuscript it turns out that Ekin derived from Aeolus winds should not necessarily be a lower limit. Therefore these statements in the abstract should be revised.

Done

(2) l.32: please add the citation Holton, 1982 in addition to Houghton, 2002

Holton, J. R.: The role of gravity wave induced drag and diffusion in the momentum budget of the mesosphere, J. Atmos. Sci., 39, 791-799, 1982.

Done

(3) l.32/33, l.41 onward: Please be more specific! For a gravity wave pseudomomentum flux (Fpx,Fpy) is conserved, but not the wave energy in general. Specifically, in your paper you are considering Ekin, which is not conserved! Even if a wave propagates conservatively, Doppler-shifting by the background wind will change the intrinsic frequency, which then leads to changes in wave kinetic energy.

Sorry, here I don't get your point. In the first paragraph of the introduction I mention that the pseudo-momentum and the pseudo-energy are the conserved quantities, if the background wind is unequal to zero. Isn't that what you wanted to be mentioned? So, could you please specify your comment? For consistency reasons, I included the info how to derive the pseudo-energy from the energy density. Now, there are the formulas for the pseudo-energy and the pseudo-momentum mentioned in the manuscript.

(4) l.51: momentum -> pseudomomentum

Done, also replaced it in the line following the equation.

(5) l.84: accuracy -> precision (see comment (8))

In principle, you are right, challenging is the precision. However, ESA only provides the error, therefore, I replaced accuracy with "error especially the precision"

(6) l.85: This measurement noise will result in a high-bias of Ekin.

Not necessarily. If the noise is due a bias constant with height, the detrending method will remove most of it. If the noise is due a lack of accuracy, we will get a higher error in E_kin. I changed the sentence to "One challenge is the accuracy error (especially the precision, since it is not removed through the detrending procedure in contrast to a bias) of Aeolus, which is lower than originally planned for and now in the same order of magnitude as typical GW fluctuations."

(7) l.127-130: To my knowledge, Metop-A is no longer operational. You should refer to the GOME-2 instruments on Metop-B and Metop-C, instead!

Metop-A was operational until 2021 (see e.g. right column, upper part of https://space.oscar.wmo.int/satellites/view/metop_a), the decommission started on Nov., 15th 2021 (https://www.eumetsat.int/europes-first-meteorological-satellite-polar-orbit-endsits-run). For our analysis, we used a combination of Metop-A and -B data in order to reduce the number and size of data gaps. We changed the sentence (p. 5, l. 131) "MetOp-AB was launched in 2006" to Metop-A was launched in 2006 (Metop-B in 2012)" to make the info more precise.

(8) l.223: What do you mean by "accuracy"? Usually, in the field of science and engineering "accuracy" refers to systematic errors/biases, while "precision" refers to random errors. See also: https://en.wikipedia.org/wiki/Accuracy_and_precision Alternatively, you could use the notation after ISO 5725 (which is rarely used in our field), but this should then be stated clearly and, accordingly, the expression "bias" should be generally avoided. Please check the manuscript throughout for the correct use of "accuracy" and "precision"!

Sorry, that was confusing. ESA provides the error and does not specify whether it is due to bias or precision. I went through the manuscript and revised it accordingly.

(9) L.264/265: This assumption is not valid for polar latitudes. Please refer to Krisch et al., AMT, 2022 for details.

Krisch, I., Hindley, N. P., Reitebuch, O., and Wright, C. J.: On the derivation of zonal and meridional wind components from Aeolus horizontal line-of-sight wind, Atmos. Meas. Tech., 15, 3465-3479, https://doi.org/10.5194/amt-15-3465-2022, 2022.

Yes, that's true and the reason why I wrote "to a large extent". I inserted "(this does not hold for polar latitudes, see Krisch et al. (2022))" to make it clearer.

(10) l.265: The expression Ekin,low is misleading as Ekin is calculated from squared wind fluctuations such that random noise will not average out and will produce biases. This should be particularly the case for Aeolus.

Ok, I get your point. I deleted all occurrences of E_kin,low and replaced them by E_kin.

(11) l.293 onward: please check for the use of "accuracy" and "precision", see comment (8)

Done

(12) Fig.6: "accuracy" should be "precision", or just "error"??

It should be precision I changed it.

(13) l.333-336: I think it is encouraging that the positive and negative mean residuals are about symmetric with respect to zero, suggesting that incomplete removal of the background does not introduce strong biases on average. This could be mentioned in the manuscript.

Thanks for the hint. I inserted a sentence in the description of figure 7 in the manuscript. Additionally, I clarified at the beginning of the description of figure 7 that the first part refers to figure 7a.

(14) l.401-412: In addition, Aeolus noise will produce a considerable offset of Ekin causing a high-bias.

That's true. I inserted "They could be the results of the relatively high Aeolus error, specifically the if it is due to a low precision." in line 412.

(15) l.415-430: It is remarkable that in Fig.10 enhanced Ekin is found in the vicinity of Greenland. The southern part of Greenland is a prominent source of gravity waves as can be seen in different gravity wave climatologies (for example, Hoffmann et al., 2013; Ern et al., 2018).

Hoffmann, L., Xue, X., and Alexander, M. J.: A global view of stratospheric gravity wave hotspots located with Atmospheric Infrared Sounder observations, J. Geophys. Res. Atmos., 118, 416-434, doi:10.1029/2012JD018658, 2013.

Ern, M., Trinh, Q. T., Preusse, P., Gille, J. C., Mlynczak, M. G., Russell III, J. M., and Riese, M.: GRACILE: a comprehensive climatology of atmospheric gravity wave parameters based on satellite limb soundings, Earth Syst. Sci. Data, 10, 857-892, https://doi.org/10.5194/essd-10-857-2018, 2018.

After pointing out that the streamer cannot be seen in figure 10, I included “However, in three out of six weeks enhanced E_kin values are observed near Greenland. This area is known to be a prominent GW hotspot (Ern et al., 2018; Hoffmann et al., 2013).”

(16) l.415-430: You should mention in the discussion that gravity waves can travel larger distances from their source to the location where they are observed (for example, Krisch et al., 2017). Therefore gravity waves of origin other than the streamer events could be superimposed in the region of interest and partly obscure the streamer gravity wave signal. Possible candidates for gravity waves of different origin could be mountain waves from Greenland and Iceland.

Krisch, I., Preusse, P., Ungermann, J., Doernbrack, A., Eckermann, S. D., Ern, M., Friedl-Vallon, F., Kaufmann, M., Oelhaf, H., Rapp, M., Strube, C., and Riese, M.: First tomographic observations of gravity waves by the infrared limb imager GLORIA, Atmos. Chem. Phys., 17, 14937-14953, https://doi.org/10.5194/acp-17-14937-2017, 2017.

Following the previous change, I added the following “Since GW can travel large distances from their source (e.g., Krisch et al., 2017), it cannot be excluded that orographic GWs generated through airflow over Greenland contribute to the time series of E_kin.“

(17) l.442: This is not correct! Aeolus is not a limb viewer! It views downward with an angle of just 35deg to the nadir.

I corrected it.

(18) l.443/444: "GWs with phase fronts oriented meridionally will cancel out entirely or at least to a large part." This is not correct because Aeolus observes in "near-nadir" geometry!

I changed it to “Aeolus as an off-nadir viewer (35° incidence angle) looks obliquely through the atmosphere and collects all information along the line of sight. GWs with phase fronts not oriented parallel to the line of sight are displayed attenuated in the Aeolus data“. Furthermore, I deleted “The effect of the vertical averaging is probably less important here”.

(19) l.456: However, gravity waves of phase speed opposite to the background wind would not be filtered out. These gravity waves could undergo considerable amplitude growth and overcompensate the filtering effect.

Yes, I agree. However, as the text is written, this possibility is not excluded. This is to stress that there may also be a physical explanation for this observed maximum in average residuals plotted against height.

(20) l.458: "the generation of secondary GWs" This statement is very speculative. Of course, this process can also happen at relatively low altitudes, however, usually it becomes important at altitudes well above 20km not covered by Aeolus.

Yes, this is a speculative statement. I changed the order, so mentioned the decrease in air density first and the secondary GWs afterwards. Additionally, I used “could” instead of “can” to emphasize the speculative character.

(21) l.495: The relatively high values of Ekin are understandable because the high noise level of Aeolus will cause an offset.

I inserted „This can be the result of a low precision of the Aeolus measurements.“

(22) l.513: There are more satellite instruments that currently observe temperature altitude

profiles in the lower stratosphere and are suited for gravity wave analysis, for example, AIRS and MLS, see Hoffmann and Alexander (2009) and Ern et al. (2022).

Hoffmann, L., and Alexander, M. J.: Retrieval of stratospheric temperatures from Atmospheric Infrared Sounder radiance measurements for gravity wave studies, J. Geophys. Res., 114, D07105, doi:10.1029/2008JD011241, 2009.

Ern, M., Hoffmann, L., Rhode, S., and Preusse, P.: The mesoscale gravity wave response to the 2022 Tonga volcanic eruption: AIRS and MLS satellite observations and source backtracing, Geophys. Res. Lett., 49, e2022GL098626, https://doi.org/10.1029/2022GL098626, 2022.

I get your point, it looks like this should be a complete list but that wasn't my intention. I inserted "for example".

TECHNICAL COMMENTS:

(1) l.23 due to -> caused by

Corrected

(2) l.25: between the daily averaged -> between enhanced daily averaged

Corrected

(3) l.33 are can -> can

Corrected

(4) l.59: by -> be

Corrected

(5) l.71: doppler -> Doppler

Corrected

(6) l.81: data has -> data have

Corrected

(7) l.112: air of low -> air of low total column ozone (TO3) ???

Meant is "which transport air from low latitudes into mid latitudes", I changed it accordingly.

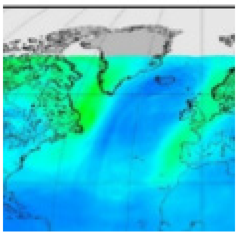
(8) l.121: The identification -> Our identification

Corrected

(9) l.134: comparable large -> comparably large

Corrected

(10) l.139: longitudes, so it has a strong meridional structure -> latitudes, so it has a strong zonal structure

Are you sure? I mean this streamer: 

(11) caption of Fig.1: starting data -> starting date
Corrected

(12) l.147: November 2020 -> September 2020
Corrected

(13) l.180: horizontal position -> horizontal orientation
Corrected

(14) Table 1: dependant -> dependent
Corrected

(15) l.397: ofKramer -> of Kramer
Corrected

(16) l.438 waves 2 -> wave 2
Corrected