

# Authors response to "Contribution of gravity waves to shear in the extratropical lowermost stratosphere: insights from idealized baroclinic life cycle experiments."

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We thank the referees and the editor for their careful reading of our manuscript. Below we address each comment in detail and outline the corresponding revisions made to the manuscript (Reviewers/editor comments in italics and corresponding revised text passages highlighted in italic blue).

## Response to Reviewer 1

### *Minor comments*

**Comment:** 1. Line 787 in the revised manuscript (without the tracked changes): *It appears to me that this citation information is incomplete, and it has already been mentioned in lines 788-789.*

**Reply to comment:** Corrected.

**Comment:** 2. Line 98 in the revised manuscript (without the tracked changes): *'Plougonven and Zhang, 2013' -> 'Plougonven and Zhang, 2014'*

**Reply to comment:** Corrected.

**Comment:** 3. Lines 775-776 in the revised manuscript (without the tracked changes): *The journal information is missing.*

**Reply to comment:** Corrected.

**Comment:** 4. Lines 746-747 in the revised manuscript (without the tracked changes): *The journal information is missing.*

**Reply to comment:** Corrected.

**Comment:** 5. Lines 845-846 in the revised manuscript (without the tracked changes): *The journal information is missing.*

**Reply to comment:** Corrected.

**Comment:** 6. Reminder: As many parts of the manuscript have been revised, please double check everything all over again before it is published officially. For example, the link in line 793 is not working. Also, please make sure that all the figures are labeled and introduced correctly.

**Reply to comment:** Thank you for the reminder. We have rechecked the manuscript as well as figures, links and references.

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## Response to Reviewer 2

**Comment:** Line 44: The expression  $S^2 \geq S_t^2$  appears before  $St$  is formally introduced. Consider simplifying the sentence leaving the "enhanced vertical shear" as in the first version and moving the inequality to line 48.

**Reply to comment:** The sentence has been modified as:

*Such interactions can give rise to the tropopause shear layer (TSL, Kaluza et al., 2021), defined as the occurrence frequency of enhanced vertical wind shear, where vertical shear is given by...*

*That is to say, the region near the extratropical tropopause characterized by the maximum occurrence frequency of  $S^2 \geq S_t^2$ .*

**Comment:** Line 240: A previous recommendation suggested rephrasing the sentence as: "Wave activity was not prominent before the indicated simulation time...". The revised version currently reads: "Wave activity was not prominent before the simulation time but horizontal divergence fields highlight the emergence and subsequent intensification of wave-induced features thereafter." It is somewhat ambiguous without "indicated," and it's unclear which simulation time is being referenced.

**Reply to comment:** We have revised the sentence as follows:

*Wave activity was not prominent before the indicated simulation time (i.e., 240 h) but horizontal divergence fields highlight the emergence and subsequent intensification of wave-induced features thereafter.*

**Comment:** Line 395-396: "... represents filtered quantities." -> "... represents a filtered quantity."

**Reply to comment:** Done!

**Comment:** Line 497: "lead to a shortening the vertical wavelength of gravity waves" -> "lead to a shortening of the vertical wavelength of gravity waves"

**Reply to comment:** Done!

**Comment:** Fig B1: Please add spaces between the panel labels and case names for clarity, e.g., "(a) REFwind, (b) REFwind MOIST, (c) REFwind".

**Reply to comment:** Done!

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## Technical editorial comments:

**Comment:** L21 deviations from geostrophic balance often resulting ->result

**Reply to comment:** Done!

**Comment:** L21 and on numerous places of the manuscript - After the GW abbreviation is defined at L17, please use it consistently across the manuscript. (Currently the word gravity waves is co-occurring randomly throughout the text.

**Reply to comment:** Done.

**Comment:** L40 from now on vertical shear, -> from now on referred as the vertical shear,

**Reply to comment:** Done.

**Comment:** L53 the vertical structure of stability ->vertical profile you mean?

**Reply to comment:** No, we use 'vertical structure' here to refer to broader spatial patterns in stability, rather than just a vertical profile.

**Comment:** L62 GWs can foster the generation of turbulent flows. ??

**Reply to comment:** Modified as:

*These GWs may lead to the generation of turbulence.*

**Comment:** L123 lowermost stratosphere - please use the abbreviation LMS consistently across the manuscript

**Reply to comment:** Done.

**Comment:** L149 Free slip boundary conditions are applied at the surface in ICON, assuming zero tangential wind velocity..- you mean zero normal velocity?

**Reply to comment:** Right.

*Free slip boundary conditions are applied at the surface in ICON, assuming zero normal wind velocity,...*

**Comment:** L169 Three-dimensional turbulent effects are neglected which is a valid approximation for simulations on the mesoscale, which means that horizontal homogeneity is assumed. -> You probably mean that turbulent effects in the horizontal direction are neglected?

**Reply to comment:** Right. Corrected accordingly.

*Turbulent effects in the horizontal direction are neglected which is a valid approximation for simulations on the mesoscale, meaning that horizontal homogeneity is assumed.*

**Comment:** L190 DCMIP2016 abbreviation is defined, but later in the text only DCMIP is used.

**Reply to comment:** Changed to DCMIP

**Comment:** L205 DCMIP stream function case - After re-reading the text, I still cannot find any details regarding the stream-function perturbation. Can you give more details on how it differs from the wind perturbation?

**Reply to comment:** Revised the text as:

*A second case uses a perturbation of the stream function. As this, not only the zonal wind but also the meridional wind is directly perturbed (see Ullrich et al., 2014, for details). We abbreviate this case as DCMIP stream and note this case has some resemblance to the life cycle type 2 described in Thorncroft et al. (1993).*

**Comment:** L225 difference..is very similar reads odd.

**Reply to comment:** very similar => changed to consistent

**Comment:** L256 this simulation time?

**Reply to comment:** Modified as,

*'...the indicated simulation time (i.e., 240 h)*

**Comment:** L277 and 278 check the definition and consistent utilization of the abbreviations BLC and LC

**Reply to comment:** We use "LC" only where it is necessary to distinguish between LC1 and LC2; elsewhere, we use "life cycle" for clarity. "BLC" is consistently used throughout the text.

**Comment:** Caption of Fig. 4 - The figure displays the distribution of the 11 km horizontal divergence field -> ..of the horizontal divergence field at 11km?

**Reply to comment:** Done!

**Comment:** L302 not shown - please provide the figures for LRES in the Appendix or Supplement.

**Reply to comment:** We added the figure to the supplement.

**Comment:** Caption Fig. 6 ...11 km perturbation vertical velocity w

**Reply to comment:** Vertical velocity perturbations are indicated here by  $w'$

**Comment:** L388 GW packages - you mean packets?

**Reply to comment:** Right!

**Comment:** L389 Velocity perturbations initially emerge above the low-level trough - everywhere in the manuscript the connection with low-level process is not well developed/visualized. Consider improving this aspect in the revision.

**Reply to comment:** The figure reference have been added for clarity.

*Velocity perturbations initially emerge above the low-level trough with small magnitudes, which then gradually intensify and form the organized GW structure in the eastern trough (see also Figure 2 between 120°E to 100°W).*

**Comment:** Fig. 8 ...N2 (a-d), S2 (b-e) and S2' (c-f) -> N2 (a, d), S2 (b, e) and S2' (c, f) - check for this issue also in other figures

**Reply to comment:** Done!

**Comment:** L475 Note that only data points in the LMS are considered for this analysis. Thus, we only see turbulence.. -> Thus, we only analyze the turbulence...

**Reply to comment:** Done!

**Comment:** L516 - not shown - consider providing the figure in the Appendix or Supplement.

**Reply to comment:** The relevant figures are now included in the supplement.

**Comment:** L576 - growing GW trains?

**Reply to comment:** GW trains here referred to the growing amplitude of GW packets

**Comment:** L608 and L609 GW->GWs

**Reply to comment:** Done!

**Comment:** L616 peaks at LMS->peaks in LMS

**Reply to comment:** Done!

**Comment:** L630-631 ...enhanced shear associated with GWs substantially is a key..??

**Reply to comment:** removed 'substantially'

**Comment:** L675 baroclinic life cycle. implying -> BLC implying

**Reply to comment:** Done!

## References

- Kaluza, T., Kunkel, D., and Hoor, P.: On the occurrence of strong vertical wind shear in the tropopause region: a 10-year ERA5 northern hemispheric study, *Weather and Climate Dynamics*, 2, 631–651, <https://doi.org/10.5194/wcd-2-631-2021>, 2021.
- Thorncroft, C. D., Hoskins, B. J., and McIntyre, M. E.: Two paradigms of baroclinic-wave life-cycle behaviour, *Quarterly Journal of the Royal Meteorological Society*, 119, 17–55, <https://doi.org/10.1002/qj.49711950903>, 1993.
- Ullrich, P. A., Melvin, T., Jablonowski, C., and Staniforth, A.: A proposed baroclinic wave test case for deep- and shallow-atmosphere dynamical cores, *Quarterly Journal of the Royal Meteorological Society*, 140, 1590–1602, <https://doi.org/10.1002/qj.2241>, 2014.