Quick reply and clarification on egusphere-2026-413

We appreciate the time which the referee took for his or her comments on our manuscript. We agree that our manuscript addresses a topic of interest and we think that the tropopause following shear layers deserve a more detailed analysis, since–among other topics–they affect the composition in the lowermost stratosphere. The composition, in particular of ozone and water vapour in this region, is known to affect the radiative balance (e.g., Banerjee et al., 2019; Riese et al., 2012) and there are still unknowns about future trends of these trace species (e.g., Ball et al., 2018; Chipperfield et al., 2018). It is therefore of importance to understand the underlying dynamics. We want to take the chance to highlight several aspects of our study which we think make our current paper worth publishing, always keeping in mind that we are open for critique and improvements. Note that this reply is intended for clarification; we will provide a point-by-point reply when all reviews are available to provide a comprehensive revision. However, we thank the reviewer for pointing out areas which lack clarity.

The first paper on the description of the tropopause following shear layers has been published by Kaluza et al. (2021). There the existence of this frequent occurrences of the enhanced shear just above the tropopause has been described for the first time, essentially with the same data set which we use in this study. The focus of the study by Kaluza et al. (2021) was on the first description of this tropopause shear layer, its hemispheric variability and its link to balanced flow. In consequent studies, the focus has shifted towards the contribution of small scale (unbalanced) dynamics which are often associated with gravity waves (Umbarkar and Kunkel, 2025; Umbarkar et al., 2025). In one of these studies numerical experiments have been used to identify the link between small scale gravity waves and enhanced shear. This relation was evident in various simulations of baroclinic waves and was quite robust across various initial conditions and also analysis time steps in the later stages of the life cycles of baroclinic waves. In a consequent study, we analysed a case study of baroclinic wave over the North Atlantic to assess whether we find the same relationship. Again we find a strong correlation between gravity wave occurrence and enhanced shear. In the latter study, we also have measurements of temperature, wind, pressure and trace species at hand and can show that irreversible mixing occurred in the region of the gravity wave and enhanced shear. These findings motivated us to further look into this relation and whether the relation between gravity wave occurrence and enhanced shear shows this relation over the course of a year. Our current study has its focus more on the monthly variation of the shear layers over the North Atlantic and whether this is linked to variations in our proxies for gravity waves and turbulence.
Besides the clarification of the general goal of our study, we want to address one of the reviewer's concerns on the use of high temporal resolution data. From previous analyses, we were aware that the relation between shear, absolute momentum flux and turbulence indices is not too sensitive when compared over a larger area. This is why we decided to use a one time step per day analysis here. We repeated parts of the analysis in the meantime with 6-hourly input data. As is evident from Figure 1, the shear layer occurrence frequency is not very sensitive in the tropopause region to the inclusion of daily input time steps as long as we stay on the monthly analysis basis. Of course we improve the statistical basis for our analysis, but the used number of input time steps per month results in the relation which we intended to describe. We would therefore be willing to include 6-hourly

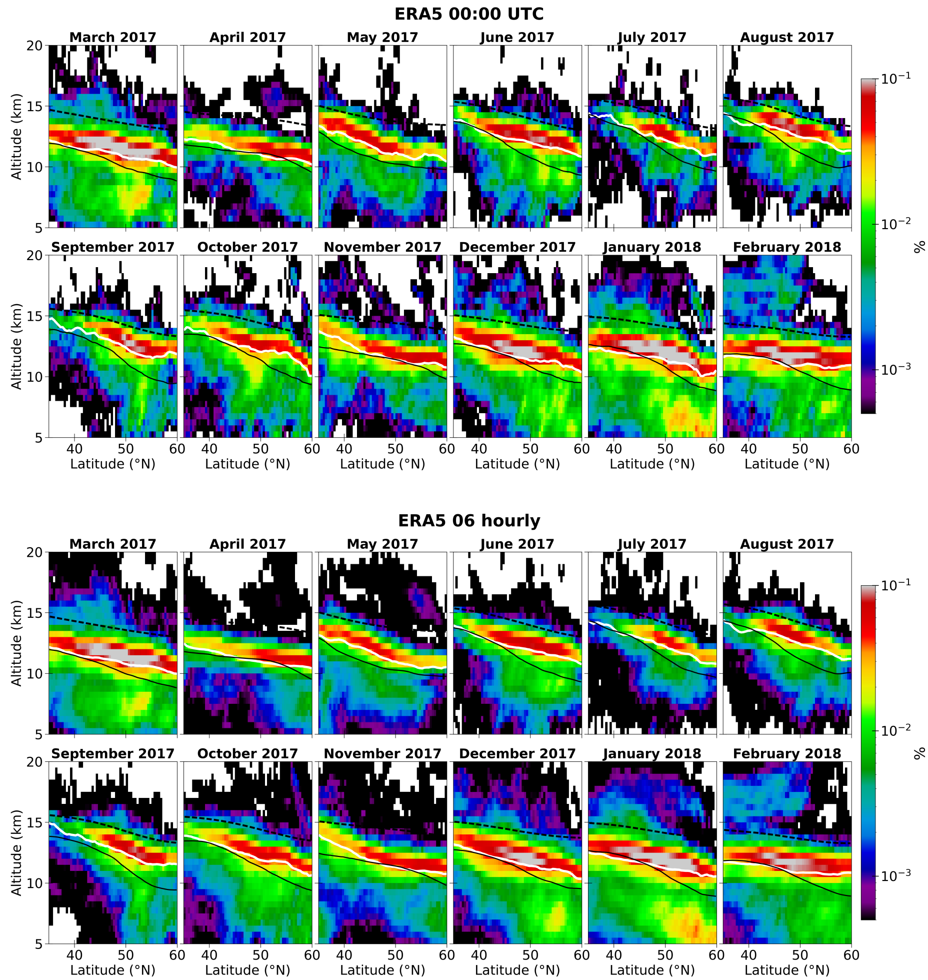

Figure 1. Occurrence frequency distribution of $S^2 \geq S_t^2$ with tropopause-based vertical coordinate system using 00:00 UTC (top) and 6 hourly data (bottom) from March 2017 to February 2018. The mean dynamical tropopause altitude for profiles $S^2 \geq S_t^2$ restored (from mean tropopause altitude + dz from the tropopause altitude) shown as white line. The occurrence frequencies are shown with logarithmic frequency contours, displaying the data in bins of sizes $\Delta y = 0.4°$ and $\Delta z = 500$ m. The zonal-mean dynamical tropopause (3.5 PVU isosurface; black solid line) and the zonal-mean 380 K isentrope of potential temperature (black dashed line) are overlaid.

data in a revised version. In a revised version, we will also elaborate more on aspects of the causality which are addressed in greater detail in previous studies, and then highlight more clearly the causes of the annual changes which we see in the shear layer, absolute momentum flux and turbulence indices.

Given the comments by the reviewer, we see the need to better explain our intention here and also to provide more insight into the robustness of our methods and we hope that we could do so during a revision.

References

Ball, W. T., Alsing, J., Mortlock, D. J., Staehelin, J., Haigh, J. D., Peter, T., Tummon, F., Stübi, R., Stenke, A., Anderson, J., Bourassa, A., Davis, S. M., Degenstein, D., Frith, S., Froidevaux, L., Roth, C., Sofieva, V., Wang, R., Wild, J., Yu, P., Ziemke, J. R., and Rozanov, E. V.: Evidence for a continuous decline in lower stratospheric ozone offsetting ozone layer recovery, Atmospheric Chemistry and Physics, 18, 13791394, https://doi.org/10.5194/acp-18-1379-2018, 2018.

Banerjee, A., Chiodo, G., Previdi, M., Ponater, M., Conley, A. J., and Polvani, L. M.: Stratospheric water vapor: an important climate feedback, Climate Dynamics, 53, 16971710, https://doi.org/10.1007/s00382-019-04721-4, 2019.

Chipperfield, M. P., Dhomse, S., Hossaini, R., Feng, W., Santee, M. L., Weber, M., Burrows, J. P., Wild, J. D., Loyola, D., and Cold-eweyEgbers, M.: On the Cause of Recent Variations in Lower Stratospheric Ozone, Geophysical Research Letters, 45, 57185726, https://doi.org/10.1029/2018gl078071, 2018.

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.

Riese, M., Ploeger, F., Rap, A., Vogel, B., Konopka, P., Dameris, M., and Forster, P.: Impact of uncertainties in atmospheric mixing on simulated UTLS composition and related radiative effects, Journal of Geophysical Research: Atmospheres, 117, https://doi.org/10.1029/2012jd017751, 2012.

Umbarkar, M. and Kunkel, D.: Contribution of gravity waves to shear in the extratropical lowermost stratosphere: insights from idealized baroclinic life cycle experiments, Atmospheric Chemistry and Physics, 25, 10 159–10 182, https://doi.org/10.5194/acp-25-10159-2025, 2025.

Umbarkar, M., Kunkel, D., Miltenberger, A., Lachnitt, H.-C., Kaluza, T., Schwenk, C., and Hoor, P.: Evidence of gravity wave contribution to vertical shear and mixing in the lower stratosphere: a WISE case study, Atmospheric Chemistry and Physics, https://doi.org/10.5194/egusphere-2025-5142, preprint, 2025.