Weather Clim. Dynam. Discuss., referee comment RC2
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Review of wcd-2021-8

Anonymous Referee #2

Referee comment on "On the occurrence of strong vertical wind shear in the tropopause region: a 10-year ERA5 northern hemispheric study" by Thorsten Kaluza et al., Weather Clim. Dynam. Discuss., https://doi.org/10.5194/wcd-2021-8-RC2, 2021

This study presents a climatological investigation of vertical wind shear zones at tropopause levels in a 10-year dataset of ERA5 reanalyses. The authors systematically study the frequency of occurrence of high vertical wind shear (based on a threshold criterion) in a framework relative to the lapse rate tropopause. They find that high wind shear mostly occurs within the lowest kilometres above the tropopause. The geographical distribution, vertical structure and temporal variability is examined for different latitudes and jet systems, and the physical processes associated with the shear layer are discussed, as well as its potential impact on the tropopause structure, stratosphere-troposphere exchange and turbulent mixing.
The paper is interesting and well-written, it is put into context of existing literature, and the study makes a relevant and new contribution to the understanding of the UTLS structure. I recommend publication subject to a few minor revisions.

General comments:

1) Generally, the existence of wind shear above the jet core and in the lower stratosphere is not a surprise as is expected from balanced dynamics, the exact structure of the shear zones however are more involved. The authors mention the relation of the shear layer to the thermal wind balance at several instances in the manuscript along with other mechanisms. How much of the structure of the shear layer can be explained by the thermal wind relation? It should be possible to quantify this based on the ERA5 fields. The possible role of gravity waves is mentioned in several sections and maybe this way the magnitude of their contribution could be narrowed down.
Furthermore, I would suggest to emphasize more clearly in the introduction, perhaps in a single summarizing sentence, what the main unknown aspects of the shear layer are (e.g. detailed structure, strength, vertical extent and occurrence in a statistical sense, formation mechanism) and which of these aspects are addressed in the study.

2) I think the authors should reconsider some expressions and definitions related to the

shear layer phenomenon.
- The words "enhanced" or "exceptional" are used frequently. In what sense is the wind shear "enhanced", compared to what reference? The study shows that the layers of strong wind shear above the tropopause occur rather frequently and strong wind shear is certainly not exceptional near jet streaks.
- The tropopause shear layer (TSL) is defined based on an occurrence frequency criterion. In this sense, it is a purely statistical feature. Since a layer of strong wind shear also seems to be physically present and nicely visible in instantaneous synoptic situations with a strong jet stream (see Fig. 13b), I find it unfortunate to define the "TSL" in a statistical sense rather than as a synoptic feature. It would be more intuitive to call the regions indicated by the red contours in Fig. 13b "TSL".

3) The authors have chosen a well-considered threshold S_t^2 and the choice is sufficiently explained. However, it would be interesting to test how sensitive the results are with respect to the threshold. How would the pattern of the occurrence frequencies change if S_t^2 was even higher?

4) I would be curious if the statistical analysis (for the midlatitudes) has also been done relative to the dynamical tropopause and whether there are any differences compared to the LRT-relative framework. This would be interesting e.g. in the context of many STE studies which focus on transport across the 2-PVU surface.

5) The introduction is quite long, the authors might consider shorten it a bit if possible.

Specific comments, suggestions and typos:

L13ff: Throughout the manuscript, the term "tropopause-based" vertical wind shear is used frequently. This expression is not very clear to me; does it mean "tropopause-relative", "near-tropopause" or "tropopause-level"?

L30: an --> a

L33: in return --> in turn

L36: to the --> its

L60 and all following occurrences: ° N --> °N, please remove the space between "°" and "N"/"E"/"S"/"W"

L61: for --> of

L67: ERA Interim --> ERA-Interim

L67: data set --> dataset

L70: remove "on"

L93: data --> forecasts

L98: analysis data --> analyses

L105: presents --> constitutes

L109: causes --> cause

L173: analysis "of" a single day

L174: Sections --> Section

L178: Please check the date and time convections of WCD

L185: ERA5 provides omega in Pa/s, not w in m/s

L189: dynamic --> dynamical

L191: Please remove the symbol for the cross product and insert a comma after equation.

L192: (with the angular velocity of the Earth, Omega).

L196: How do you derive the vertical distance between the model levels, do you use geopotential?

L201: can not --> cannot

L202: for --> to

L203: It is a bit confusing to read about static stability in combination with the notation S_t^2.

L209: majorly --> mostly

Fig3: It would be interesting to see contours of S^2 in the snapshot vertical cross sections in addition to wind speed. This would illustrate not only the general position of the shear zones but also the spatial variability.

L259-264: Here, it would be helpful to explicitly point out the different positions of the solid/dashed black lines in Fig. 5a.

L267-270: While the schematic illustration in Fig. 5b is very helpful and easy to understand, I find the explanation in the text rather unclear. The authors might consider rewriting these sentences.

L298: barclinic --> baroclinic

L299: remove "is"

L315-316: I assume your background state is still latitude-dependent? From this sentence it is not clear if you also average over latitudes.

Fig7a: What does the black dot indicate?

L326: Why did you choose exactly 51°N?

L355: DFJ --> DJF

L416: and "references" therein

L440-441: No co-location of TIL and TSL: Can you show this in a figure? Maybe a snapshot vertical cross section would do. Or perhaps something like a frequency distribution of N^2 in the lowest 2 km above the LRT, showing grid cells with S^2 > S_t^2 separately and comparing them to the N^2 distribution of all grid cells.

L449-453: Are gravity waves (partially) resolved in ERA5?
Fig13b: Do the black circles indicate the LRT?

L487: I believe that throughout the summary the expressions "exceptionally pronounced/strong/enhanced vertical wind shear" and "enhanced tropopause-based vertical wind shear" are used synonymously. Perhaps consider using the same formulation throughout the paper (including introduction) to not confuse the reader.

L528: dynamic --> dynamical