

**Referee report of the manuscript “*Evidence of small-scale quasi-isentropic mixing in ridges of extra-tropical baroclinic waves*” by Daniel Kunkel et al.**

This study presents a strong argument for the occurrence of quasi-isentropic turbulence-driven mixing of air masses near the tropopause in ridges of baroclinic waves. The evidence comes from a meticulous analysis of constituent measurements from the WISE campaign accompanied by meteorological data from ECMWF forecasts and by trajectory calculations. While the authors cannot quantify the overall effect of this process on the chemical composition of the LS using data from a single event (nor is it the goal of the study) the great value of this paper is in introducing this, to my knowledge, largely neglected mechanism of stratosphere-troposphere exchange. The authors nicely connect their analysis with previous results regarding the TIL associated with baroclinic waves and come to a neat and well-argued, perhaps surprising conclusion that the enhancements of static stability at the top of a ridge can enhance, rather than inhibit, mixing.

The paper is very well written, the analysis is thorough and convincing. It’s one of those manuscripts that seem to anticipate the reader’s questions and answer them. And I really like the photo in Fig. 2! I think that the study is suitable for publication in ACP almost as is. I only have very few, mainly technical comments.

**Minor comments**

P2. L14-17. I’m confused about the terminology here. In my reading of, e.g. Birner and Bönish 2011 and Abalos et al. 2017 the distinction between the shallow and deep branches of the Brewer-Dobson circulation is not identical with a separation between mean advection and mixing. Rather, the shallow branch transport is comprised of both two-way eddy mixing and slower advection by the residual circulation, the two largely balancing each other. The definitions of the two branches have more to do with transit times, stratospheric entry regions, etc. Am I wrong on this? It may be true that it is eddy mixing that connects the tropics with the high latitudes (as in Krause et al.) but in the region considered in the present manuscript, with latitudes south of 60N it seems the mean advection also plays a role. All this is tangential to the subject of this study and all I mean is that the terminology used here doesn’t seem consistent with the literature. Also, I think that Birner and Bönish 2011 could be cited here.

P6 L13. The description of the COSMO model could use just a little more detail. It’s a regional model, right? Where do the boundary conditions come from? Also, define the acronym (I believe, Consortium for Small-scale Modeling)

P16 L15. I think it should be stated explicitly what this classical meaning is. This comes up again below in Section 3.3.

P19. L14-17. Again, I’m confused about the “classical” STE and how it’s opposed to what we have here. Isn’t “an air parcel crossing the dynamic tropopause” the one and only meaning of TST? Does this sentence simply mean to say that we can’t tell, based on the trajectory analysis, whether a STE event has occurred or not but the analysis provides evidence that it has? Maybe

it's just a matter of defining things more clearly. Also, I would say "classical sense" instead of "classical meaning"; just a preference.

### **Technical corrections**

P4 L11. The acronym 'TIL' is introduced here but later "tropopause inversion layer" it is almost always spelled out throughout the paper. It should just be "TIL" from now on.

P3 L17. "All processes which lead to cross tropopause transport of air parcels have one common impact on this air parcel," There's something grammatically wrong with this sentence

P4 L14 initial → initially

P4 L22. "data of" → data from

P6 L4. forecast → forecasts

P7 L13, "in this study we use the 2 pvu isosurface as dynamic tropopause" this was already stated in the first paragraph of section 2.3. I suggest deleting this sentence.

P9 L5. "(Figures 1c,d)" Should it be 1c,e?

P10 L14-L16 This sentence a little awkward. It talks about crossing the tropopause above the tropopause, which doesn't make sense to me!

Fig 3a caption. Richardson number contour is not mentioned in the caption.

P10 L33. "defincies" → deficiencies(?)

P12 L5. "seek for" → seek (or search for)

Figure 4 Caption. I think the symbols  $\Theta_M$  and  $\Theta$  should be swapped. Also, lrt1 (first lapse rate tropopause) is not described in the caption or discussed in the text.

P20 L9. 240.000. I think you want a comma there: 240,000

P20 L13. propability → probability.

P23 L 10 passioing → passing

### **References**

Abalos, M., W.J. Randel, D.E. Kinnison, and R.R. Garcia, 2017: Using the Artificial Tracer e90 to Examine Present and Future UTLS Tracer Transport in WACCM. *J. Atmos. Sci.*, **74**, 3383–3403, <https://doi.org/10.1175/JAS-D-17-0135.1>

Birner, T. and Bönisch, H.: Residual circulation trajectories and transit times into the extratropical lowermost stratosphere, *Atmos. Chem. Phys.*, 11, 817-827, <https://doi.org/10.5194/acp-11-817-2011>, 2011.