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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Where do the air masses between double tropopauses come from?" *by* A. C. Parracho et al.

Anonymous Referee #1

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General comments:

In the current study, the origin of air masses between double tropopauses are investigated using a Lagrangian method. Double tropopause occurrences are identified at various domains in the northern subtropics and 10-day backward trajectories are calculated twice a day for every January between 1980 and 2010. From the position of these trajectories 5 days before and the mean values of potential vorticity (PV) along the trajectories, the authors conclude that a significant part of the air between double tropopauses is of tropospheric origin (lower latitude, lower PV values).

The paper is very well written and the figures are clear. While I have some remarks and questions that I would like the authors to consider and answer, I think the trajec-

tory analysis presented in this study provides valuable material for a discussion of the question formulated in the title. Thus I would recommend this manuscript for publication, subject to minor revisions.

Specific comments:

1) In the introduction, the authors only mention the research on tropopause dynamics carried out in the last 10-15yr. The dynamics of the tropopause has been studied for over 60yr, mainly in the context of upper-level frontal zones and tropopause folds (e.g. review paper by Keyser and Shapiro (MWR,1986,http://dx.doi.org/10.1175/1520-0493(1986)114%3C0452:AROTSA%3E2.0.CO;2). Near a tropopause fold (defined using PV) along the subtropical jet stream, it is common to find zonally aligned double tropopauses (WMO) with limited meridional extent (Pan et al. (2009), their Fig. 2, top panel), which they also describe in the paragraph starting on their page 4, right column, bottom. The main event over North America studied in the mentioned paper (depicted in their Fig. 3), however, is clearly of different character (cf. their Fig. 2, bottom panel). Thus, also by looking at your Fig. 1, I get the impression that you are mainly studying the zonally aligned folds in the vicinity of the subtropical jet stream and your conclusions may not directly be transferable to cases as the one described by Pan et al. (2009). In fact, you might 'only' be confirming the well-known meridional secondary circulation around the jet and it has already been shown 10yrs ago that the subtropical jet stream is a 'hot spot' for tropopause folds (Sprenger et al., JGR, 2003, DOI: 10.1029/2002JD002587).

2) I would thus highly appreciate to see a vertical cross-section of a typical situation (as in Pan et al. (2009) with N^2 and PV) where you indicate the vertical extent of your domains. This would make it more clear to the reader what portion of the 'tropospheric intrusion' you are exactly studying and whether your situations are 'Shapiro-like' tropopause folds (Shapiro, JAS, 1980, http://dx.doi.org/10.1175/1520-0469(1980)037<0994:TMWTFA>2.0.CO;2) or 'Pan-like' 'tropospheric intrusions' that are spread over a large area. This might possibly also explain the discrepancy be-

tween your results and the ones of Wang and Polvani (2011) and Añel et al. (2012).

3) It is not clear to me why you chose to first calculate monthly averages of tropopause heights, from which you define the (then fixed) vertical boundaries of your (small) domains, but then still look at every time step individually and check, using somewhat complicated and not completely unambiguous criteria, whether this fixed domain lies between two tropopauses (DT case) or completely above the only tropopause (ST case). Please explain why you don't simply calculate the lower (and, if present) upper tropopause at every time step and start the particles between the two surfaces.

4)The asymmetry given by two vs. one standard deviation (eqns. 1 and 2) ensures that your domains preferably contain the upper part of the potential 'tropospheric intrusion'. This is justified by referring to the case shown in Pan et al. (2009) but as mentioned above, you may be describing different phenomena. Please state this even more clearly because I imagine this choice has a large impact on your results. Also, did you check that there always is a 'layer of extratropical stratospheric air' (p1354,l4) just above the first tropopause or do you just assume that from the aforementioned case study? I believe that a closer analysis of the lower part of the 'tropospheric intrusion' could yield interesting results, too.

5) Generally, it is unclear to me what you gain from comparing the DT cases to the ST cases? And in how many cases is there neither ST nor DT? Isn't it enough to just look at the DT cases and show that the air, just before reaching the domain, is transported poleward? In the ST case, you are clearly following air parcels from the extratropical stratosphere back in time and since the jet stream is most likely quite a bit equatorward of your domains in such situations, it is not surprising to me that they have high PV values (and don't come from the troposphere).

Technical comments:

p1350,l1: Do the air masses really 'end up' there? I am not sure that this is the right way to describe the situation as the air masses will be transported away from your domain

at a later stage. This term ('end up') is used at various locations in your manuscript.

P1350,l10: Whereas -> While?

P1351,l28: ERA-Interim is sometimes written as 'ERA-Interim' and sometimes as 'ERA Interim'. Please choose one version and be consistent throughout the paper.

P1353,l9: Maybe start the sentence with 'The DT events occur most frequently. . .'?

P1353,l24: Is there a reason to define Z_1 (here) and h_1(n,D_i) (on p1355) separately? To me, they appear to be the same thing? (Namely the lower boundary of your domain D_i, as obtained from monthly averaging plus two standard deviations. Please correct me if I am wrong.)

P1354,l3: Maybe write: 'As may be seen from Figs. 1 . . .'?

P1354,l7: Maybe move the part of the sentence 'to better identify the intruded tropospheric air alone' to the end of the sentence?

P1355,l15: Replace the comma by 'as'

P1355,l19: comma not necessary (same on p1356,l7)

P1355,l23: 'at the nth year'->'in the nth year' (same on p1356,l12)

P1357,l8: 'be only'->'only be'?

P1358,l22: Is this due to the very small spatial overlap? Please clarify.

P1358,l24, 'the North America'->'North America'

P1361,l18: 'smaller'->'small'?

P1362,l4: What is a box plot distribution? To me, a box plot is a way to visualize any distribution => Maybe only write 'distribution'?

P1362,l17: 'the winter'->'winter'

P1362,l27: Why can this not be explained by excursions of the tropical tropopause alone? Do you have any evidence for that?

P1363,l13: Please re-write this sentence.

P1363,l19: ‘make a significant contribution’ -> contribute significantly?

Fig. 1 (caption): ‘Frequency’->’Relative frequency’? (You are comparing DT events to ST events not to all time steps, right?).

Fig. 3 (lower panel): What is the meaning of the nuber ‘18’?

Fig. 5 (caption): ‘vorticities’->’vorticity’?

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 1349, 2014.