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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Global Tropopause Altitudes in Radiosondes and Reanalyses" *by* Tao Xian and Cameron R. Homeyer

Anonymous Referee #2

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This paper presents a comparison of tropopause heights and double tropopause frequency between radiosondes and modern reanalyses. Most modern reanalyses on average reproduce the radiosonde tropopause heights very well, except for MERRA-2, which is biased high by ~0.5 km. Double tropopause frequency is generally underestimated by the reanalyses, as expected due to their relatively coarse vertical resolution. In overall agreement with previous estimates, an upward tropopause trend is found based on radiosondes and reanalyses. Double tropopause frequency is found to show an increasing climate trend. The authors also show results based on a tropopause-break relative latitude coordinate, which shows sharper structures in the subtropics and is useful for deducing tropopause-based tropical width trends.

Overall this is a nice study, which can serve as important reference for future estimates

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Discussion paper

of tropopause characteristics and associated trends. My main suggestion is to try harder to interpret some of the findings, see detailed comment below. In its current form the paper is very descriptive and leaves almost all of the deeper understanding of its main results to future studies, which is fine for some results, but others would strongly benefit from a bit more analysis, which I'd think is meaningful within the scopes of the current paper.

I have two general comments that may require extra work, which is why I've recommended "major revisions". See further below for a list of minor comments, including of editorial nature.

General comments:

1) The fairly large bias in MERRA-2 is interesting and I was surprised that it didn't receive more attention by the authors (at least not in the writeup). After all, this is a (re)analysis, i.e., it includes a modern data assimilation scheme, presumably assimilating the radiosonde observations that here used as a reference. So my expectation was that all modern reanalyses essentially reproduce the tropopause. Fig. 1 furthermore stimulates suspicion: how can a reanalysis have such large temperature biases (> 5 K!!) in the upper troposphere? Without labelling I would have guessed that this is a free-running model. Don't you expect all modern reanalyses to very closely agree about temperature in the upper troposphere? This is the case between the other three products: ERA-Interim, JRA-55, CFSR. Is this simply an outlier example or do you often find such large biases in MERRA-2? Is this something that's documented in the literature? To be honest, if this is a robust bias in MERRA-2, then this product shouldn't be used for UTLS studies . . . in any case, this requires more discussion by the authors.

2) Vertical resolution is mentioned at many places to potentially explain differences between radiosondes and reanalyses. Isn't this easily testable? You could degrade the radiosondes to the model resolutions and see if that really explains the differences. You could even study some of the characteristics (e.g., double tropopause frequency) as

a function of vertical resolution by gradually degrading the radiosonde data. Perhaps the authors have already tried this, in any case, I would strongly suggest to include corresponding results / discussion in the paper.

Minor comments:

page 2, line 16: “uncertainty that is comparable to the vertical resolution of the model” âĂŤ this makes intuitive sense, but is this a priori clear given that you interpolate between levels for the tropopause calculation?

page 2, line 19: the lapse rate is equal to _minus_ the vertical temperature gradient

page 2, line 28-29: Anel ref’s

page 3, line 7-8: sentence doesn’t work like this; how about: “PV, which is conserved . . ., is commonly used for transport studies in the extratropics and often used to define a dynamical tropopause . . .”

page 3, line 10: “threshold used varies considerably” âĂŤ seems like an exaggeration (I’d suggest to remove “considerably”), note a lot of the STE studies (e.g., Wernli group and others) use 2 PVU and this value seems to be used mostly

page 5, lines 11-12: these are somewhat subjective choices âĂŤ have you checked the corresponding sensitivity? E.g., are the results sensitive to obtaining tropopause levels from the native horizontal and vertical grid, and interpolating to the 1-by-1 lon-lat grid afterwards? I’m also not sure I understand the purpose of oversampling to the 200-m grid in the vertical for tropopause identification âĂŤ please provide rationale (relevant for line 24 as well).

page 6, line 24: how do you assess whether data points are roughly evenly distributed?

page 7, line 8-9: do you do this separately for the two hemispheres? How do you then handle the equator, which in the relative coordinates “moves” around?

page 7, line 13-14: so here you suggest that you do use the native model grids for

tropopause calculations, in contrast to the description on page 5 âĂŤ please clarify

page 7, line 18: is this bias a function of latitude?

page 8, discussion of Fig. 2: have you considered normalizing these RMS differences by a measure of internal/natural variability (e.g., interannual standard deviation)? Larger RMS differences would be expected in regions with larger internal variability, so part of the latitudinal differences could be related to different internal variability.

page 9, line 5: over the Atlantic trends are larger at the edges of the tropics compared to the equator, which stands in contrast to the statement of "uniformly upward trends throughout"

page 10, bottom (Figs. 7, 8): not sure these Figures need to be included in the paper, perhaps as supplement is enough? They don't look that much different from the Eulerian versions (as the authors remark) and aren't discussed much either.

page 11, bottom paragraph: this discussion based on differences in how O3 is handled is useful and should be extended a bit: notably, ERA-Interim and MERRA-2 are very different in this regard with ERA-Interim using a climatological O3 product in their radiative scheme and MERRA-2 using its own O3 field âĂŤ so the effect of O3 on the tropopause and its trends will likely be very different between these two reanalyses.

page 11, line 33: please clarify that you are referring to _anomalous_ upwelling and downwelling (the full residual circulation is still downward over the polar latitudes)

page 12, line 28: awkward sentence structure ("Significant trends . . . were found to be increasing . . .") - please modify

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