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Atmospheric Chemistry and Physics Discussions

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Interactive comment

Interactive comment on "3-D tomographic observations of Rossby wave breaking over the Northern Atlantic during the WISE aircraft campaign in 2017" *by* Lukas Krasauskas et al.

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We thank the reviewer for the comments and suggestions that helped to improve this paper. We are especially grateful for the ideas on mixing analysis, that helped to extend the relevant part of the manuscript.

The reply is given below. We do not discuss small technical or typesetting remarks and typos spotted by the reviewer here, those were simply applied as recommended. The original reviewer comments are indented, exerpts from the revised version of the paper are given in italic.

General comments

> Terminology: - replace age or age of air by 'stratospheric residence time' or 'statospheric transit time' - use the terminology established by e.g. Stohl et al., 2003: - troposphere-to-stratosphere-transport (TST) - stratosphere-to-troposphere-transport (STT) - stratosphere-troposphere-exchange' (STE including both TST, STT).

The use of "age of air" was replaced throughout the paper.

> The analysis of the 3D history in Figs.6-9 could be sharpened by analysing for the (diabatic) processes which lead to diabatic changes and TST (and distinguish from quasi-isentropic exchange). It allows determining the complex interplay between different processes and should be really stressed a bit more as pointed out above. - The analysis of diabatic changes and tropopause crossings are really great, is it possible to deduce where and by which process diabatic ascent was produced (frontal uplift,WCB,...?) in contrast to more isentropic transport (e.g. for exchange at hight Thetavalues)? - Fig 9c) is remarkable, but are the processes creating the distinct TST maxima the same or is the upper part from quasi-isentropic TST? Is the maximum number at lower Theta due to midlatitudinal synoptics (again more diabatic TST: WCB, frontal uplift in mid latitudes...)?

The analysis mentioned here was extended by including air mass origin (TTL, PBL, extratropical troposphere) analysis and uplift locations into the former Figure 9 (Figure 10 in the new version), and expanding the relevant discussion in the main text. In short, the higher theta TST maximum is almost entirely due to isentropic transport from the TTL. The lower theta maximum exists because of the transport from extratropical upper troposphere, and has contributions both from the TTL and extratropics. The direct PBL contribution (i.e. without passing the TTL first) was rather small for the 3D data set, explaining the relative lack of water vapour in the hexagonal part of the flight.

> Further, as indicated below more specifically I missed isentropic PV maps to diagnose mixing. It’s clear, that the native coordinate of aircraft and observation is geometric, but the analysis of dynamical features and mixing should also be done analyzing isentropic PV maps, particularly when looking at TST.

PV maps at 340 K potential temperature levels were added as the new Appendix D, as requested here and in the more specific comments below.

Specific comments

> l.166: The statement about water vapor holds for the extratropics. The upper tropospheric part of the TTL can be very dry ($<$10 ppmv) as well, which is important forexchange at high potential temperatures.

The statement was corrected to *"Generally, water vapour has high volume mixing ratios in the extratropical troposphere [..]"*. The paragraph in question is mostly relevant to the regions where we measured (far from the tropics), the role of the TTL is discussed separately.

> l.177. The mixing time scale is an completely open issue and I wonder, if this manuscript using the 3D information from GLORIA and the mixing parametreisation of ClaMS can further quantify these mixing time scales? This could be a really novel aspect.

Mixing analysis that would use GLORIA data and the ClaMS mixing scheme is something we would like to do in the future, but we think it is out of scope of this paper. For now, we did extend the mixing analysis using the ideas in the reviewer comment on lines 216-218 (see below) to gain some insight into mixing time scales.

> l.180-185: The Figure 2d is great, but also puzzling, since it implies tropospheric impact all over the curtain with residence times from 0 to 30 days. Could the authors provide a complementary figure with the fraction or amount of trajectories staying inthe stratosphere? This would further support the potential impact of TS (troposphere-to-stratosphere-transport)

In Figure 2d the air parcels with stratosphere residence time of 30 days or more are all depicted in the same colour (the clarification was added to the plot). We thought it appropriate, because we expect any tracer structures due to STE to be erased by that time (Juckes and McIntyre, 1987, as cited in the paper). Our results seem to generally confirm this, tracer contrast is seen between air masses with smaller residence times. The figure, therefore, does not imply tropospheric impact all over the curtain with residence times from 0 to 30 days, many trajectories originate from stratosphere. It just does not seem very meaningful to distinguish between the high residence times in this context.

> l.208: The use of water vapor to identify stratospheric air masses is ambiguous since in the tropical and subtropical upper troposphere low water vapor below 10 ppmv at low ozone levels also show up leading to mixing between stratospheric and TTL air(e.g. greenish in the lower left quadrant of Fig.4a). The opposite, however, holds(and is important for the paper): enhanced water vapor clearly indicates tropospheric contributions from mid and high latitudes (e.g. 4b) 5) and the upper right quadrant clearly shows mixing. Is it possible to use this also to support the trajectory analysis in Fig. 9a,c)?

The simple classification described here serves the purpose of introducing the reader to the tracer-tracer correlations and, we believe, is appropriate for identifying STE-related mixing that occurs in the region where we measured (we did not measure in the tropics). The more detailed understanding of air mass origins and possible mixing within the stratosphere does indeed require further analysis, which was attempted with the new Figures 4c, 5 and the accompanying discussion.

The Figure 9 (old version of manuscript) is based on the 3D data set. The region inside the hexagon, sadly, did not contain the interesting water vapour structures seen elsewhere in the stratosphere with the help of 2D retrievals.

> Line 216- 218.: How do you infer an 'influx' of stratospheric air into the UT? This would imply stratospheric water of >20 ppmv, which is unrealistic. Do you mean influx of stratospheric air (as in l218-220)? The two branches seen in GLORIA in Fig.4a seem to indicate mixing into the stratosphere (i.e. to ozone values above 100 ppmv) from different source regions: To check this a second plot using simply potential temperatures color would be helpful. In case of different isentropic source regions, this should show up. Is it possible to indicate these air masses (branches in Fig 4a) in one of the curtains in Fig.2? A discrete color bar in Figs. 4/5 would help.How does the stratospheric residence time (from Fig.2d) look as color code in the correlations (Fig.4)? Mixing of distinct air parcels may show up and would indicate eventually a mixing time scale (or provide an upper limit).

We are especially grateful for this insightful comment, as it gave ideas for extending our mixing analysis. We believe that the high ozone values at low potential temperatures mentioned in Lines 216-218 were caused by a partially mixed air mass descending from the stratosphere. See Figures 4 and 5 in the new version of the manuscript, as well as the additions to Section 3.1 for more detailed discussion based on backward trajectories and tracer correlations. The new analysis also gives some insight into mixing time scales.

l.223: Not necessarily uplift ,could be isentropic transport as well.

The sentence was reformulated, referring to the new mixing analysis.

l.280: Which air masses are meant with isentropically mixed (in Fig9)? The continuous color code is not easy to read. See previous comments: I think this could be elaborated a bit more, which trajectories of those in Fig.9a came from the PBL, which from the TTL(e.g. color coding max/ pressure of TST-trajectory), this should also help to distinguish rapid uplift from quasi-horizontal exchange.

This question was addressed by extending Figure 9 (now Figure 10) to indicate the regions of air mass origin and adding some backward trajectory examples as the new Figure 9, which would hopefully make the role of RWB clearer.

l.324: dashed magenta line: I can only find one in Fig. 1a)

This was a typo, the dashed line is black.

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