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Atmospheric Chemistry and Physics Discussions

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.

Anonymous Referee #1

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The paper presents novel observations of the three dimensional tracer structures during subsequent measurements of a Rossby Wave breaking event. Ozone and HNO3 observations are obtained from the GLORIA -instrument onboard the HALO aircraft during the WISE mission in September / October 2017 over the Atlantic.

The authors first present an analysis of the two dimensional tracer structure during the wave breaking parallel to the flight track. Data cover curtains of 2-6 km below the aircraft flight altitude. The authors focus on the distribution of H2O , ozone and HNO3 to infer signatures of cross tropopause mixing. The tracer observations indicate a very rich tracer structure in the tropopause region indicating a highly complex dynamical

history of transport and mixing. Using the chemical Lagrangian Model of the Stratosphere (CLaMS) the authors analyze transport time since tropopause crossing which they can link to the observed tracer structures. The highlight and core of the paper is the three dimensional view on the tracer structure, which they study to derive transport and mixing histories for the different tracer filament. They analyze the apparent filsmentes by a comprehensive use of CLaMS information and show the complex diabatic history of the encountered filaments and air parcels. They particularly show a complex interplay of diabatic processes which is remarkably well represented in the tracer structure indicating, that the mixing process is rather inefficient preserving the chemical separation of air masses surprisingly long. On a consecutive flight two days later they could trace back the stirred filament via CLaMS trajectories to the 3D tracer structure two days before. Notably they could trace back the chemical anomalies to the tomographic volume, which is another highlight result. It shows, that the mixing time scale is slow allowing still to have chemically distinct regimes after several days of stratospheric residence times.

All in all the results presented here are clearly novel and clearly merit publication in ACP. The manuscript contain the analysis of an unprecedented 3-D view on the effect of RWB on the chemical structure of the lower stratosphere and the diabatic changes which are associated with this. This last process-based aspect should be a bit more elaborated. To make it a highlight the authors should exploit and extend their analysis of Figs.6-9, since this is the first comprehensive 3-D view on such an event. With CLaMS they could easily get closer to the cross tropopause exchange process than just stating RWB), by e.g. analyzing mixing strengths, driving factors of diabatic changes along the trajectory etc. They could get much more out of the analysis especially Fig.6-9). There are also a lot of slang-like expressions and a terminology, which is qualitative or non-scientific which should be changed to a more concise scientific wording. After these revisions have been applied I highly recommend the manuscript for publication.

General points: 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 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 Theta values)? - 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...)?

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.

Specific: Could you add in one of the cross sections in Fig. 2 the horizontal wind speed to motivate the classification of 'near jet' and 'away from jet' relative to the cross sections?

l.104-106: This sentence is weird, rephrase.

l.125: Replace 'were executed' by e.g. 'were flown' or similar.

l.150 and whole paper: replace 'Age of air' by stratospheric residence time' or 'stratospheric transit time'

l.166: The statement about water vapor holds for the extratropics. The upper tropo-

spheric part of the TTL can be very dry (<10 ppmv) as well, which is important for exchange at high potential temperatures.

l.168: Ozone and HNO3 are not produced by photolysis, better use 'photochemistry'.

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.

l.181: Though the authors clearly indicate their use of the term 'age' I highly recommend to replace it by 'stratospheric residence time' or 'stratospheric transit time' since the term 'age' is used for the mean stratospheric age of air (i.e. the mean of the transit time distribution of individual stratospheric air parcels).

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 in the stratosphere? This would further support the potential impact of TS (troposphere-to-stratosphere-transport)

l.191 'a'ffected

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)?

Caption Figs. 4/5: Distance to the PV-gradient-derived, the dynamical tropopause or the thermal tropopause?

Line 216- 218.: How do you infer an 'influx' of stratospheric air into the UT? This would imply stratospheric water of >20ppmv, 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 temperature as color would be helpful. In case of different isentropic source regions, this should show up.

Is it possible to indicate these airmasses (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).

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

l.256: What is meant with 'the retrieval sampled...'? Better rephrase

l.262: The old and young air masses indicated by dark colors in Fig.7...

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 ?

l.313: The Netherlands (instead of 'low countries')

l.311: 29 September (replace October)

l.323: '. . .. RWB squeezed into a thin filament sounds weird.

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

l.326/327: Avoid 'thin' and 'thick' in this context, that's non-scientific.

l.332: Whats a sizeable air parcel? Change term.

l.336: and later 'middling' - whats middling?

L3.67: 'Age-of-air -concept': must be removed here, since this is a reserved term for stratospheric age.

Figures in general: The use of continuous color bars is not always useful, e.g. the comparison of Figs 9 and 7b) is difficult.

Fig.1: Could you present the evolution of the filament crossing the hexagon on isentropic PV maps from 7.Oct to 9. October in steps of 12 hours (eventually, not necessarily, for the appendix)? Isentropic PV maps are commonly used to track dynamics and would facilitate the discussion and cross sections of the second flight.

Figs.2/12: It would be helpful to provide vertical cross sections of PV (discrete color), Theta- and windspeed contours as one additional cross section.

Refs: Stohl, A., Wernli, H., James, P., Bourqui, M., Forster, C., Lin-iger, M. A., Seibert, P., and Sprenger, M.: A new perspectiveof stratosphere-troposphere exchange, Bull. Am. Met. Soc., 84,1565–1573, 2003.)

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