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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A convolution of observational and model data to estimate age of air spectra in the northern hemispheric lower stratosphere" *by* Marius Hauck et al.

Anonymous Referee #3

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This study presents an extension of the inverse methodology in Hauck et al. (2019) to derive stratospheric age of air from mixing ratios of a set of tracers, including entry of air masses through the tropical and extratropical tropopause of both hemispheres with corresponding seasonality scaling factors. The methodology is in general valid and a novel result is an important role of upward transport from the extratropical tropopause, which could help explain inconsistencies in previous age of air results in the lowermost stratosphere. The paper is well written, especially the methodology sections. However, some clarification is needed on the proposed processes behind the results before I can recommend publication, in particular there is some confusion regarding the seasonality of the mass flux from the extratropical tropopause.

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Discussion paper

General comments

1) The discussion of the seasonality of upward flux from the extratropical tropopause and the obtention of scaling factors is quite confusing. In Section 2.2.2 (Extratropical seasonal cycles) it is stated that the scaling factor obtained based on previous works implies maximum upward flux from the tropopause into the stratosphere in spring, and minimum in fall (lines 23-26, ll27-32 page 8). In contrast, the paper results suggest the opposite seasonality, with maximum in SON for the NH (e.g. lines 7-8 page 23). Nevertheless, the authors state that their results agree with previous works (e.g. lines11-12 page 23).

Importantly, I believe there is a wrong interpretation of the results in Fig. 6 of Appenzeller et al. (1996), which show the 'net mass flux across the tropopause due to mass variation of the lowermost stratosphere alone', that is, the dM/dt term in their Eq. 1. This flux is considered here as 'the net flux across the tropopause', which is then argued to change sign with season (P8L4-5). However, the net flux across the extratropical tropopause is shown in Fig. 8 of A96, and corresponds with the term Fout in their Eq. 1. This flux is downward (negative) year-long, as argued also by subsequent works (including Olsen et al. 2004 cited here, see their Figure 2).

The seasonal cycle of the scaling factors is obtained taking reciprocal values of the 380 K downward flux from Olsen et al. (2004). This is justified by saying that "this downward motion should be coupled inversely to the flux across the tropopause, exerting a similar forcing as the downward control principle (Haynes et al 1991)." First, I fail to see any connection at all to the downward control principle. I guess what the authors are referring to is mass conservation? Second, there is a seasonal cycle in the mass of the lowermost stratosphere, captured by the term dM/dt mentioned above, which implies a time lag between the downward fluxes at 380 K and at the tropopause. It seems that a direct link is being proposed between the downward flux at 380 K and the upward flux at the tropopause, with some time lag that is somewhat unclear (3 or 4 months). However it is not obvious to me why such a link would be expected. Perhaps the adi-

abatic flux from Olsen et al. (2004) or Schoeberl (2004) could be used instead, which constitutes the upward mass flux component. It peaks around October-November in the NH and March-April in the SH. This seasonality is in agreement with Skerlak et al. (2014), who find maximum TST flux in November for the NH and March for the SH.

2) The vertical movement of the WMO tropopause plays a crucial role in cross-tropopause flux, and it has strong seasonality, rising in spring and lowering in fall. Hence, the seasonality of the mean age of air probably changes substantially in tropopause-relative coordinates. These coordinates are used for the observational campaign data analysis (Fig. 6) but not for the ClaMS results (Fig. 5). The influence of tropopause altitude seasonality on the extratropical lower stratosphere age of air seasonality should be discussed.

Specific comments

- P7L5-6: however, the area is different for each region (larger for the tropics)

- P18L2-5: Could you explain why the seasonality of the fractions is not included? Would it not be more realistic if they were included? Otherwise why are they introduced for?

- P19L24-25: This sentence seems completely speculative. Please justify or remove.

- P21L10-15: Could it also be that isentropic transport around the subtropical jet is identified some times as tropical and other as extratropical, since the tropopause break is located at 30°N/S? In this case it would not be surprising that both tropical and extratropical spectra present recent flushing.

Technical corrections

- P2L10: succumbs - > presents, undergoes? (also on P22L12)

- P3L24: radioactive tracers is sometimes written with “” and sometimes not. Please uniformize.

- P6L6: remove comma

- P8L5: inhibits - > prevents

- P8L7: ‘the division of both fluxes in these seasons’ - > the ratio of fluxes in these two seasons

- P8L10: ‘should be coupled inversely to the flux across the tropopause’ - > to the upward flux across the tropopause (see general comment 1)

- P8L20: ‘feedback’ - > connection?

- P8L30: ‘resemble’ - > correspond to approximately?

- P10L7: ‘transit time gradient of the mixing ratio’ - > dependence?

- P15L29: ‘maximum of downward forcing’ - > maximum of downward transport

- P16L21: inhibit - > reduce / avoid

- P18L20: trends - > seasonal departures

- P18L24: with fresh tropospheric air

- P19L30: remove vice versa

- P20L23: what do you mean by ‘finite datapoints’?

- P21L2-4: It would be useful to remind the reader the seasons in which each campaign took place

- P22L27: features - > provides

- P25L28-29: This sentence is unclear.

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