Reply to Reviewer #1.

We thank the Reviewer #1 for the positive review and fair remarks, which have all been carefully implemented in the manuscript.

Line 100: Maybe it would be good to change the order of 2.4 TROPOMI and 2.5 OMPS Limb Profiler in order to have OMPS Nadir Mapper and OMPS Limb Profiler in a row.

Done

Line 135: How do you justify the thresholds: "0.01 for SAOD and 8 for ER"

These thresholds were empirically defined as a trade-off between the sensitivity to enhanced aerosol layers and minimization of false detections of aerosol layers. The threshold values roughly correspond to seven standard deviations of the zonal-mean values in the non-perturbed conditions. This is now mentioned in the text.

Line 238: North America or Canada?

Corrected to "Canada"

Line 252: Is the threshold of AAI > 15 arbitrarily chosen?

This threshold has been previously defined by Peterson et al. (2018) by combining OMPS-NM AAI data and CALIOP aerosol profiling

Table 1: WCB used as acronym but only defined in line 391

WCB is now defined in the table caption.

Fig. 1: Why starting at different years 2003, 2013, 2012 for A, B, C and not in the same year for all?

The pyroCb inventory is available only since 2013 whereas the GFAS data set is available since 2003. We included GFAS data prior to 2013 to demonstrate the exceptional character of the 2023 wildfire season. The seasons of interest (represented by coloured curves) have all occurred after 2013 anyway.

Fig. 4: legend caption: kg m^3 there is a minus missing before the "3"

Fixed.

Fig. 4 and lines 457-463: The events 3, 4, 5, 6 all bring parts of the smoke into the lower stratosphere. You write that the lofting of smoke is meteorologically driven in the WCB and that the diabatic lofting plays a minor role. I understand that vertical transport of smoke in the WCB towards the tropopause is predominantly meteorologically driven. But how can you be sure that the smoke transport through the barrier of the tropopause would happen if it is only meteorologically driven? How would this barrier be passed even in a WCB?

Isentropic mass exchange across the mid-latitude tropopause (e.g., through tropopause folds) is a well-established process. In this context, the upper-level circulation associated with a WCB is expected to modify the tropopause structure on synoptic scales, thereby facilitating cross-tropopause exchange. The ability of the model to reproduce this transport based solely on meteorological reanalysis supports the physical realism of WCB-driven cross-tropopause transport.

How can you exclude that at this point diabatic lofting might dominate to come across the barrier as diabatic lofting plays a big role in the stratosphere?

The role of diabatic lofting driven by solar heating is difficult to quantify without dedicated radiative transfer simulations constrained by multiple observational datasets. Nevertheless, the ability of the meteorologically-driven transport simulation alone to reproduce the uplift of air masses up to the tropopause level suggests that diabatic self-lofting is likely of secondary importance under the relatively low aerosol concentrations observed in the uppermost WCB filaments.

And could differences in the absorptivity of the smoke compared to the Australian wildfire smoke in 2020 explain differences in diabatic lofting behavior?

Variations in the radiative properties of smoke particles, which depend on the type of burned biomass, could indeed influence diabatic lofting. However, basic considerations, supported by radiative transfer simulations (e.g., Ohneiser et al., 2023), suggest that the dominant factor is the concentration of absorbing aerosols rather than their specific absorptivity.

Please discuss this in your manuscript in more detail.

The following text has been added into the Discussion and summary section:

Our results are consistent with cross-tropopause smoke transport in WCBs being predominantly meteorologically driven, while diabatic self-lofting likely plays only a secondary role under the relatively low aerosol concentrations observed. Differences in smoke radiative properties may influence lofting efficiency; however, radiative transfer simulations suggest that the absolute concentration of absorbing aerosols is the primary factor. That said, the role of radiatively-driven diabatic self-lofting of smoke in the upper troposphere requires further investigation.

Another question that just comes to my mind: Did you also find smoke transport towards the UTLS (within the tropopshere) if the smoke was not within a WCB (or pyroCb) before?

While the diabatic self-lofting of highly-concentrated smoke plumes in the troposphere cannot be ruled out, all of the observed stratospheric intrusions identified in this study could be associated to either pyroCb- or WCB-driven uplift.

Line 688-690: Too general. In France? Or at that station? Or for Canadian smoke? How can you be sure it was a new record? At least the Australian 2020 smoke had a higher AOD for single layers in the stratosphere.

The mention of the new record has been removed. The 2025 smoke has surpassed this record anyways.

General: Maybe it would be a good idea to include a schematic figure comparing pyroCb and WCB vertical pathways, showing uplift speed, plume structure, and evolution over time.

We have considered several options for such an illustration (including AI-generated renditions) with varying levels of detail, but we were not able to produce a version that we found suitable. Given the considerable uncertainties that remain regarding both pyroCb and WCB dynamics, we believe that such a schematic would be most valuable once the processes are better understood and can be represented with greater confidence.

General: It is good to see that the model could show the lofting of the aerosol in the WCB. It is good to see that the lidar profile shows an AOT of around 1 with a thick smoke plume in the stratosphere. But do you have any case where you also see the observational evidence that the smoke plume does not originate from a pyroCb but was injected at around 2km height in Canada and was later found at a significantly higher altitude? The manuscript would benefit from it.

As a matter of fact, all the non-pyroCb-driven uplift episodes were associated with the smoke that was initially found in the lower troposphere (as the MOCAGE simulation assumed injection altitude of 2 km for all the FRP anomalies). An example of such uplift from the trajectory point of view is provided in Supplementary Fig. S4.

Technical comments:

Line 37: Empty space missing after „precipitation”

Line 39: Bracket opened but not closed

Line 56: Which year of the study Peterson et al. ? (“n.d.”)

Line 60: Bracket opened but not closed

Line 62: Commas around “however” missing

Line 62: Brackets around Zhang et al need to be removed

Line 78: Brackets around Fromm et al need to be removed

Line 106: Empty space before “OMPS” missing

Line 109: Point missing at the end of the sentence

Line 134: Bracket opened but not closed

Line 168: remove brackets around Guth et al…

Line 184: remove brackets around El Amraoui et al., 2022; Sič et al., 2015

Line 197: remove brackets around (Nédélec et al., 2015)

Line 198: remove brackets around (Blot et al., 2021)

Line 220: remove brackets around Khaykin et al., 2017

Line 392: lofting air instead of lifting

Line 436: these instead of this

Line 505: remove brackets once around Yu et al.

Line 576: 23 UTC, not 23 h UTC

All above has been taken care of.