Review of: Estimates of carbonyl sulfide and methane stratospheric lifetimes based on AirCore profiles

The authors estimate stratospheric lifetimes of OCS and CH_4 using ten AirCore profiles and an age-of-air analysis following a methodology similar to that presented by Karu et al. for the IAGOS-CARIBIC aircraft dataset. The resulting OCS and CH_4 lifetime estimates are generally consistent, within their uncertainties, with previous assessments. I particularly appreciated the historical comparisons with other datasets presented in Figures 1 and 13. However, I encourage the authors to also consider the more comprehensive historical analysis of OCS observations presented in:

Gurganus, C., Bednarz, E. M., Rollins, A., Waxman, E., Ray, E., Hintsa, E., et al. (2026). Constraining the stratospheric sulfate budget in global models: Insights from in situ OCS measurements during 2023 SABRE and comparison with satellite, balloon and surface data. Geophysical Research Letters, **53**, e2025GL117405. https://doi.org/10.1029/2025GL117405

The AirCore dataset analyzed here was comprehensively described in the accompanying Zanchetta AMT publication, so I believe the concise methodology section in the present manuscript is appropriate. Overall, the manuscript presents a useful application of existing age-of-air techniques to a high-quality AirCore dataset. However, I recommend a substantial reduction in the number of figures and tables, many of which add little to the scientific discussion and could be consolidated or moved to the Supplement. The principal conclusions do not substantially alter the current understanding of stratospheric lifetimes or age of air for either species. Nevertheless, the manuscript provides a useful discussion of the uncertainties associated with estimating age of air from different assumptions regarding tropospheric boundary conditions, particularly for species such as CH_4 and N_2O with long-term increasing trends.

Authors' response (AR): We thank the referee for the insightful comments and the positive feedback. *We provide our point-by-point responses below.*

We have now added and discussed Gurganus et al. (2026) throughout the manuscript. Most of the Figures and Tables presented in the original submission have been moved to the Supplement, following the suggestion of both Referees:

Table 2 is now Table S1 in the Supplement.

Table 3 is now Table S2 in the Supplement.

Tables 4-6 and 7-9 are now Tables S3-S5 and Tables S6-S8 in the Supplement, respectively.

Figure 4 is now Figure S19 in the Supplement.

Figures 5-7 have been incorporated in one multi-panel figure, now Figure 4 (a-c).

Figures 8-10 have also been incorporated in a single figure, now Figure 5 (a-c).

Major Comments

1. Comparison with ACE-FTS climatology

The manuscript compares a relatively small number of AirCore profiles with more than a decade of ACE-FTS observations. While the ACE-FTS climatology provides a reasonable representation of long-term, large-scale stratospheric transport, it is difficult to directly compare such a climatological average with individual AirCore profiles, which sample specific air masses. I encourage the authors to provide additional dynamical context for the AirCore observations. For example, trajectory analyses or plotting the measurements as a function of equivalent latitude would help determine whether differences arise from transport variability rather than methodological differences.

AR: We thank the referee for raising this important point. We agree that direct comparison between ACE-FTS climatology and individual AirCore profiles requires dynamical context. In the revised manuscript, we have therefore included equivalent-latitude coordinates (following Nash et al., 1996) for a more dynamically meaningful comparison. Contextually, we introduced Sect. 4.3 as follows:

4.3 Equivalent Latitude of AirCore observations

To further contextualize the AirCore results and their comparison with ACE-FTS averaged data, the equivalent latitude (Nash et al., 1996) was calculated from the ERA5 hourly potential vorticity data (Hersbach et al., 2023) for every flight. Equivalent latitude, in fact, represents the transport history of air parcels more accurately than geographic latitude, particularly in the upper troposphere/lower stratosphere region. The computed equivalent latitudes for each pressure level of the retrieved AirCore profiles are shown in Sect. S5 (Fig. S20-S28) in the Supplement. From these results, we computed the stratospheric partial columns of COS, CH_4, and N_2O for both AirCore profiles and their respective ACE-FTS profiles between the tropopause and 12 km above it, and investigated the difference between them. Figures 9-11 show the resulting differences against the average stratospheric equivalent latitude. TRN4 is not shown due to missing data that prevented the calculation of the stratospheric partial column of COS. Overall, it is evident that most of the sampled air had mid-latitude origins and that the partial columns obtained from TRN samples underestimate all tracers when compared to those obtained from ACE-FTS mid-latitude averaged profiles. The opposite is true for the AirCore samples collected in SOD. From the principle of AirCore sampling, we see no reason that biases could differ at the two different sites. Therefore, these opposing differences likely indicate that the AirCore profiles capture localized, latitudinally dependent air masses that are not fully represented by the zonally averaged ACE-FTS. Notably, the average equivalent latitude of the samples collected in KRN and SOD is well below polar latitudes, which may partially explain the larger discrepancies (though not significant) observed between the CH_4 lifetimes obtained with the Volk et al. (1997) method (see Fig. 7).

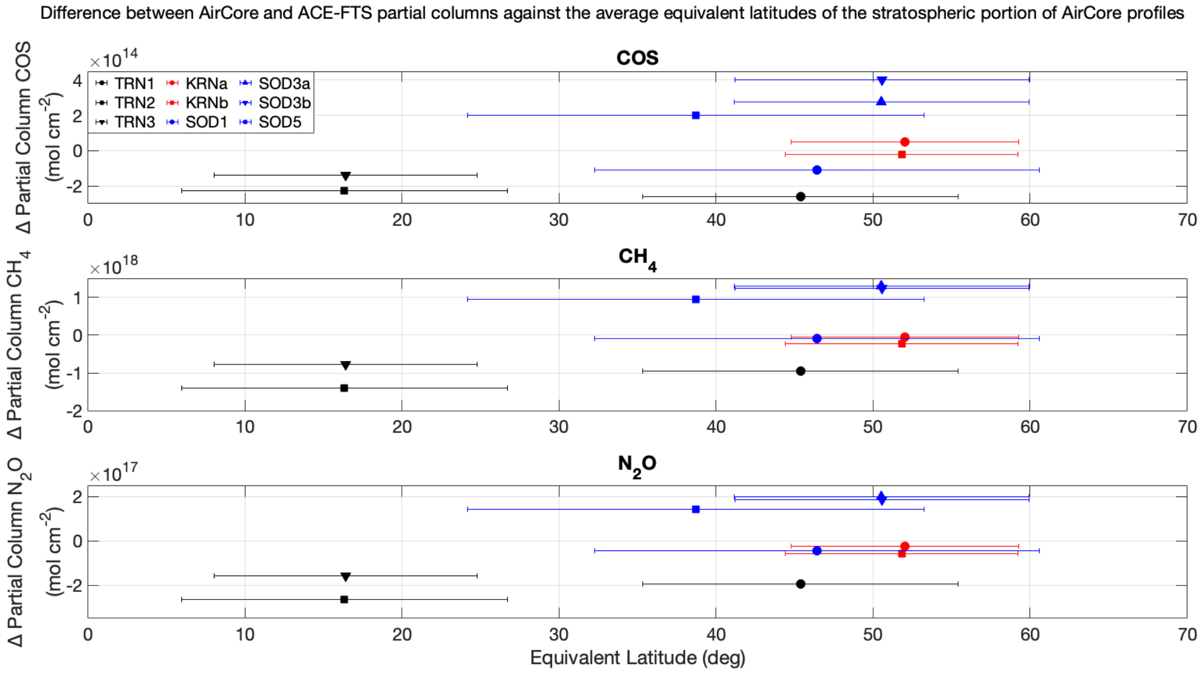

Figure 1: retrieved differences between COS stratospheric partial columns of AirCore and ACE-FTS profiles, against the average stratospheric equivalent latitude of AirCore profiles.

Moreover, Section S5 in the Supplement now reports the plots of all tracers against the retrieved equivalent latitude over the retrieved profiles.

2. Comparison between the Volk and Plumb & Ko methodologies

The manuscript devotes considerable discussion to differences between the Volk and Plumb approaches for calculating age of air. However, both methods ultimately use the same Equation (2); the primary distinction lies in how the tropospheric "burden" (i.e., the representative mean tropospheric concentration) is calculated.

Based on the values presented in Section 3.1, the difference in the OCS/N_2O burden ratio for 2023 is less than approximately 3% (487/336.8 using Plumb & Ko versus 457/324 using Volk). This difference is comparable to, or smaller than, the measurement uncertainty of the AirCore OCS observations (approximately 4% assuming a 20 ppt precision for QCLS). Consequently, the small differences in derived age of air between the two methodologies are expected to remain well within the observational uncertainty, consistent with the overlap shown in Figures 11 and 12. I therefore recommend shortening this discussion and emphasizing that, for the present dataset, the methodological differences are small relative to the measurement uncertainties.

AR: We thank the referee for this careful and quantitative assessment. We agree that the both methods ultimately rely on the same underlying mathematical framework and the differences in the derived burden ratio are indeed small. We also acknowledge that this difference is comparable to the measurement uncertainty of the AirCore OCS observations and that the methodological differences unlikely cause a significant impact on the derived lifetimes.

However, we would like to clarify that the major difference between the two methods not only lies in the calculation of the tropospheric burden, but also resides in the method employed to obtained the tracer-tracer slope. While Plumb and Ko (1992) infers this slope by a tracer-tracer regression (e.g., against N_2O) over altitude, Volk et al. (1997) refines this approach and extrapolates the tracer-tracer local slope at the tropopause, which is formally more correct, as the slope over altitude (and, therefore, time) may change due to different stratospheric transport and chemistry patterns.

Within the selected altitudinal range of our profiles, the differences between the local slopes obtained by the two methods are generally small. For COS, they average around 5%, but show peaks up to 12%. Similarly, for CH_4 the average difference is around 5.5%, with peaks of 14%.

To address the referee's suggestion, we have shortened and focused the discussion in Sect. 4.2. To clarify the referee's point, we added the following sentences (lines 477-481):

Overall, within the methods applied in this study, we believe that COS and CH_4 lifetime and sink calculations share the same sources of uncertainty. **The differences between burdens and local tracer-tracer slopes obtained with the two employed methods remained moderate within the selected altitudinal range. Since the two studies are based on a similar mathematical construction, where Volk et al. (1997) is more formally correct, these results suggest that Plumb and Ko (1992) provides an acceptable approximation for estimating the lifetime of COS and CH_4 within these altitudes.**

Specific Comments

- **Table 3:** This table primarily summarizes basic data analysis and does not appear to provide information that substantially advances the discussion. I recommend removing it or moving it to the Supplement.
- **Figure 4:** Presenting a "global average" ACE-FTS profile is potentially misleading because the ACE-FTS sampling is strongly biased toward middle and high latitudes, with relatively sparse tropical coverage. This limitation should be acknowledged more clearly, or the figure should be reconsidered.
- **Figures 5–10:** I do not see a strong scientific justification for including these figures in the main manuscript. They would be more appropriate in the Supplement, where readers can examine the individual profiles if desired.
- **Tables 4–6:** The OCS results would be much easier to interpret if they were consolidated into a single table, allowing readers to directly compare the results obtained using the Volk and Plumb & Ko methodologies.
- **Tables 7–9:** Similarly, the CH_4 results should be combined into a single summary table to facilitate direct comparison between the two age-of-air methods.

AR: We have implemented most of these suggestions (see above). The tables reporting the data for each methodology have been kept separated in the Supplement, mostly to avoid an overloaded single table.

Overall, I believe this is a worthwhile contribution that demonstrates the application of established age-of-air methods to a valuable AirCore dataset. The principal conclusions are generally consistent with previous work, but the manuscript would benefit substantially from a more concise presentation, consolidation of figures and tables, and a more focused discussion of the practical significance of the differences between the two age-of-air methodologies.

AR: We thank the referee for the insightful discussion and we modified the manuscript considerably following the suggestions.