This paper presents a global multi-year methane data product obtained by synergetically merging TROPOMI (XCH_4) and IASI (profile) Level-2 observations via a geo-matching step and a computationally efficient Kalman filtering scheme. The merged product provides three diagnostics—XCH_4, $utsXCH_4$ (≈450 hPa to TOA), and $troXCH_4$ (surface to 450 hPa)—with the stated goal of enhancing lower-tropospheric sensitivity and mitigating contamination from strong CH_4 gradients near the tropopause. The dataset covers Jan 2018–Jun 2021 with ~289 M combined samples, and the authors discuss uncertainty components (noise, dislocation/mismatch), DOFS patterns, and practical quality filters.

The contribution is valuable and timely. However, the physical and methodological explanation of why and how the Kalman synergy yields a lower-tropospheric partial column that is robust to tropopause height variability is under-developed in the current draft. The paper needs (i) clearer exposition of the state vector, observation operators, averaging kernels, and Kalman gain in the synergy; (ii) explicit sensitivity demonstrations showing reduced influence of UT/LS variability on $troXCH_4$; and (iii) several additional validations/robustness checks.

We would like to thank the referee for their interest and time spent in reviewing our manuscript. In the following, we write our replies to the comments of the referee as text in red fonts.

In comments #1, #5, #6, and #7, the referee points to the reduced $troXCH_4$ data quality (increased noise, reduced sensitivity) for elevated surface levels. This dependency of the $troXCH_4$ data quality is because of our choice of a fixed pressure level (450 hPa) for separating the surface-near atmosphere from the upper atmosphere. Naturally, for a high surface elevation, the surface-near layer up to this fixed pressure level becomes relatively shallow. It often becomes too shallow to be detectable at high quality using the signal provided by the satellite observations.

For the revised data set, we propose a separation into the lower 50% and the upper 50% of the atmosphere. This kind of separation avoids the strong degradation of the data quality for very shallow layers. Instead of trying to detect very shallow structures --- structures that are actually not detectable with the information available from the satellite measurements --- the 50%/50% separation used for the revised data set will focus on the quantities that are detectable. Please note that the fusion of IASI and TROPOMI data generates a full vertical profile. The separation into a surface-near and an upper atmospheric data product happens after the fusion calculations and should be chosen in a way that is most useful for the data users. Considering the comments of the referee, we think it is most useful to provide the data for layers that can be reasonably detected by the satellite measurements, i.e., a 50%/50% separation.

Moreover, we will provide the averaging kernels of the revised data set in the same vertical gridding as the original TROPOMI data product. We think that this facilitates data usage since the original TROPOMI data are already widely used in the community.

1. The manuscript claims and qualitatively illustrates that $troXCH_4$ (surface–450 hPa) is below the tropopause and therefore “independent from the strong CH_4 signals introduced by the location of the tropopause.” This is a central selling point and should be

demonstrated more rigorously：Include row-wise AKs (and cumulative contribution functions) for several regimes (low vs. high tropopause, ocean vs. high terrain, clean vs. dusty/snow scenes). Demonstrate that *A* for the tro layer largely suppresses UT/LS influence, while the uts layer captures most tropopause-related variability. This will convert a qualitative assertion into a physical demonstration.

The partial column kernels shown in Fig. 4 are for mid latitudes. We will expand the figure and show example partial column averaging kernels in addition for low and high latitudes.

Moreover, in an additional Appendix, we will show the respective full vmr profile kernels and the respective Kalman gain profiles similar to Figs. 1 and 2 of Schneider et al. (2022b).

2. Justify the 450 hPa boundary physically (global climatology of tropopause heights, retrieval DOFS distribution, and typical IASI vertical sensitivity). Provide a sensitivity check with an alternative boundary (e.g., 500 hPa) to show that conclusions are not fine-tuned to a single threshold. (You note that even extreme tropopauses at 300–400 hPa leave troXCH_4 below the tropopause; quantify this across latitudes and seasons.)

The 450 hPa level has been chosen because been it is below the climatological tropopause for all seasons and locations. The climatological temperature tropopause height is between 17 km (about 150 hPa, tropics) and 7 km (about 420 hPa, Antartic summer), and the chemical tropopause is typically between 18km (about 100 hPa) and 10km (265 hPa). Both is derived from the CESM1–WACCM (Community Earth System Model version 1 – Whole Atmosphere Community Climate Model, Marsh et al., 2013, https://doi.org/10.1175/JCLI-D-12-00558.1) monthly output of 1979–2014 and documented in Fig. 5 of Schneider et al. (2022a).

However, the amount of information provided by the radiances measured by the satellite sensors depends on the quality of the satellite data (spectral noise, spectral resolution), and on the correct understanding of the spectroscopy (line intensities, line broadening, water continuum, etc.). The spectroscopic understanding and the measurement quality is good enough to separate the troposphere above 450 hPa from the atmosphere at lower pressures as long as the surface elevation is not too high. However, for a high surface elevation, the layer limited by the 450 hPa level becomes rather shallow and is difficult to retrieve from the available radiances. It cannot be detected clearly (lower DOFS) and only with large uncertainties (larger noise errors).

For the revised data set, we propose to separate surface-near and upper atmosphere at 50% of the surface pressure. This is practically the same as a separation at 450 hPa (for lowland, i.e., surface pressure above 800 hPa), but avoids very shallow and undetectable layers for a high surface elevation.

3. Add a controlled sensitivity test: perturb the a priori UT/LS by ±(50–100) ppb and show the response in XCH_4, utsXCH_4, and troXCH_4. I expect utsXCH_4 and XCH_4 to respond strongly, while troXCH_4 remains comparatively stable if the mechanism holds. Your Madrid/Iberia analysis already hints at this separation (XCH_4 shows superposition; troXCH_4 tracks near-surface seasonality/emissions), but a targeted experiment would make the case bullet-proof.

Yes, we agree. This additional test on global scale can give further insight and better document the usefulness of the data product.

We will document how shifts of the tropopause height affect the retrieved XCH_4, $utsXCH_4$, and $troXCH_4$. We will test this on a global scale by simulating an uncertainty of +/-33% of the climatological tropopause pressure (to pressures that are 33% lower/higher, which corresponds to a vertical up-/downward shift of about 3km). Moreover, we will document how a 10% increase of CH4 in the first layer above ground affects the retrieved XCH_4, $utsXCH_4$, and $troXCH_4$. We will add additional plots for JJA and DJF after Fig. 6.

Please note that in Schneider et al. (2022b), we already show the representativeness error, which is closely related to these tests and shows how typical CH4 variations are detected in the partial column products. There, we document a large representativeness error on the IASI $troXCH_4$ compared to the combined $troXCH_4$. This reveals that the IASI $troXCH_4$ is not really sensitive to surface-near CH4 and/or is strongly affected by CH4 in the upper troposphere / stratosphere, whereas the combined $troXCH_4$ mainly reflects tropospheric CH4.

4. Provide a workflow schematic (geo-match constraints in space/time/surface pressure; selection of the "best match"; then Kalman update; then layer integration). Summarize the role of the surface-pressure proximity filter in reducing representativeness error before the merge. (Readers will appreciate why Δpsfc and distance/time windows matter for the dislocation kernel.)

Yes, we agree: providing a workflow schematic summarizing the different processing steps will be helpful. We will add an additional figure with the schematic to the manuscript.

5. Interpret the covariance terms physically: when and why does dislocation error rise (latitudinal gradient of temporal mismatch; high terrain where the tro layer is shallow), and how this interacts with the first kilometer above ground (largest representativeness uncertainty). The text mentions these patterns; add a concise, quantitative example (e.g., Himalaya vs. adjacent lowlands).

Ok, we will try to improve the text in Section 5.2, providing a more detailed discussion of the observed dislocation error patterns.

6. Clarify how the DOFS patterns co-vary with the noise maps (you note this relationship; add a 2-D density scatter to quantify correlation). Also, discuss the implications for regional comparability across seasons/latitudes.

This anti-correlation between DOFS values and measurement noise is typical for optimal estimation methods, which minimize the a posteriori uncertainty. The a posteriori uncertainty ($S_{\hat{x}} = (S_a^{-1} + K^T S_{y,n}^{-1} K)^{-1}$, see Eq. (A5) in Schneider et al. 2022b) can also be written as the sum of the propagated a priori uncertainty (Eq. (A7) in Schneider et al., 2022b):

$$S_{\hat{x},r} = (A - I) S_a (A - I)^T = S_{\hat{x}} S_a^{-1} S_{\hat{x}} = \left(S_a^{-1} + K^T S_{y,n}^{-1} K\right)^{-1} S_a^{-1} \left(S_a^{-1} + K^T S_{y,n}^{-1} K\right)^{-1},$$

and the propagated measurement noise (Eq. (A6) in Schneider et al., 2022b):

$$S_{\hat{x},n} = GS_{y,n}G^T = S_{\hat{x}}K^T S_{y,n}^{-1} K S_{\hat{x}} = \left(S_a^{-1} + K^T S_{y,n}^{-1} K\right)^{-1} K^T S_{y,n}^{-1} K \left(S_a^{-1} + K^T S_{y,n}^{-1} K\right)^{-1}.$$

Here A is the averaging kernel, I the identity, S_a the a priori uncertainty, K the Jacobians (transformator from the measurement domain to the domain of the atmospheric states), and G the gain matrix (for more details, please refer to Rodgers, 2000, or Schneider et al., 2022b, Appendix A). It is easy to prove that $S_{\hat{x}} = (S_a^{-1} + K^T S_{y,n}^{-1} K)^{-1} = S_{\hat{x},r} + S_{\hat{x},n}$. As can be seen from the two equations above, both $S_{\hat{x},r}$ and $S_{\hat{x},n}$ in-/decrease with in-/decreasing measurement noise ($S_{y,n}$) or in-/decreasing a priori uncertainty (S_a). De-/increasing $S_{\hat{x},r}$ and $S_{\hat{x},n}$ means de-/increasing measurement noise and in-/decreasing DOFS values, i.e., the anti-correlation as observed when comparing Figs. 5 and 7.

We will elaborate a plot that shows the covariance between DOFS and noise for XCH_4, $utsXCH_4$, and $troXCH_4$. This plot will then be shown in an additional Appendix to the manuscript.

7. Because $troXCH_4$ uncertainty grows over high terrain where the partial layer is shallow, add a topography-stratified analysis showing error growth and AK distortions with decreasing surface pressure, and recommend region-specific usage notes (e.g., Himalaya/Andes filters or uncertainty inflation).

We think that Fig. 6(c) is very clear in this context: it shows that for surface pressures below 750 hPa, the layer up to 450 hPa is too shallow to be fully detected ($K^T S_{y,n}^{-1} K$ representing the troposphere gets too small). The respective noise errors are then also increased (see also our reply to comment 6). We will elaborate on a plot that shows the noise error with respect to the surface pressure and the tropopause pressure (in line with the plot for DOFS, Fig. 6). This new plot will then be shown in an additional Appendix to the manuscript.

Nevertheless, please note that by separating the atmosphere at 50% surface pressure, the "artificial" $troXCH_4$ data quality degradation for high surface elevation will disappear. So, it is likely that for the revised data set, there will be no need for Fig. 6 and for a similar figure for the noise error (dependency of DOFS and noise on surface and tropopause pressure).

In this context, we can again refer to Table 2 (data filter recommendations).

8. A brief bias analysis for $troXCH_4$ XCH_4 against independent references (even if indirect) would greatly increase confidence.

We fully agree that the validation with independent reference data is very important for showing the reliability of a new data product. In this context, please note that this data set is extensively validated by detailed comparisons to data from TCCON, Aircore, and GAW (see Sect. 4 of Schneider et al., 2022b). We will better expose this existing validation work in the manuscript.