Dear Luca,

Thank you very much for your careful reading of our revised manuscript and for your positive assessment. We greatly appreciate your constructive and insightful comments, which have helped us further improve the manuscript.

In particular, we sincerely thank you for bringing Kylling et al. (2018) to our attention. This important and highly relevant study has allowed us to place our results in a broader context of passive aerosol layer height retrievals, particularly regarding the differences among retrieval approaches based on different spectral regions, the definition of aerosol layer height, and the reported retrieval biases. We have carefully considered the points raised in this study and incorporated the relevant discussion into the revised manuscript.

Following your suggestion, we have incorporated Kylling et al. (2018) into the manuscript and expanded the relevant discussion of the systematic differences in ALH retrievals associated with different spectral windows. We have also clarified the relationship between the ALH definition used in our study and the cumulative-extinction-based definition adopted in Kylling et al. (2018), and added a comparison between our HARP2 retrieval biases and those reported for the O_2 A-band and thermal infrared retrievals. In accordance with your suggestion, we have also strengthened the closing part of the Conclusions to better highlight the broader significance and potential of multi-angle polarimetry for aerosol layer height retrieval.

We sincerely appreciate your valuable guidance and encouragement throughout the review process. We hope that the revised manuscript satisfactorily addresses all of your comments and suggestions and is now suitable for final publication in 《Atmospheric Measurement Techniques》.

Please find our detailed responses to your comments below.

Yours sincerely,

Yong Xue

I noticed one omission during the recollection of past literature. That is the following paper https://doi.org/10.5194/amt-11-2911-2018.

We sincerely thank the Editor for pointing out this important omission and for bringing Kylling et al. (2018) to our attention. We greatly appreciate the Editor's careful reading of our manuscript and the valuable guidance in identifying this highly relevant study. We have carefully considered the paper and incorporated its relevant findings into the revised manuscript, particularly in the discussions of ALH definitions, differences among passive retrieval approaches, and retrieval biases.

1. Your discussion at page 3, lines 89-113, and the systematic difference in ALH from the use of different spectral windows.

Response:

We sincerely thank the Editor for pointing out this important and highly relevant study. Following this suggestion, we have added Kylling et al. (2018) to the discussion of passive ALH retrievals in the Introduction (Lines 114–124).

Specifically, we have expanded the discussion to emphasize that ALH retrievals based on different spectral windows can exhibit systematic differences. Kylling et al. (2018) compared dust-layer heights retrieved from the O_2 A-band using GOME-2 and SCIAMACHY and from thermal infrared observations using IASI with CALIOP observations. Their results demonstrated that the retrieved layer heights can differ systematically among sensors and retrieval approaches, reflecting differences in spectral sensitivity, retrieval assumptions, aerosol vertical representation, and the definition of the reference layer height.

We have incorporated this finding into our discussion of O_2 A/B-band and thermal infrared approaches and clarified that ALH retrievals from different spectral windows should not necessarily be expected to provide identical height estimates. We further emphasize that the measurement sensitivity associated with each spectral region determines which aspects of the aerosol vertical distribution are most strongly constrained.

This additional discussion also provides a clearer motivation for our multi-angle polarimetric approach. Rather than relying primarily on a specific spectral absorption or thermal emission feature, multi-angle polarimetric observations provide complementary information through the angular dependence and polarization characteristics of aerosol scattering. We therefore suggest that combining

complementary measurement dimensions may help reduce some of the ambiguities associated with ALH retrievals from individual spectral windows.

2. For the ALH definition at lines 371 and ff, Eq. 10.

Response:

We thank the Editor for highlighting the relevance of Kylling et al. (2018) to the definition of ALH used in our validation analysis. Following this suggestion, we have revised the description associated with Eq. (10) and added Kylling et al. (2018) to the manuscript (Lines 388–393).

Specifically, we have clarified that the ALH derived from the ATLID extinction profiles is an extinction-weighted mean altitude. We also added a discussion of the different ALH definitions considered in previous studies, including geometric-mean, cumulative-extinction, and extinction-weighted heights, and noted that different definitions can lead to systematic differences in ALH comparisons.

We have therefore explicitly stated that the extinction-weighted definition in Eq. (10) is adopted as the reference ALH for the ATLID-based validation in this study. This definition provides an effective measure of the vertical center of the aerosol extinction profile and is consistent with the effective layer-height quantity retrieved by our algorithm under the assumed quasi-Gaussian vertical aerosol distribution.

We believe that these revisions provide a clearer physical interpretation of Eq. (10) and improve the consistency of the comparison between the HARP2-retrieved ALH and the ATLID-derived reference ALH.

3. Your section 5.2, where you can readily compare your bias to those reported in the paper for the O2A and the TIR sensors

Response:

Thank you very much for this helpful suggestion. Following the Editor's recommendation, we have added a quantitative comparison between our HARP2 results and the passive ALH retrievals reported by Kylling et al. (2018) in the manuscript (Lines 981–993).

Specifically, for the three dust transport events analyzed in this study, the HARP2 retrieval yields an overall mean bias of +0.22 km and an RMSE of 0.92 km relative to the extinction-weighted ATLID ALH. We now compare this result with the biases reported by Kylling et al. (2018), who found systematic negative biases of

approximately −1.39 km and −1.10 km for the O_2 A-band retrievals from GOME-2 and SCIAMACHY, respectively. Their IASI thermal infrared retrievals showed smaller and algorithm-dependent differences, ranging approximately from −0.64 to +0.09 km.

The revised manuscript now discusses that the magnitude of the HARP2 bias is substantially smaller than the systematic negative biases reported for the O_2 A-band retrievals. At the same time, we explicitly acknowledge that this comparison is not strictly one-to-one because the two studies use different sensors, aerosol scenes, retrieval methodologies, and reference-height definitions. In particular, our ATLID reference ALH is defined as an extinction-weighted mean height in Eq. (10), whereas different CALIOP-based layer-height definitions were considered by Kylling et al. (2018).

We appreciate the Editor's suggestion, which has helped us place the HARP2 results in a broader context of previous passive ALH retrieval approaches.

4. For the open points listed at the end of their discussion (page 2927, points 1-a/c, 2-a/e): will multi-angle polarimetry help addressing them?

Response:

We sincerely thank the Editor for highlighting these important open questions raised by Kylling et al. (2018). Our results indicate that multi-angle polarimetry provides complementary information that may help address several of these issues.

Regarding point 1a, concerning the inclusion of other aerosol types, the present study demonstrates the applicability of the multi-angle polarimetric approach to two contrasting aerosol types, namely smoke and dust. The results show that HARP2 can provide reasonable ALH retrievals under both aerosol conditions, although the retrieval characteristics differ because of their distinct optical and microphysical properties. This demonstrates the potential of multi-angle polarimetry to extend ALH retrieval beyond a single aerosol type. Nevertheless, additional aerosol types and a substantially larger number of cases are required to fully assess the general applicability of the approach.

Regarding point 1c, concerning the development of an optimal ALH algorithm covering all situations, our results suggest that multi-angle polarimetry can provide an important additional constraint on aerosol vertical structure, but a universally optimal algorithm cannot be established from the present study alone. The retrieval sensitivity depends on aerosol type, aerosol optical properties, surface reflectance, and viewing geometry. Future development may therefore benefit from combining multi-angle

polarimetric information with spectral absorption measurements, AOD, aerosol-type information, and other ancillary observations to construct a more general retrieval framework.

Regarding point 2a, concerning the physical reasons for differences between the IASI algorithms, although our study does not directly investigate the individual IASI retrieval algorithms, it provides a relevant perspective on the physical origins of differences among passive ALH retrievals. Different retrieval algorithms may have different sensitivities to aerosol optical and microphysical properties and may adopt different assumptions regarding aerosol vertical structure. The multi-angle polarimetric measurements used in this study provide additional constraints on aerosol scattering properties and their angular dependence, illustrating how differences in measurement sensitivity and aerosol-model assumptions can lead to different retrieved layer heights. These results provide a useful framework for interpreting the differences among retrieval approaches discussed by Kylling et al. (2018).

Regarding point 2e, concerning pixel-level uncertainties in retrieved layer height, the radiative-transfer-based LUT framework adopted in this study provides a basis for evaluating the sensitivity of ALH retrievals to key input parameters and for quantifying retrieval uncertainties. In particular, our sensitivity analysis demonstrates the impact of AOD uncertainty on the retrieved ALH, while the LUT explicitly accounts for variations in viewing geometry, aerosol optical properties, AOD, and ALH. This framework can therefore be extended to estimate pixel-level ALH uncertainties by propagating measurement and input-parameter uncertainties through the retrieval process. A comprehensive pixel-level uncertainty budget incorporating measurement noise, aerosol model assumptions, surface reflectance, viewing geometry, and ancillary-data uncertainties remains an important direction for future work.

Overall, our results indicate that multi-angle polarimetry provides additional physical constraints that can help address several of the open questions identified by Kylling et al. (2018), particularly those related to aerosol-type dependence, the development of more general ALH retrieval algorithms, the interpretation of differences among retrieval approaches, and pixel-level uncertainty characterization.