# Final Response for AMT-2024-145 (technical corrections)

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## 1 Regarding comment 2, referee #1, report #2

**My point was just that for cases where the met model used by CAMS is simulating a cloud where ISCCP is flagging as clear, then the RH in the simulation will be 100%, which will yield an unphysically high AOD due to hygroscopic growth. Provided the model and ISCCP differences are small this won't matter too much, but I would prefer just using the cloud data from the ERA5 model to be self consistent in the OSSE. As far as I can tell the main reason for using ISCCP is to simulate realistic observability statistics. My intuition would be to opt for self-consistency above this. It is a relatively minor point (not worth redoing simulations) but I would consider doing this in future studies.**

We now better understand the original comment made and concede that we had not considered the impact on the aerosol particle sizes as influenced by the mismatch between CAMS and ISCCP cloud locations, and thus the mismatch between the humidity profiles; meaning: if CAMS produces a cloud at a location for which ISCCP does not indicate a cloud, the hygroscopic aerosol types would grow to much larger sizes compared to if CAMS did not assume a cloud at that location.

We consider this potential bias to be not significant for the results of our study. The mismatch in humidity profiles would produce higher optical depths (as mentioned in the above comment) to an extent only, as most of the aerosol load is found in the lower levels of the troposphere where the enhancement due to the potential cloud-influenced humidity increase would be minimal or none at all (see the illustrative Figure 4 in the revised manuscript). This possible high-bias in total aerosol optical depth would thus stem from the upper-tropospheric portions. Overall, the bottom-line impact would be that our forward simulations are potentially (slightly) biased towards higher total aerosol optical depths. Of course in terms of the OSSE, the bias is unobservable to the system as we compare against the forward simulations, and not the physical truth.

For the sake of completeness, we chose the ISCCP dataset due to the high spatial resolution, and the fact that we did not have to spend time on creating a spatially consistent cloud scheme that preserves the overall cloud fraction as indicated by the (for example CAMS) model.

## 2 Regarding comment 5, referee # 1, report #2

**[...] I'm not sure you can necessarily conclude that aerosol-surface impacts do not drive changes in multi-band retrievals because surface pressure and CO2 profile shape are the main predictors in the bias correction. An alternative explanation could be that the impact of aerosol scattering may induce changes in the retrieved surface pressure and CO2 profile shape. Both are modified by aerosols - perhaps surface pressure more obviously, but changing the vertical distribution of CO2 can also be related; To first order the CO2 layer jacobians are strongly correlated but differ by scaling factor due to pressure broadening (effectively absorption becomes less efficient at higher altitudes, because the narrow lines are already saturated). In this case unphysical profile shapes could actually be a result of compensating for errors induced by not simulating the correct wavelength-dependent aerosol optical properties between the bands. It is possibly more informative to look at the change in XCO2 as a function of albedo (e.g. Fig 5. of Taylor et al. (2023)). In that case at least I think you still do see correlations between the bias correction and surface. I am not saying the multi-band retrievals are useless. My interpretation is that the retrievals are not perfect, aerosol-surface interactions induce some unphysical changes to the retrieved state (which only happens because of the additional light path constraints from the additional bands), and this allows an empirical correction. [...]**

We were attempting to make a comment on the overall magnitude, suggesting that at the moment, for the case of multi-band greenhouse gas retrievals of this type, the surface pressure- and gas profile shape-related bias correction terms contribute more than the surface-aerosol bias. It was certainly not the intention to suggest that multi-band retrievals are immune to this, so to speak. In order to clarify the point about multi-band retrievals, we changed and extended the paragraph on page 3 to now read the following:

> In most related studies (e.g. O'Dell et al. (2018)), the major drivers of biases are identified as retrieved surface pressure as well as the retrieved $CO_2$ profile shape. The retrieved aerosol optical depth and surface albedo contribute much less to the total bias correction (OCO-2 Science Team, 2023). It seems plausible that surface-aerosol interactions manifest as a different type of bias, for example through interference of surface pressure and aerosol optical depth retrieval. Regardless of the actual mechanism, the utilization of 3-band retrievals from GOSAT, OCO-2 and OCO-3 have made surface-aerosol biases less apparent, and the surface bias is no longer a dominant contribution to the total observer errors.

## 3 Regarding comment 6, referee # 1, report #2

**I wasn't suggesting a study of the 1.6 micron CH4 band. The paragraph currently states that with regard to aerosol-surface biases, there is "no reason to assume that the same behavior arises with retrievals from the 1.65 $\mu$m window". However the underlying mechanism for the bias is still the same, and because the band is at a shorter wavelength, aerosol and Rayleigh scattering are larger, so if anything it may be slightly worse for the single band retrieval case. I was pointing out the reason why such surface-correlated biases may be lessened is that retrievals from this band often use the CO2 proxy method.**

We have modified the paragraph in the Discussion & Conclusions section of the manuscript:

> One can expect that the same behavior arises with retrievals from the 1.65 µm window since the fundamental mechanism that drives the bias is the same, despite the spectroscopic features having different characteristics. The often-used "proxy method" (Frankenberg et al., 2005) provides a solution for some spectral regions, in which a ratio to some reference trace gas is retrieved. In that ration, biases from unaccounted light path modification due to aerosols largely cancel out. This is the retrieval strategy of choice for the MethaneSAT (Chan Miller et al., 2023) mission. In fact, Chan Miller et al. (2023) present first results from the airborne MethaneAir instrument and do not observe any strong surface-related biases.

## References


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