Comment on egusphere-2024-1936:

This manuscript develops a method for the mitigation of 3D radiative transfer effects on retrievals of carbon dioxide concentration from the Orbiting Carbon Observatory satellites. The novelty of this work is that it provides a pathway for physics-based mitigation of 3D radiative transfer effects using parameterizations that can be applied operationally.
I enjoyed reading this paper, and I have several comments and suggestions detailed below:

As I understand it, all of the forward modelling of the OCO bands in this paper utilizes the linear approximation suggested by Schmidt et al. (in prep). For this paper, it is important that we know how the error in the linear approximation propagates into uncertainty in the relationship between ΔX_{CO2} and the radiances i.e., how accurate is the reference calculation?
At the moment, Section 2 states the result of Schmidt et al. (in prep) but doesn't provide much physical justification for the linear approximation itself. I think this section would benefit from a short paragraph discussing approximate acceleration methods for 3D RT such as (Partain et al., 2000; Doicu et al, 2020) in comparison to exact calculations like Emde et al. (2011), so that the strengths/weaknesses (accuracy vs. speed) of the linear approximation can be contextualized.

The mitigation parameterization is based on simulated scenes derived from observations. Due to weak atmospheric scattering, the 3D enhancement effect studied here depends primarily on cloud-surface interactions. These will strongly depend on the geometric distance between cloud and surface (i.e., cloud base height and thickness). At the moment, the methodology doesn't state how the cloud base height is retrieved from the MODIS observations to form a synthetic cloud field, or its uncertainty. This procedure's uncertainty will feed into the simulations and affect how the intercept and slope parameters scale with effective distance. It would be good to address this within the manuscript as it will affect both the baseline and bypass approaches.

For the parameterization, it might be beneficial to have a generalized distance that doesn't just take into account horizontal distance but rather the 3D distance of a surface point from cloud base (or side). For isotropic scatterers, the downwelling flux impinging on a point on the surface would scale with the inverse square of this distance, so square distance weighting seems like a good choice as used in the study. Along with that, not all clouds are equally bright, and their 3D enhancement should increase with overall cloud brightness. It might be useful to have a generalized distance that includes weighting by cloud reflectance. This might help the parameterization/bypass approach generalize more effectively.

The vertical distribution of aerosol will also influence the distance scaling of the slope and intercept parameters. Currently, the study examines aerosol within the cloud layer and states that it localizes enhancements to regions closer to cloud due to reduced free paths. The effect of an elevated aerosol layer may differ. Higher-altitude scattering layers tend to increase the horizontal distance over which ‘adjacency’ effects occur (Minomura et al., 2001). I think it would be worthwhile to discuss the role of the vertical distribution of the aerosol.

The issues of cloud base height and aerosol don’t seem insurmountable at least for measurements acquired in vicinity of A-train sensors. I think it would be beneficial to provide a sketch of how these additional measurements can be used to constrain these other factors and develop an operational parameterization.

References:

Partain, P. T., A. K. Heidinger, and G. L. Stephens (2000), High spectral resolution atmospheric radiative transfer: Application of the equivalence theorem, *J. Geophys. Res.*, 105(D2), 2163–2177, doi:10.1029/1999JD900328.

Doicu, A.; Efremenko, D.S.; Trautmann, T. A Spectral Acceleration Approach for the Spherical Harmonics Discrete Ordinate Method. *Remote Sens.* **2020**, *12*, 3703. https://doi.org/10.3390/rs12223703

Minomura, Mitsuo, Hiroaki Kuze, and Nobuo Takeuchi. “Adjacency Effect in the Atmospheric Correction of Satellite Remote Sensing Data: Evaluation of the Influence of Aerosol Extinction Profiles.” *Optical Review* 8, no. 2 (March 1, 2001): 133–41. https://doi.org/10.1007/s10043-001-0133-2.