We thank the two anonymous reviewers for their encouraging comments. Below, we explain how the comments are addressed and make note of the revisions in the revised manuscript. The reviewers' comments are in blue color. Our replies are in black, and our corresponding revisions in the manuscript are in red.

Responses to reviewer #1

I thank the authors for their response and careful consideration of my suggestions. Other than requesting more additional clarification on the MODIS product used which appears to require another product for comparison (please see below), I only have some minor suggestions to make regarding the inclusion of some of the details in the responses to the manuscript itself:

Reply: Thanks for your time and the encouraging comments. Please see our responses to your final comments below.

1) Regarding point #8, what version of MODIS is being used? Are the LWPs from Collection 5 or 6? The Platnick et al. 2003 reference is specifically about MODIS on Terra. The model observations should be compared to the MODIS product designed for comparisons with COSP as described by Pincus et al. 2012 which allows for apples-to-apples comparisons and also uses both Terra and Aqua.

Reply: Thanks for pointing this out. The MODIS LWP data we used were from Collection 5.1. Following your suggestion, we replaced it with the Pincus product. The overall conclusion regarding the LWP comparisons does not change. We added some descriptions regarding the Pincus product in the revised manuscript:

Line 542-548: "Two MODIS datasets are used, including the standard Collection 6.1 product (Pincus et al., 2012; P12) and Khanal et al. (2020; K20). The P12 product combines MODIS observations from Terra and Aqua and is designed for apples-to-apples comparisons with modelling results from the Cloud Feedback Model Intercomparison Project (CFMIP) Observation Simulator Package (COSP). The standard product has a well-known positive zonal bias that is strongly correlated with the solar zenith angle (SZA)."

The revised Figure 14 and its caption look as follow.

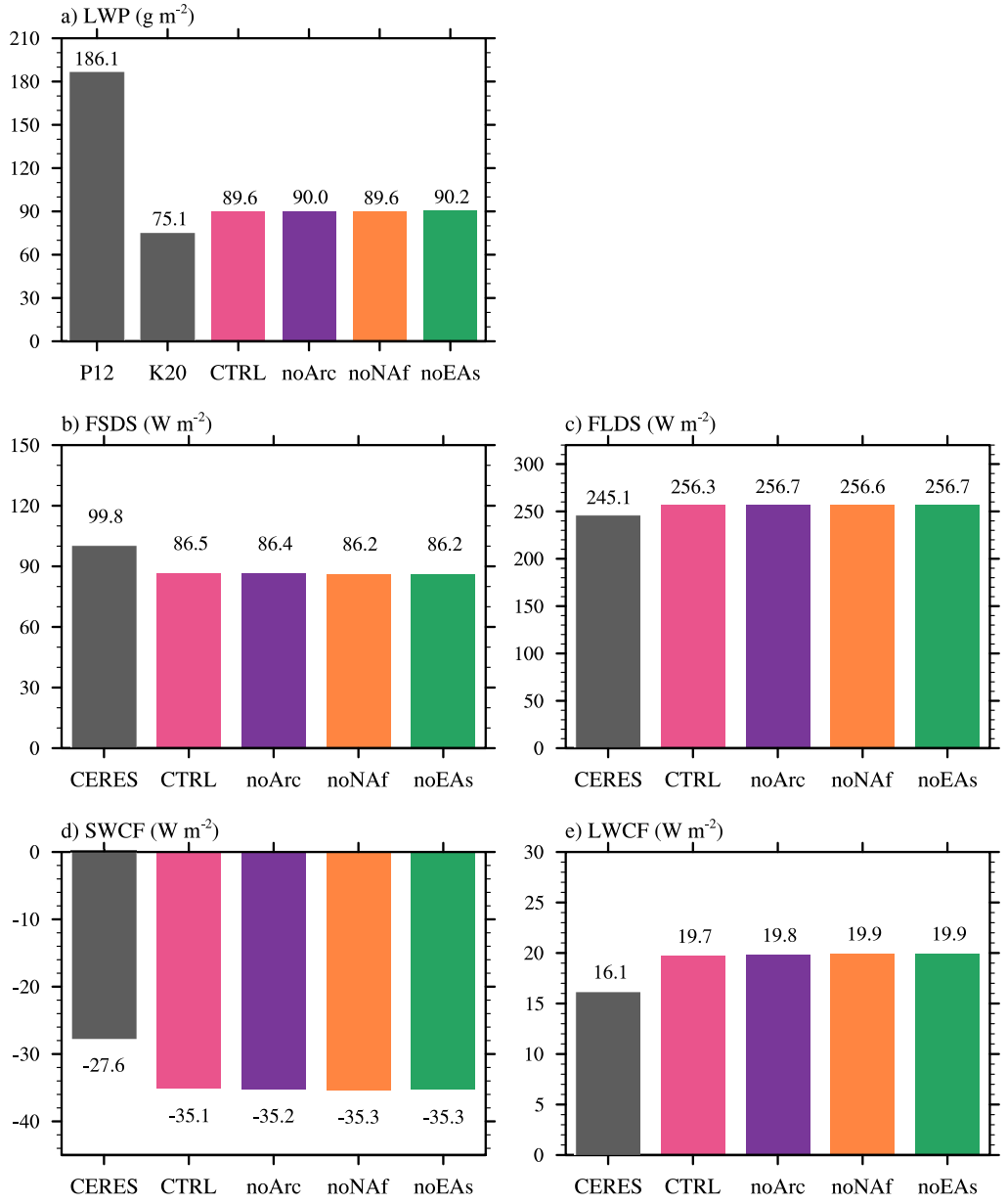

Figure 14. a) Annual mean Arctic (60°N to 80°N in this subplot) averaged LWP over ocean for the MODIS observations and the four simulations (2007-2008). Two MODIS datasets are used, including the standard product (Pincus et al., 2012; P12; averaged from 2007 to 2008) and an improved one (Khanal et al., 2020; K20; averaged from 2007 to 2009). The MODIS simulator is used to calculate the simulated LWP. b) - e) Annual mean Arctic (60°N to 90°N in these subplots) averaged b) FSDS, c) FLDS, d) SWCF, and e) LWCF for the CERES observation (2007-2011) and the four simulations (2007-2011).

Minor suggestions:

1) Regarding point #7, although the dominant role of wet despoliation is speculative, I think it is worth mentioning the authors' plausible explanation in the manuscript (understanding that it is beyond the scope of the manuscript to do a detailed analysis on this).

Reply: Thanks for the suggestion. We added a brief discussion regarding this issue in the revised manuscript:

Line 336-341: "For example, the wet removal process is expected to have large discrepancies among different models, because of the large uncertainties in the model representation of clouds and precipitation. The different spatial distributions of dust emission due to the use of different emission parameterizations may also contribute to the discrepancies (e.g., North Africa dust in our study contributes slightly less (51.9%) to the global dust emission than the other studies (from 57% to 67%)."

2) Also regarding point #8, please clarify what the bias in LWP is with respect to. Specifically, the Khanal product reduces the correlation between MODIS LWP and its dependence on large SZA near the poles. Please also include a brief description of how the Khanal product differs from the standard MODIS product, i.e. that the new method utilizes two parameters: the solar zenith angle and cloud heterogeneity index, both of which are available for each MODIS pixel.

Reply: We clarified this issue in the revised manuscript as follow.

Line 546-549: "The standard product has a well-known positive zonal bias near the poles that is strongly correlated with the solar zenith angle (SZA). The K20 product largely reduces this bias by utilizing the SZA and cloud heterogeneity index in their retrieval algorithm."

3) Regarding point #9 in response : "…CALIPSO, which significantly improves the detection of optically thin dust layer, especially in the Arctic" — improved compared to what? Please also include this information in the manuscript itself in addition to what was included on lines 266-268.

Reply: It is compared to the standard CALIOP Level 2 5 km layer products. More details can be found in Luo et al. (2015b) (see their Figure 3). We included this information in the manuscript.

Line 266-269: "This data set has improvements in dust separation from other aerosol types and thin dust layer detection in the Arctic compared to the standard Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) Level 2 product (Winker et al., 2013)."

Responses to reviewer #2

The authors did a thorough job with addressing my comments, I really like the revised version of the paper and recommend it for publication.

Reply: Thanks for your time and the encouraging comments. Please see our responses to your final comments below.

I only have one follow-up comment regarding Figure 5: You nicely added uncertainty bands to the other comparison figures for model results and observations. Is it possible to assign an uncertainty range to the CALIPSO observations as well?

Reply: We added the uncertainty bands to the CALIPSO retrievals in the revised manuscript. We assume the uncertainty bands for the CALIPSO retrievals to be 20% following Yang et al. (2022). The revised Figure 5 and the figure caption look as follow.

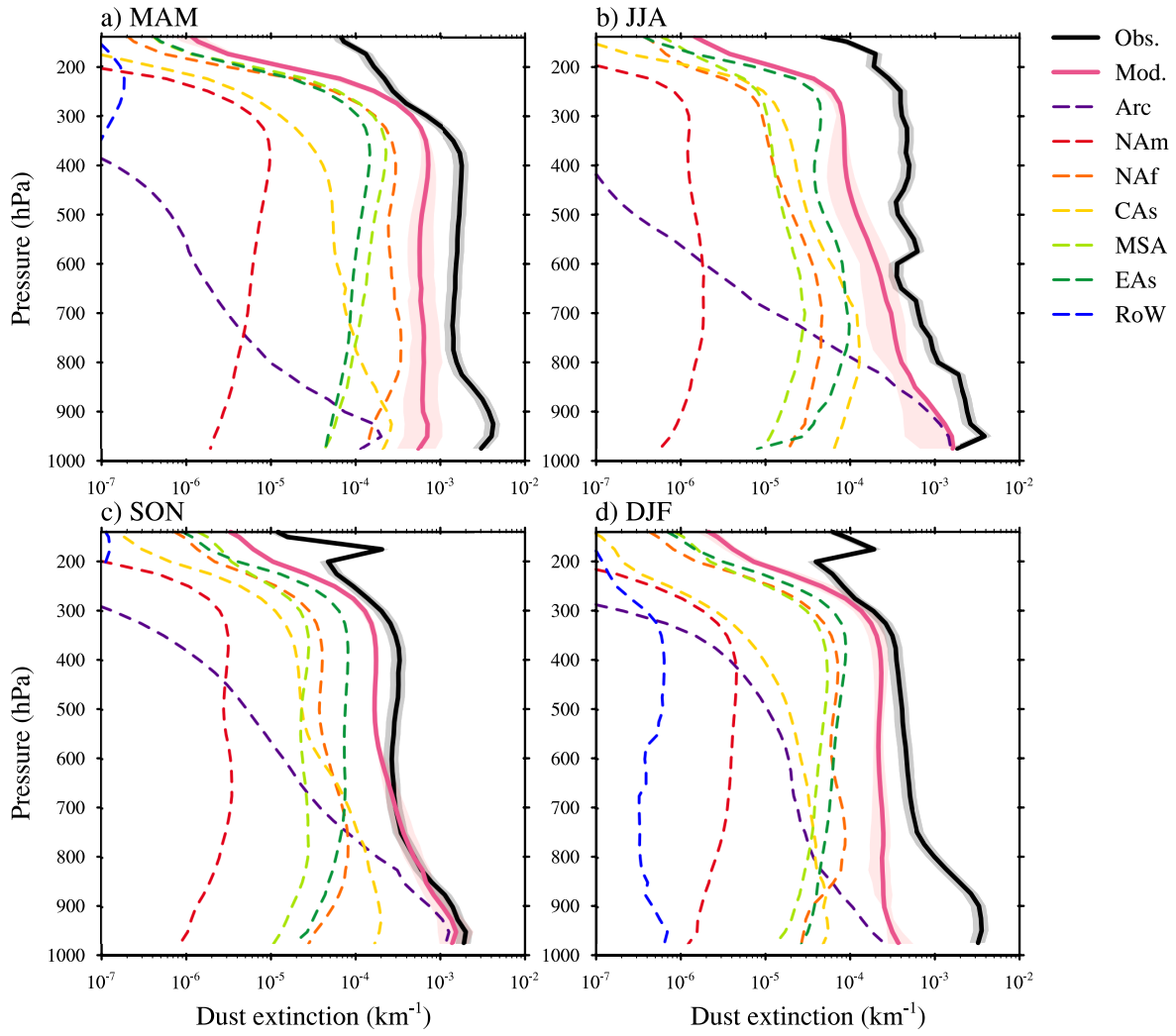

Figure 5. Comparison of seasonal CALIPSO retrieved (Luo et al., 2015a, b; Yang et al., 2022) (black solid line; with gray shade representing uncertainty) and model simulated (pink solid line; with pink shade representing year-to-year variability) dust extinction vertical profiles in the Arctic (above 60°N). Contributions from seven tagged sources are shown by colored dashed lines. The CALIPSO retrievals are for the year 2007 to 2009, while the model results are averaged over the same years. The uncertainties of the CALIPSO retrievals are assumed to be 20% following Yang et al. (2022).

And lastly, it is unfortunate that the new code developments cannot be made available due to DOE restrictions, but accept that this is not something that can be resolved within this review cycle.

Reply: We thank the reviewer for the understanding.