Reply to Anonymous Referee #2

We thank the reviewer for the comments and careful reading of the manuscript. We address the minor concerns in detail below.

1. *Page 2, Line 23: Change "aerosol distribution" to "aerosol size distribution".*

The text has been adjusted.

2. *Page 5, Lines 4-5: This sentence "The large-scale precipitation is described using variables like cloud cover and water content" is very ambiguous and it is not clear how this actually is distinct from that of convective precipitation. Cloud cover describes a sub-grid scale property of a cloud and I also assume that the large- scale precipitation is parameterised.*

LSP used for the wet deposition routine is derived from IFS variables coupled to TM5, being liquid/ice water content and cloud cover. In the new deposition scheme, this is extended by variables of falling liquid/ice precipitation, together with ice/liquid formation and evaporation.

However, aerosol transport and scavenging by convective precipitation uses a different approach and is based on entrainment and detrainment fields.

We have clarified the text as follows:

"Scavenging due to large-scale precipitation is derived from prognostic precipitation variables from IFS coupled to TM5, i.e. liquid and ice water content and cloud cover, extended in this work by the variables liquid and ice precipitation, precipitation formation and evaporation. Aerosol transport and scavenging by convective precipitation uses a different approach and is based on entrainment and detrainment variables of IFS."

3. *Page 5, Line 14: I assume that these are boundaries categorizing warm, mixed, and ice clouds. However, it could be more clearly stated.*

We have clarified the text. It now reads:

"In the current version, in-cloud scavenging is different for liquid, mixed and ice stratiform clouds (Stier et al., 2005). This distinction is based on the local temperature (Croft et al., 2010), where clouds are assumed pure liquid above $0^{\circ}C$ and pure ice below $-35^{\circ}C$. Between these boundaries, the clouds are classified as mixed as shown in Table 1."

4. *Page 5, the last line of the page: What do you mean by "partly"?*

'Partly' refers to the exponentially decreasing factor to scale down the scavenging efficiencies that compensates for the erroneous scavenging of the clear part of the grid box. In hindsight, this only confuses the text as it is introduced afterwards and has been removed. We have adjusted the description (see also reply to Reviewer 1, comment 4).

5. *A more appropriate location for Section 2.5 would be after the model description (at the end of Section 3).*

Following the advice of the reviewer, the paragraph describing the observational data has been moved to the end of Section 3.

6. *Page 11, Equation 10: Why do you calculate the mean density volume weighted as opposed to mass weighting?*

By definition of mass density being mass over volume, volume weighting has to be applied to correctly calculate the mean density of an internally mixed aerosol.

7. *Page 19, Line 7: I don't understand this sentence "This shows that a substantial part of the scavenged aerosol, has been scavenged and released before." Before what?*

'Before' points to a previous cycle of scavenging and resuspension. The sentence has been removed, as its message is the same as the next.

8. *Page 19, Line 12-14: Change "raindrops only release one aerosol" to "each raindrop re- leases one aerosol".*

The text has been adjusted.

9. *Section 4.3: Which MODIS product do you use?*

In this work, the combined Dark Target and Deep Blue retrievals of MODIS Level 3 monthly mean 1x1 gridded product is used. The text has been adjusted and now refers to the section describing the observational datasets.

10. *Page 20, the last line of the page: What do you mean by "a valid MODIS AOD"?*

Not all grid cells are assigned an AOD value in the MODIS product, i.e. in winter not enough sunlight is available for reliable retrievals. Model data in the affected grid cells are excluded for these instances in the calculation of the annual mean AOD.

The sentence has been changed to:

"Here, the (monthly mean) model values are only sampled for grid cells where MODIS AOD retrievals are available."

11. *Page 20: Why don't you collocate all time instances of the model AOD to when there is a MODIS observation (see e.g. Schutgens, N. A. J., Partridge, D. G., and Stier, P.: The importance of temporal collocation for the evaluation of aerosol models with observations, Atmos. Chem. Phys., 16, 1065-1079, https://doi.org/10.5194/acp-16-1065-2016, 2016.)*

We agree with the reviewer that collocation of model results with MODIS overpasses improves the evaluation. However, such a detailed analysis requires hourly output, slowing down the model considerably. Because the main focus of this work is to address the importance of including the effects of precipitation evaporation and introducing a method to implement this process in a global modal, the choice was made to produce monthly means from daily mean AOD to be compared to the monthly mean MODIS product. For a fair comparison that justifies complete collocation of the simulations and observations, other uncertainties of the aerosol emissions should also have to be addressed and the model would have to be re-tuned.

12. *Page 22, Figure 10: Please add the uncertainties of CALIOP observations to the figure.*

For the comparison with CALIOP retrievals we use the results derived in Koffi et al. (2012). These data are stored as a benchmark on the Aerocom website http://aerocom.met.no/databenchmarks.html). These data are grouped by season and do not include uncertainty estimates. Since we do have data for a number of years, the spread between the years can be used as an indication for uncertainty. The figure has been adjusted to include the maximum and minimum seasonal mean AOD value found in the benchmark data (see Figure below).

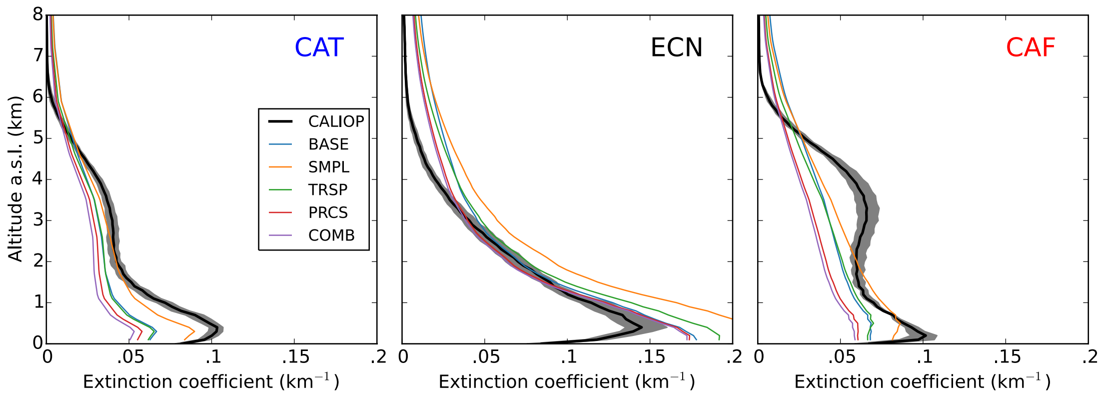

Figure 10. Summer season (JJA) mean extinction coefficient (km^{-1}) profiles for 2005 (models) and 2007-2009 for CALIOP observations in the Central Atlantic (CAT), Eastern China (ECN) and Central Africa (CAF) regions as used in Koffi et al. (2012). The grey shaded area indicates the spread between minimum and maximum seasonal values in the CALIOP observations.

13. *Page 22, Line 29: What do you mean by small aerosols? The aerosol particles that are the most efficient scatterers of 550 nm solar radiation are few hundred nanometers in diameter while the smallest particles have a very small radiative effect.*

As the reviewer justly points out, the term 'small' here is ambiguous. Small here would refer to any aerosol smaller than the M7 coarse mode. Because of the scale gap in number concentration between aerosols and raindrops, virtually all resuspensded aerosols are returned to this M7 coarse mode. Aerosols of these sizes are on average less effective scatterers than the smaller-size particles they originate from before scavenging. The sentence has been adjusted to:

"This has an impact on the AOD evaluated at 550 nm because the coarse sized aerosols are less effective in scattering incoming solar radiation than the smaller-size particles they originate from."

14. *Page 22, Line 37: what do you mean by "relative magnitudes"?*

'Relative magnitudes' refers to the magnitude of the extinction coefficients in the different regions, which are relatively well reproduced by the model.

The sentence has been adjusted:

"Model performance differs depending on the region, but vertical profile shape and the difference in magnitude of the extinction coefficient between the regions are captured well."

15. *Page 23, Line 15: what do you mean by "underlying patterns or mechanisms"? How do you deduce that they don't have any major errors?*

'Underlying patterns' refers to large-scale wind patterns or (global) distribution of emission regions. The exponentially decreasing pattern in the ECN region really points to a local source. If the dominant aerosol source would be outside the region, this would show up in a pattern similar to the CAT and CAF region.

The text has been adjusted: 'underlying large-scale meteorological and/or emission patterns, as these would change the shape of the extinction profile.'

References

Croft, B., Lohmann, U., Martin, R. V., Stier, P., Wurzler, S., Feichter, J., Hoose, C., Heikkilä, U., van Donkelaar, A., and Ferrachat, S.: Influences of in-cloud aerosol scavenging parameterizations on aerosol concentrations and wet deposition in ECHAM5-HAM, Atmos. Chem. Phys., 10, 1511–1543, https://doi.org/10.5194/acp-10-1511-2010, 2010.

Koffi, B., Schulz, M., Bréon, F.-M., Griesfeller, J., Winker, D., Balkanski, Y., Bauer, S., Berntsen, T., Chin, M., Collins, W. D., Dentener, F., Diehl, T., Easter, R., Ghan, S., Ginoux, P., Gong, S., Horowitz, L. W., Iversen, T., Kirkevåg, A., Koch, D., Krol, M., Myhre, G., Stier, P., and Takemura, T.: Application of the CALIOP layer product to evaluate the vertical distribution of aerosols estimated by global models: 5 AeroCom phase I results, J. Geophys. Res. Atmos., 117, n/a–n/a, https://doi.org/10.1029/2011JD016858, d10201, 2012.

Stier, P., Feichter, J., Kinne, S., Kloster, S., Vignati, E., Wilson, J., Ganzeveld, L., Tegen, I., Werner, M., Balkanski, Y., Schulz, M., Boucher, O., Minikin, A., and Petzold, A.: The aerosol-climate model ECHAM5-HAM, Atmos. Chem. Phys., 5, 1125–1156, https://doi.org/10.5194/acp-5-1125-2005, 2005.