

**Response to the reviewer**  
**24-01-2023**

Topical Editor review of "Incorporation of aerosols into the COSPv2 satellite lidar simulator for climate model evaluation", by Marine Bonazzola et al.

This manuscript describes the incorporation and testing of a "lidar simulator" module within the CF-MIP Observation Simulation Package (COSP), progressing the existing COSP concept to additionally enable General Circulation Model to evaluate simulated aerosol profiles, compared to the extensive information gathered from satellite-borne lidar measurements such as CALIOP.

Two reviewers have provided reviews on the submitted manuscript, both confirming the manuscript to be within scope for publication in GMD. The reviewers have provided a set of minor revisions, mainly aimed at improving the manuscript's communication of the necessarily quite-complicated specifics of the sampling and aerosol attenuation calculations that enable a General Circulation Model's simulated aerosols to be evaluated consistently with that observed from space-borne lidar.

The authors have replied to each of the reviewer comments, and made appropriate revisions to the text, and the manuscript is improved as a result, now close to being ready for publication in GMD.

From reading the track-changes manuscript, I noticed however that there are still quite a few places where the wording could still be improved, and have provided below a pre-final list of minor revisions to further sharpen up the text.

The only 1 of these revisions that requires some explanation, is in relation to the text in the revised manuscript still tending to refer to "CALIPSO" when it should refer to "CALIOP". If the text is referring to a satellite orbit, then it is correct to refer to "CALIPSO", since this is the name of the satellite. But there are multiple cases where the text refers to "CALIPSO data", when this should be clear it's the data from the CALIOP lidar instrument, that being only one of the instruments on the CALIPSO satellite.

The acronym CALIPSO stands for "Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation", and in addition to the CALIOP cloud-aerosol lidar, the CALIPSO satellite also hosts for example an imaging infra-red radiometer to measure cirrus cloud emissivity and particle size (see for example the information here [https://calipso.cnes.fr/en/CALIPSO/GP\\_iir.htm](https://calipso.cnes.fr/en/CALIPSO/GP_iir.htm)).

In my initial Topical Editor review, I corrected some of the instances where the term CALIPSO was used when CALIOP should have been stated. But it's clear that the revised manuscript, including in the Observation section (lines 18 to 40 of page 8 of the author track-changes manuscript), the text still refers to CALIPSO, when it is referring to the CALIOP lidar (on the CALIPSO satellite).

The other minor revisions refer to improving the initial sentences of the

Abstract, some parts of the Introduction and to improve the new Table 1 (page 7 of the ATC-manuscript) the authors added to explain the sub-scripts 1, 2, 3 and 4 in the variable names used in the code, as requested by reviewer 1.

Once the authors have revised the manuscript to address these remaining minor issues, the manuscript can then proceed to publication in GMD.

#### Remaining minor revisions

-----

1) Abstract, lines 1 & 2 -- the authors have addressed reviewer 2's request to change the term "aerosols" instead to "aerosol", but the grammar of the sentence from the plural "aerosols" now does not read correctly with the change to simply "aerosol".

Whilst reviewer 2 was correct to request this change (avoiding the term "aerosols"), the sentence should also be adapted to be correct for the new singular word, even though technically the word "aerosol" can be considered to refer to different types of aerosol with the aerosol.

To further clarify the issue, my recommended change here is to, for this initial overarching sentence, add also the word "atmospheric" prior to "aerosol".

I'm also requesting, considering the size distribution of the particles is one aspect of the science related to the lidar emulator, to avoid the word "large" in this context of the magnitude of the impacts on climate, suggesting to refer instead to "substantial impacts".

The requested change then, is to replace the current text "Aerosol have a large impact on climate, air quality and biogeochemical cycles" instead with "The atmospheric aerosol has substantial impacts on climate, air quality and biogeochemical cycles".

I am also suggesting to make the current very short 2nd sentence instead be a continuation of this short first sentence, changing ". Their concentrations are..." instead to ", and its concentrations are...".

With both of those changes, the recommendation is to make the first sentence of the Abstract be, "The atmospheric aerosol has substantial impacts on climate, air quality and biogeochemical cycles, and its concentrations are highly variable in space and time."

*Done (see lines 1-2) : **Abstract** *The atmospheric aerosol has substantial impacts on climate, air quality, and biogeochemical cycles, and its concentrations are highly variable in space and time.**

2) Abstract lines 2 to 3 -- using a possessive determiner such as "their" is not really appropriate in this formal scientific context, particularly in these initial sentences of the Abstract. In changing the wording, I'm requesting to make this 2nd sentence start to refer to the simulation of aerosol in models, this being the main application within the manuscript's topic.

#### Request to change

"A key variability is in their vertical distribution, because it influences..."

instead to

"A key variability to evaluate within models that simulate aerosol is the vertical distribution, this influencing..."

*Done (see lines 2-5 p1) : A key variability to evaluate within models that simulate aerosol is the vertical distribution, this influencing atmospheric heating profiles, and aerosol-cloud interactions, to help constrain aerosol residence time, to better represent the magnitude of simulated impacts.*

3) Abstract, lines 3 to 4 -- the text correctly points out the vertical distribution influences atmospheric heating profiles and aerosol-cloud interactions, but continuing also to "aerosol lifetime" is not correct with that sentence construction. The sentence then refers to the vertical profile having an influence on aerosol lifetime, but it's rather that the vertical profile is indicative of a particular aerosol lifetime. I'd also advise to use the term "residence time" rather than "lifetime".

The end of this sentence also needs re-wording because the "as a result" is not quite correct either, since aerosol concentrations at the surface are probably less affected by residence time than those aloft -- so the surface concentrations are not really the correct aspect to refer to in relation to changes in aerosol lifetime/residence-time.

My suggestion here is to have the text refer to changes in the lifetime affecting the strength of the effects referred to in the 1st sentence.

And the specific suggested re-wording is then to change

", aerosol-cloud interactions, aerosol lifetime and, as a result, surface concentrations"

instead to

"and aerosol-cloud interactions, to help constrain aerosol residence time, to better represent the magnitude of simulated impacts."

*Done (see lines 2-5 p1) : A key variability to evaluate within models that simulate aerosol is the vertical distribution, this influencing atmospheric heating profiles, and aerosol-cloud interactions, to help constrain aerosol residence time, to better represent the magnitude of simulated impacts.*

4) Introduction, page 2 lines 36 to 39 -- I do not understand why the authors have chosen to talk about these specifics for configuring a general circulation model: nudging, fixed sea-surface temperatures or interactive ocean. Firstly the nudging capability within a model does not preclude it from having fixed sea-surface temperatures, so the text is not quite right where it refers to these as different configurations. Secondly, and most importantly, this referring to these different configurations of a general circulation model is irrelevant to the description of the lidar emulator described in the manuscript, and including this only serves to divert the focus of the reader.

Including some discussion on page 3 from lines 1 to 9 is OK, but constructing these in this way suggests they are alternative configurations, which is not the case, (the nudging to re-analysis can be applied whether the model is using fixed SST or coupled to an interactive ocean).

Having this single-sentence paragraph on lines 36 to 39 will also seem strange when the accepted manuscript is type-set, and my suggestion here is to delete the text on lines 37-39 of page 2 of the revised manuscript. And instead have the re-worded sentence be the 1st sentence of the next paragraph, i.e. join up with the text on line 41.

Referring to "the closer bridge between observations and models" I'm suggesting should instead have the re-worded sentence refer to the observational constraints the satellite lidar measurements provide.

Specifically, I suggest to re-word the current sentence starting on line 36 instead to "These studies point to the potential for satellite lidars to provide important constraints for the aerosol distributions in climate models, of benefit to a range of different configurations."

*Done (see lines 36-37 p2) : These studies point to the potential for satellite lidars to provide important constraints for the aerosol distributions in climate models, of benefit to a range of different configurations.*

5) Introduction, page 2 line 41 -- with the lines 36-39 reworded to the shorter sentence above, and now referring to constraints, delete "the constraints of" from this sentence, changing the start of the sentence from "First, the constraints of 15 years of ..." instead to "The 15-year record of..."

Further to my general comments above, it's important to be clear here that CALIOP is the name of the lidar, and CALIPSO is the name of the satellite.

And with that re-wording, insert "the space-borne CALIOP lidar on" after "15-year record of", and insert "satellite" after "Satellite Observations (CALIPSO)".

The current sentence is already a bit too long, and then with making the wording clarify this common misunderstanding of CALIPSO being the name of the lidar, the suggested re-wording is to split this into 2 sentences, the first reading:

"There is now a 15-year record of the space-borne CALIOP lidar on the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite (2016-2020)."

*Done (see lines 37-39 p2) : There is now a a 15 year-record of the space-borne CALIOP lidar on the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite (2006-2020).*

The second sentence can then refer to the utility of this re: the evaluating transport and removal processes in models, changing the wording then to continue after that, as:

"In evaluating the simulated vertical aerosol distribution, these measurements can provide important observational constraints to improve transport and removal processes in models."

And then change ", when those observations are.." instead to re-start another new sentence, adding "satellite lidar" there -- i.e. "When the satellite lidar observations are..."

*We rephrased this part as (see lines 39-42 p2) : In evaluating the simulated vertical aerosol distribution in nudged simulations where e.g. winds are relaxed towards reanalyses, these measurements can provide important observational constraints to improve transport and removal processes in models.*

6) Introduction, page 3, line 33 -- Change the "within the COSPv2 to leverage.."

instead to "within the COSPv2 software package to leverage.." and change to past tense (since that is already done) -- then "We choose to implement" instead written as "We have chosen to implement..." -- it's just easier for the reader to appreciate what the sentence is aiming to communicate there.

*Done (see lines 31-32 p3) : We **have chosen** to implement the lidar aerosol simulator within the COSPv2 **software package** to leverage all the simulator capabilities available in COSPv2.*

7) Section 2.1, line 9 -- the justification here of the text is incorrect, please correct this so that it does not stretch the text to the end of the line.

*Done, see line 7 p4.*

8) Section 2.1, lines 21-22 -- change "which determines the refractive index of the medium" instead to "the latter determining its refractive index."

*Done, see lines 17-18 p4 : The 180° backscatter and extinction coefficients for aerosol depend on the microphysical properties (size distribution) and chemical composition of the particles, **the latter determining its** refraction index.*

9) Section 2.1, lines 12-14 -- This sentence needs to be clearer here, please re-word the current "The optical properties computed by the GCM can be directly the extinction and 180o backscatter..." instead to "The aerosol optical properties computed in GCMs varies, with some models having diagnostics for single-wavelength extinction and 180o backscatter..."

Suggest to have this sentence continue to the key difference, that some models don't calculate these -- calculating only the waveband-integrated optical properties (extinction, absorption and phase function). Note that the current text refers to both "absorption" and "single-scattering albedo" but those are just different measures of essentially the same property.

In summary, the correction is to change the current sentence

"The aerosol optics diagnostics in GCMs vary, with some models computing single-wavelength extinction and 180o backscatter, whilst others calculate only the waveband-integrated aerosol optical properties (i.e. extinction, absorption and phase function).

With that re-wording the existing wording " which can be used to compute the ATB" can be deleted.

*Done, see lines 6-9 p 5 : **The aerosol optics diagnostics in GCMs vary, with some models computing single-wavelength extinction and 180° backscatter, whilst others calculate only the waveband-integrated aerosol optical properties (i.e. extinction, absorption and phase function).***

10) Section 2.2, page 5, lines 17-19 -- Replace "at a given wavelength:" with "monochromatically (i.e. at specific wavelengths):" and replace ", which are typical outputs" instead with ", these being standard wavelengths". On lines 21, also change "may also" to "could also", and delete "inputs for".

Done, see lines 11-14 p5 : These coefficients must be defined *monochromatically* (i.e. at specific wavelengths) : 532 and 1064 nm for CALIPSO/CALIOP, these being standard wavelengths for most GCMs. Coefficients defined at other wavelengths, such as 355nm for EarthCare/ATLID, could also be added as additional diagnostics.

11) Section 2.2, page 5, lines 23-24 -- I do not understand why this sentence has been added here. Is this sentence referring to an example in the code?

In my opinion this is not so relevant to the GMD article, and I would actually suggest to delete this sentence altogether. Or if this is referring to the data shown in the Figure, please integrate "shown in Figure 2" or similar into the sentence.

We added the sentences : "In the steps listed below, it is assumed that the process applies to a vertical profile, and that it is repeated for all longitude-latitude grid cells and for each instantaneous model output. In this study, the model writes out at 1:30 am and 1:30 pm local time, corresponding to the CALIPSO overpass time" in the previous version of the paper because it was a request of one of the reviewers. Indeed the points 1 to 6 listed below are repeated for each grid cell and for each instantaneous model output (ie twice a day at the satellite observation times). So we preferred not to delete these sentences in the current version.

12) Page 7, Table 1 -- There needs to be text added to an upper row of the Table to explain what is shown in each of the columns in the Table.

For example in the far-left column in new upper row, the text needs to state "Variable sub-script in article" or similar, with the 2nd-from-the-left stating "Description of variable" or similar. These 2 labels could be added in the existing upper row (in the far-left and 2nd-from-left boxes that are currently blank). But there does need to be a new upper-row added at the top of the Table, and suggest to have a banner stretching across the 3 right-hand columns stating "Name of variable in code", or if there is space (which there should be, with stretching across those 3 columns) "Name of variable in lidar simulator code".

Please change "Correspondence between.." instead to "Translations between.." and also correct the typo in the caption to the Table, at the far-right end of the 1st line (change "FOr" (or is it "F0r"?) instead to "For").

The table and its caption have been modified according to the reviewer's suggestions, see p7. We preferred to write in the upper row "Name of variable" instead of "Name of variable in code" as the names of variables in code are specifically the 12 table cells of the right-lower corner of the table.

13) Page 8 -- this is where I found several instances of "CALIPSO" that should be stated as "CALIOP" when referring to the measurements, or to the instrument.

13.1) Page 8, line 4, change "CALIPSO" to "CALIOP"

13.2) Page 8, line 7, change "CALIPSO" to "CALIOP"

13.3) Page 8, line 22, change "CALIPSO" to "CALIOP"

13.4) Page 8, line 23, change "CALIPSO" to "CALIOP"

13.5) Page 8, line 26, change "CALIPSO" to "CALIOP"

13.6) Page 8, line 28, change the two instances of "CALIPSO" both to "CALIOP"

*CALIPSO have been every time changed to CALIOP. As it is mentioned by the reviewer, we refer to the instrument and not to the satellite.*

14) Page 8, line 35, change "As each" to "Since each"

*Done, see line 36 p8.*

15) Page 8, line 39, change "simulations, to identify" to "simulations, then able to detect".

*Done, see lines 39-42 p8 : which permits the use of a lower aerosol detection threshold in both observations and simulations, **then able to detect** optically thin aerosol layers at the 20 km spatial scale (Ma et al. 2018).*

16) Page 9, lines 1-6 -- the new text added here is not clear enough re: this gridded data product -- this is an "example gridded data product", right?

16.1) Page 16, line 1 -- change "a gridded" to "an example gridded"

16.2) Page 16, line 1 -- add a comma after "consisitent with the GCM grid"

16.3) Page 16, line 2 -- change "the model and the simulator results can" instead to "the translation from the model to the simulator results can"

16.4) Page 16, line 2 -- change "be evaluated against the observational data" instead to "be more easily understood by the reader, in relation to how it can affect the interpretation of an comparison to the CALIOP observation profile".

*Done, see lines 1-4 p9 : In this study, we created **an example** gridded data product from CALIPSO that is consistent with the GCM grid, so that the **translation from the model to the simulator results can be more easily understood by the reader, in relation to how it can affect the interpretation of a comparison to the CALIOP observation profile.***