

# ***Interactive comment on* “Evaluation of aerosol and cloud properties in three climate models using MODIS observations and its corresponding COSP simulator, and their application in aerosol-cloud interaction” by Giulia Saponaro et al.**

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We would like to thank the referee for carefully reading our paper and for the helpful comments and suggestions. We have modified the manuscript according to these suggestions, and detailed answers to each comment are listed below. The reviewer comments are in italic and our answers are in normal font. In the modified manuscript the changes are shown in red font. The modified manuscript can be found from the supplement material of this post.

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## Major comment:

*The methods section admits that the MODIS Angstrom Exponent product (used in the C1 ACPD Interactive comment Printer-friendly version Discussion paper Aerosol Index [AI] calculation) is not calculated over land due to its low data quality in these locations. However, Figure 5 still shows MODIS AI values over land. Why is this? In Levy et al., 2013, which describes the collection 6 Dark Target product, it says, “On a global basis, we and others have found little quantitative skill in MODIS-retrieved aerosol size parameters over land (e.g., Levy et al., 2010; Mielonen et al., 2011). We have decided to discontinue further attempts at validating Ångström Exponent (AE) and fine-AOD. A user can still choose to derive AE (from spectral AOD) or fine-AOD (from product of  $\tau \eta$ ) and evaluate the results themselves.”*

*Levy et al. 2013: <https://www.atmos-meas-tech.net/6/2989/2013/amt-6-2989-2013.pdf>*

*Levy et al. 2010: <https://www.atmos-chem-phys.net/10/10399/2010/acp-10-10399-2010.pdf>*

*So did you calculate AE from the spectral AOD over land? Is this any good? Is there any value to compare MODIS AI to the model's AI over land if MODIS AE over land does not have skill? I think that the AI values over land should be removed from Figure 5 and discussion unless these values are tested against e.g. AERONET.*

Author response:

We agree with the reviewer that the use of MODIS AI over land has not carefully been explained in the manuscript. The Ångström exponent over land was derived from spectral AOD. Although the resulting AI over land is shown in Figure 5, the values are not used for the calculation of mean values in Table 1 not in the calculation of ACI (Figure 8). For these reasons, the author agrees with the reviewer: AI over land is masked out from Figure 5 and from the discussion section. Furthermore, the text now clearly states that AI excludes values over land.

Changes:

Figure 5 and Figure 7 were updated and replaced. The text describing the figures and

the results were updated throughout the manuscript.

***Specific comments:***

*P2 L16: I'd remove "primarily" here as climate models serve many purposes.*

Author response:

Accepted.

*P3 L16-17: This sentence makes it seem like ISCCP is itself a cloud simulator. However, ISCCP is much broader than this, and foremost it has observational data products. Could say "are the simulator developed as part of the of International Satellite. . ."*

Author response:

Accepted. Sentence modified as suggested.

*P3 L23 and many places throughout: The clause following "which" is a non-restrictive clause (it does not help specify which simulator you're writing about and only provides additional information about it), which means there should be a comma before "which". If it were a restrictive clause, it would continue to not have a comma, e.g., "We use the cloud simulator which was developed as part of CMIP" (the clause after "which" is necessary to know the specific simulator you are referring to). I found many non-restrictive clauses throughout that did not contain commas, so please update. <http://www.cws.illinois.edu/workshop/writers/restrictiveclauses/>*

Author response:

Clause updated at P7, L14; P9, L24; P10, L2, L19 and L24; P14, L9; P15, L18; P18, L34.

*P3 L24: Should these acronyms be defined here?*

Author response:

Accepted. Acronyms have been included and the sentence has been rephrased as: "COSM is a software tool developed within the CFMIP (Webb20 et al., 2017), which extracts parameters for several spaceborne active sensors, such as the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) and the Cloud Profiling Radar (CPR), as well as for passive sensors, such as the Multi-angle Imaging Spectro-Radiometer (MISR) and the Moderate Resolution Imaging Spectroradiometer (MODIS).

*P3 L33: I'm generally used to AIEs specifically referring to the radiative effects of ACIs rather than being a synonym for ACIs in general, as AIE is presented here.*

Author response:

The nomenclature describing the aerosol-cloud-radiation interaction has been changing throughout the years and the IPCC 5AR (IPCC2013) introduced the new terminology which is used in the manuscript.

Changes: the acronym AIE is not used and the abbreviation AIE has been removed from the text.

*P4 L20: Although Koren et al., 2007 is cited at the end of the sentence, it seems jargony to list "twilight zone" without definition. May be more clear to replace with "near-cloud impacts on radiative transfer".*

Author response:

Accepted. The sentence has been modified as suggested: "The primary artifacts known to affect satellite estimation of aerosol-cloud interactions are related to (1) the inability of untangling aerosol and cloud retrievals from meteorology (e.g. aerosol humidification, entrainment, cloud regimes dependency), (2) inaccuracies in the retrieval algorithms (e.g. near-cloud impacts on radiative transfer, contamination, statistical aggregation) and (3) assumptions in the retrieval algorithms (Koren et

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al.,2007; Oreopoulos et al., 2017; Christensen et al., 2017; Wen et al., 2007)."

*P5: I'm confused as to why the MODIS L2 products are discussed in detail after it is stated that L3 products were using in the paper. I assume it is because the L3 product is built from the L2 product (which is stated), but it would be good to make it clear why the L2 products are discussed in detail.*

Author response:

The sentence was expanded to explain why MODIS L2 data are described. The new sentence is: "As the L3 1 x 1 gridded average values of atmospheric properties, along with a suite of statistical quantities, are derived from the corresponding L2 atmosphere data product, a brief description of Level-2 MODIS aerosol and cloud products is now presented."

*P5 L22-: Which aerosol product(s) are you using? Just the Dark Target product or also Deep Blue? I assume MAIAC is not used since it says the spatial resolution is 10x10km. It looks like the Dark Target - Deep Blue combined product is used in Figure 5 based on there being AOD information over deserts etc.*

Author response:

Indeed the combined product Dark Target - Deep Blue is used in this study.

*P5 L27: Here it says that AE is only derived over ocean, which is correct, but why does AI have land values in Figure 5? See Major Comment above.*

Author response:

See Author response to Major Comment.

*P7 L19: How are the model fields downscaled? It seems like there would be a lot of necessary assumptions to break a partially cloudy coarse gridbox into finer*

*subcolumns. These assumptions should affect the results in theory. At a minimum, please add a statement such as, "details of this downscaling process and assumptions are provided in XX", assuming that this process has been documented elsewhere. If these details haven't been documented, please do so here or in the supplement.*

Author response:

The following sentence citing the proper documentation has been added at P7, L25-L26: "A comprehensive explanation about the methodology and results of the COSP MODIS simulator is presented in Pincus et al. (2012)."

*P8 L4: "...referred to \*here\* as. . ."*

Author response:

Accepted.

*P8 L23-25: This sentence didn't make sense to me. Please rewrite for clarity.*

Author response:

The sentence was to explain that instantaneous output cannot be used with the implementation of the COSP satellite simulator in ECHAM-HAM. The sentence was rewritten to:

"The output of the COSP satellite simulator is also three-hourly. The implementation of the COSP satellite simulator in ECHAM-HAM does not allow instantaneous output. The COSP satellite simulator is called every radiation time step (i.e. every two hours) and the output of the COSP satellite simulator is averaged over the three hourly output period. This means that on average 50% of the values in the output of the COSP satellite simulator are instantaneous values (i.e. from only one time step) and 50% of the values are an average over two radiation time steps (i.e. an average over two instantaneous values which are two hours apart)."

*P8 L29: M7 should be mentioned/discussed in the previous subsection on*

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*ECHAMHAM (without SALSA).*

Author response:

A brief description of M7/HAM was added: "Aerosol microphysical processes such as nucleation, coagulation, condensational growth are computed by the modal scheme M7 (Vignati et al, 2004). HAM computes further processes such as emissions, sulfur chemistry (Feichter et al., 1996), dry deposition, wet deposition, sedimentation, aerosol optical properties, aerosol-radiation and aerosol-cloud interactions."

*P9 L20: What does "aerosol life cycle scheme which calculations production tagged mass" mean? Is this an aerosol microphysics scheme? Does it track aerosol composition by its emission/process source in addition to chemical composition? Please rewrite for clarity.*

Author response:

We have rewritten and expanded the description of the aerosol scheme to improve clarity as follows: "The aerosol microphysics scheme in the NorESM version of CAM, called CAM-Oslo, consists of 12 log-normally shaped background modes which are tagged according to emission source and chemical composition (Kirkevåg et al., 2018). The shape of these modes can change due to condensation and coagulation."

*P9 L34: Reference is missing a year.*

*P11 L22: "CER" isn't defined until below.*

Author response:

The acronym CER is already introduced at P6, L34.

*P12 L24-25: Is there a figure that we should be looking at to see these biases?*

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We included the reference to the corresponding figures.

*P13 L26: Do you specifically mean the \*model\* datasets here, or is the MODIS data being lumped into this comparison too.*

Author response:

Indeed we referred to the model datasets. The sentence was modified as suggested: "The spatial distribution of the cloud physical and optical properties is remarkably similar among the model datasets with the exception of CER<sub>ice</sub>, IWP (Fig. 2 d and l) and COT (Fig. 3g,k)."

*P15 L22: It seems very subjective to say that a bias of -0.2 is "quite close" given that most of the globe has an AI below 0.2 according to MODIS (so this bias is larger than the AI value in nearly all locations. (Also, most of the locations with AI > 0.2 are over land, where we should not trust the Angstrom Exponent).*

Author response:

The sentence was unclear. The author meant that a similar bias is shown by the three models, as each bias is on average about 0.2. The sentence has been rephrased as: "The biases between values of AI from directmodel output and MODIS observations are quite close among the model as their average is about of +0.2."

*P17 L9: There is a discussion here about AI over land, but there is no acknowledgement that the MODIS aerosol team does not publish AE over land.*

Author response:

The following sentence was added: "As these negative values are derived over land regions, it could be indicative of retrieval biases over bright surfaces (i.e. snow or ice). Furthermore, it is important to inform the readers that MODIS aerosol size parameters over land (i.e. AE or fine-AOD) are no longer official products directly provided by the MODIS aerosol team. The publication of these variable were discontinued due to low



quantitative MODIS skill (Mielonen et al., 2011; Levy et al., 2013). Using spectral AOD, we derived AE over land and derived AI on a global scale to allow estimates of ACI on a global scale (Fig.S4). However, the AE values over land were not evaluated."

*P18 L25-26: "possibly owing. . ." onward. It is unclear to me what this is saying.*

Author response:

The sentence has been updated accordingly to the new version of Figure 7.

*P19 L3-4: What is the difference between "model calculation" and "cloud parameterization". These seem like synonyms? Or is the "model calculation" specifically referring to the COSP simulator (rather than the atmospheric model).*

Author response: The terms "model calculation" and "model parametrization" describe different aspects of atmospheric modeling. While the term "model calculation" refers in the sentence to the COSP simulator, the term parametrization refers to the climate model. In particular, the latter term is used to describe the approach implemented in any atmospheric model to simplify too complex or too detailed processes to be explicitly resolved within the model.

*P19 L22: How does one select dry aerosols when using satellite-derived properties? Or is this a statement of when using modelled properties only?*

Author response:

The sentence refers to the study that Neubauer performed, using the model ECHAM-HAM.

The sentence has been rephrased in the manuscript as follows: "The results highlight that a minimum distance between cloud and aerosol gridded data should be taken into account in the analysis of satellite data, and that dry aerosols should be selected to reduce the influence of aerosol growth due to humidity for model simulations when comparing satellite-based and model estimates for ACI."

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*P19 L34-35: What property is being underestimated?*

Author response:

Cloud fraction is the parameter omitted in the sentence. The sentence has been rephrased as: "We highlighted many discrepancies in cloud spatial and vertical representations and the results showed that the three models overall similarly underestimate cloud fraction for the stratocumulus cloud regime being when compared to MODIS."

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