Anonymous Referee #2

Summary: The MISR Joint aerosol (JOINT_AS) level 3 products are a descriptive summary of the MISR Level 2 aerosol product. This paper evaluates the statistics of aerosol optical depth (AOD), as a function of different aerosol classes (non-absorbing, absorbing and non-spherical). The JOINT_AS products are compared with statistics of Spectral RadIatioN-TrAnSport (SPRINTARS) model results, and are shown to agree well.

: We would like to thank the reviewer for the constructive comments. As indicated in the following responses, we have incorporated all these comments into our new revision. Comments are listed first, followed by replies. Please note that the brown text inside parentheses is from the revised version and the red text shows changes from the previous version.

Overall: This is an interesting paper, and potentially very important for the aerosol community (thinking AEROCOM here). The paper is nice because it is relatively short. Of course, being short, there are loose ends. I would have really liked a comparison of three things, MISR, model, and some sort of ground-based data, preferably in-situ. Although the authors reference MISR vs AERONET comparisons, I think a three-way comparison (MISR/SPRINTARS/AERONET) would have made sense here.

: We agree with the importance of using in-situ measurements in our work. The observation period is limited, but the total AOD from AERONET is compared with MISR and the two chemistry model results (GOCART and SPRINTARS) in the revised manuscript. Please see revised Figures 2, 3, 4 and 6.

Also, why SPRINTARS model (as opposed to a different model)? And why only one week during July? I am wondering if using the 7km model (to compare with 17.6 km MISR) is not the best use of the model (why not 14 km, or 21 km?) I am just not satisfied with the amount of comparison; the paper begs another paper. On the other hand, if only going to use one week in July, then really focus on that one week only, and don't make assumptions about other years. For an ACP paper, I generally like to see something with more insight. Yes, it is hard to compare models and retrievals. What I see is the beginning of useful study, but only the beginning. With the lack of temporal coherence between model and retrieval, I find the conclusions to be weak. In effect, the conclusions are that, there "can be misleading conclusions", that "positive skewness . . . is indicative of large outliers that may be due to episodic events or differences in sampling that must be considered", and that, "further research along these lines would clarify uncertainties of chemistry models on regional and global scales".

: The main objective of the 7 km SPRINTARS simulation was to study aerosol-cloud interaction without a cumulus parameterization. We agree with that the simulation period of SPRINTARS is too short to compare the simulated AOD with MISR's climatology. The other reviewers also pointed out the short simulation time of SPRINTARS. In the revised manuscript, we now also compare AOD from the GOCART model for 8 years between 2000 and 2007 with the MISR climatology for the same period, along with the 8-days average from SPRINTARS.

Specifics:
Abstract: Page 33897 – henceforth 897
- Line 1: “Joint Aerosol = AS” What is the “joint” and why “AS?”
: JOINT_AS is MISR’s standard product name.
(https://eosweb.larc.nasa.gov/project/misr/joint_as_table). We tried to use the same naming convention so that interested readers can easily use JOINT_AS data. We have added a sentence in the revised manuscript.
(“Joint” refers to the joint distributions of aerosol types reported in this product, and “AS” refers to the MISR Aerosol-Surface algorithm that produced the original Level 2 product from which JOINT_AS is derived.)

- Lines 13-15: This statement bothers me: “Overall, the AOD distributions of combined MISR aerosol types show good agreement with those from SPRINTARS.” While I understand what the authors are trying to do, the sentence appears to suggest that the model is being used to validate the observation-based data. I suggest instead something like: ‘The AOD spatial distributions retrieved from MISR and modeled by SPRINTARS agree with each other in a qualitative sense.’
: We have revised the abstract following the suggestion.
(Overall, the AOD distributions retrieved from MISR and modeled by GOCART and SPRINTARS agree with each other in a qualitative sense.)

Page 899:
- CCM is mentioned in line 22, but not defined until later. Also, this is for my own information – what is the difference between a CCM and a CTM?
: We have added a sentence on the difference in the revised manuscript.
(Unlike CCMs, that generate their own meteorological fields, CTMs require meteorological input from another GCM.)

- Page 900:
- Line 5: “Unfortunately, the retrieval of AOD by type from satellite observations and using the retrieved AOD for chemistry model evaluation have been, and remain, a significant challenge.” Why it is a challenge? The paragraph goes on to provide a list of many satellite-model intercomparisons. This is a nice summary, but in a way, completely irrelevant to the hypothesis statement of the pargraph. - Instead, the reason why it is difficult to compare “observations” versus “model” data, is that it is a comparison of apples and oranges. Retrievals from satellites are defined by optical properties, and model output is defined by moving mass around. There is no one-to-one correspondence between optical properties and physical properties, meaning that the two communities have to meet in the middle.
: We appreciate the comment. The following sentence has been added in the Introduction.
(Even these state-of-art satellite observations providing information on AOD by components cannot be readily compared with simulated AOD for different aerosol types. The aerosol type in satellite retrievals is defined by optical properties, whereas the simulated aerosol type is specified by chemical composition.)

Page 901: - Line 9: “74 “mixtures” based on eight “pure” particle types.” How does that work? Are some allowed to mix, and others are not? –

: There are only five mixtures that assume existence of one “pure” particle type. The other 69 are specific mixtures of two or three components, in proportions specified by mid-visible AOD fraction. You can find the entire MISR Version 22 Aerosol Mixture Properties in Table 2 of the Kahn and Gaitley (2015) paper cited in our manuscript.

Page 902-03: - I would like more information on how the 74 mixtures gets brought back into the 8 “pure” types. And I am finding it difficult to comprehend the idea of the 8-dimensional histograms, and how the clustering then turns into something useful. Maybe a summary of the Braverman (2002) paper would be helpful, but I found that paper confusing as well.

: First of all, thank you very much for the interest in MISR’s aerosol type information and JOINT_AS product. I hope the following paragraph in the revised manuscript helps your understanding.

(Conceptually, one can think of the JOINT_AS product as being created as follows. For a given grid cell, all mixtures that pass the algorithm acceptance criteria are transformed into an eight-vector that aggregates component proportions across mixtures, to yield total proportions of each component. Next, these proportions are multiplied by the total retrieved mid-visible AOD (``RegBestEstimateSpectralOptDepth'') to create an eight-vector of AODs that sums to the total reported AOD. To summarize the multi-dimensional distribution of AOD, the JOINT_AS product uses a clustering algorithm to partition the eight vectors into groups with similar members. These are effectively new, statistically representative mixtures of the eight components. A detailed description of the clustering algorithm used to generate the JOINT_AS product can be found in Braverman and Di Girolamo (2002). In this study, we use Version 1 of the MISR JOINT_AS, based on the operational (Version 22) Level 2 MISR aerosol retrievals, for all months during the 15-year period from March 2000 through February 2015.)

Page 903-04 (and Figure 1):

- I understand that lots of whitespace on a plot is not desirable, but I think in this case, it would help the interpretation if the two axes spanned the same interval. Then it would be easily understood that absorbing and non-absorbing AOD are not equal. It might even be more useful to compare absorbing AOD versus total AOD (and then would easily understand single scattering albedo).

: Figure 1 has been redrawn based on the suggestion. Now non-absorbing and absorbing AOD use the same axes scales. Unfortunately, a histogram of SSA cannot be obtained from the JOINT_AS product.

- Line 10: How should this statement:

“here is very little covariance between the absorbing and non-absorbing AOD in this case” be interpreted as?

: We have added a sentence.

(In other words, the changes in retrieved non-absorbing AOD over the area are not related to retrieved absorbing AOD.)

Page 904-05

– Lines 904-20 to 905-11: Does skewness of aerosol optical depth have any physical interpretation?
: As we mentioned in the manuscript, high positive skewness is related to extreme aerosol events. Also the skewness of log-normal distributions is always positive. If the skewness of an AOD distribution is close to zero, we could assume it follows a normal distribution. However, our analysis shows that we cannot assume normality of AOD distributions.

Page 905:
- Lines 13- The fact that the model is NICAM; why does it matter for aerosols?
: NICAM provides meteorological fields for driving aerosol transport of SPRINTARS in an interactive manner. NICAM-SPRINTARS is an aerosol-coupled global cloud-resolving model so that the upward aerosol transport due to convection is represented in an explicit manner that does not rely on cumulus parameterization as in traditional climate models.

- Lines 15- Really amazing that the SPRINTARS model is at 7 km globally. But the fact that it can only be run from 1-8 July seems to me that it is not yet the best model to do this comparison. Would a model run at 14km, or 20 km globally provide a more useful comparison to global MISR data, which is at 17.6 km resolution? 7 km seems like a waste – I would rather see full Julys and other months with SPRINTARS.
- Lines 22 – 26: .. and then everything is being compared at 5◦x5◦ resolution? I am also feeling uncomfortable with the "assumption that the AOD distribution does not change significantly from one year to the next during the month of July". Scale is really important here. Maybe it would appear similar qualitatively, but maybe not.
: We agree with these two points above. So the revised manuscript also compares the AOD simulated by GOCART with MISR and SPRINTARS. GOCART and MISR data for the 8 years between 2000 and 2007 is used in the revision.

- - Page 905-06:
- lines 26 – Lines 5: "We adopt this approach because we found that the JOINT_AS product for the single month of July 2006 contained a significant number of missing values even at $5^{\circ} \times 5^{\circ}$ spatial resolution. The missing data are likely due to cloud screening and locations being flagged as inappropriate for aerosol retrievals. . .".
Are data in SPRINTARS being excluded when SPRINTARS detects clouds? Can you tell from SPRINATRS whether there are conditions that MISR would have trouble with?
: All-sky and clear-sky AOD can be different, and clear-sky AOD from the model is more comparable to the MISR product. However, we did not exclude simulated AOD when there are clouds in the models. We would need hourly AOD and cloud cover information from a model for a longer period than 8 days to make this rigorous comparison.

- Page 906; line 8-20: I would like to see more discussion here. Maybe an expansion of table 1 that shows comparisons of the optical properties. Maybe these analogues make sense, from a qualitative sense, or even common sense standpoint, but I think rigorous comparisons of

optical/physical assumptions are in order here (e.g. details of SSA, of fine/coarse lognormal radii, size distributions, etc.).
: In the revision, we refer to Table 1 in Kahn and Gaitley (2015). The table provides all the optical/physical assumptions applied to the MISR's standard retrieval algorithm.

Page 906-08, as related to figure 2 (actually relevant for figures 4 and 6 as well).
- I am noticing the map panels look "smooth". These are all created using 5◦ x 5◦ values?
: Yes, the maps for MISR AOD uses 5° x 5° degrees. The models have higher spatial resolution.

- Explanation for Figure 2: While I agree that qualitatively, the histograms for PDFs from MISR and SPRINTARS look similar, the non-comparability of the time domain is concerning. Also, since there seems to be no attempt to screen out clouds in the SPRINTARS dataset, I wonder whether they are truly comparable (in a sampling sense). However, I do agree it is promising that the SPRINTARS model seems to capture the basic shape of the PDF. Or should I read it as "that MISR shows the basic shape of the model?" (I hope not).
: As the reviewer notes, it would have been better if we had obtained clear-sky AOD from the models to compare with MISR AOD. Comparison of AOD PDFs between MISR and models is better than comparing mean AOD only because the AOD PDFs from models include both clear-sky AOD and cloudy-sky AOD. By including comparisons with GOCART, we offer more compatible temporal sampling. We believe that the agreement between MISR and GOCART shown in the revised manuscript is a promising result, but a more direct comparison can be the focus of the future work.

- Why do SPRINTARS panels tend to show lower "background" values than MISR?
: SPRINTARS AOD shows greater spatial gradient than MISR in Figure 2. We think that this may be related to the lifetime of aerosols in the SPRINTARS model. However, the spatial scale of the AOD gradient is too small to talk about aerosol lifetime, as we do for the dust aerosols in the Eastern Atlantic.

- Looking at Figure 2a: What is the source (or explanation) of MISR's "non-absorbing" aerosol towards northeast of the map (that is not model sulfate).
: We think the peak in northeast of the map is related to transport of non-absorbing aerosols from the continent. When we use 8-year climatology between 2000 and 2007 July in the revision, we cannot clearly see the peak anymore.

- Looking at 2c/d: What is the explanation for the unexpected (nonlognormal) behavior above AOT = 1.0 (or relative lack of values between 0.5 and 1.0).
: We found and fixed a bug in our data collection routines to plot the histogram. After debugging the code, the non-lognormal peaks are smoothed out in the revised Figure 2d.

- P 907, lines 21: I beg to differ, I think that the histograms have very different shapes. The model one is very smooth and clearly lognormal-like, the MISR histogram is not. Just because one can envelope the entire histogram with a lognormal curve (e.g. p908; lines 10-12), is not sufficient. –

: After fixing the bug mentioned above, the revised Figure 2d shows that non-absorbing AOD from MISR and the models follow lognormal curves.

Page 909-discussing Figure 3

- I like Figure 3, but would like to see component types for the SPPRINTARS model as well. Should panels A + B + C = D (and E + F + G = H?) Since my comments on Figures 4 and 6 will be similar to those in Fig 2, I do not comment on them specifically. I do ask however, if MISR-model dust has any absorbing characteristics? That might explain why MISRs "absorbing" aerosol is placed north of SPRINTARS' "carbonaceous" aerosol in Fig 6.

: The revised Figure 3 shows AOD by components from GOCART and SPRINTARS. SSA of the non-spherical aerosols in MISR's retrieval algorithm is not 1, so the non-spherical aerosols have very weakly absorbing characteristics.

Conclusions:

- For an ACP paper, I like to see something with far more insight. Yes, it is hard to compare models and retrievals. What I see is the beginning of useful study, but only the beginning. With the lack of temporal coherence between model and retrieval, I find the conclusions to be weak. In effect, the conclusions are that, there "can be misleading conclusions", that "positive skewness . . . is indicative of large outliers that may be due to episodic events or differences in sampling that must be considered", and that, "further research along these lines would clarify uncertainties of chemistry models on regional and global scales".

Yes, of course there should be another paper, and a future paper will give the authors an opportunity to cite their own paper. But I would much rather see a better comprehensive study in this paper. Maybe only focus on one region (e.g. the China region) and study it in detail.

: We hope that the revised manuscript and plots with the added GOCART simulation results for 8 years can address the reviewer's concerns relative to the previous version.