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Interactive comment on "MISR Dark Water aerosol retrievals: operational algorithm sensitivity to particle non-sphericity" *by* O. V. Kalashnikova et al.

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We thank the reviewer of our paper for the constructive ideas and thoughtful comments, and we have tried to respond to them as much as possible. Below we provide detailed responses to each of the comments, with the original comments in italic.

I would like to suggest some effort be made to present using flow diagrams and bullets instead of long prose.

This point was the basis of a great deal of discussion among the authors. In the end, it was decided to present the pieces of the MISR Dark Water aerosol retrieval algorithm in the manner it appears in the text with the idea that the prose would provide some sort of logical flow. In the revised version we combined algorithm discussions in the separate section. Bullets were included where feasible.

Page 1594: Lines 4-11: A very long sentence, should be split.

The sentence has been changed to read: "The basic approach of the V22 MISR Dark Water retrieval is to assemble a set of aerosol models considered to be representative of the aerosol types likely to be found over the globe into a look up table (LUT), known as the Simulated MISR Ancillary Radiative Transfer (SMART) dataset. The algorithm determines which models and corresponding AODs satisfy a particular set of four 'goodness-of-fit' ($\chi 2$) criteria by comparing the MISR observations with the results of precalculated, multiple scattering, radiative transfer simulations stored in the SMART (Martonchik et al., 1998; Kahn et al., 2001; Diner et al., 2002; Martonchik et al., 2002, 2009)."

Page 1594: lines 15: With so many (74) aerosol mixtures, how sure are you that you don't already have too many? Or why not 75? Is MISR sensitive to all of these? Probably published in other papers, but maybe small description of what is here and what isn't might be helpful.

Given that the focus of this paper is specifically to the sensitivity of the MISR Dark Water aerosol retrieval to particle non-sphericity, we simply described the approach taken in the current (V22) MISR operational retrieval algorithm. The paper by Kahn et al. (2010) referenced at the end of this sentence referred to by the reviewer contains a detailed description of the models (Table 3 in that paper) as well as some discussion on the ability of MISR observations to discriminate among different particle types.

Page 1595: lines 12-16: The statement about size truncation is more important than should be simply referenced. My experience is that truncation is leads to missing radiation, especially as you go to longer wavelengths (e.g .NIR). Also Mie theory is not appropriate for non-spherical particles so truncation may lead to other artifacts.

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We agree that the truncation of the size distribution is an important point, which is why it appears in this paper. Just to be clear, as stated in the paper, Mie theory was not used to model the non-spherical particle scattering, as the reviewer seems to think. Instead the Discrete Dipole Approximation (DDA) technique was used for the fine mode, and T-matrix was used for the coarse mode. Again, the point of this section is simply to describe the particles that are used in the V22 algorithm.

Page 1595: Noting Figure 2: I can't read the text on the figure.

In the version of the manuscript downloaded from the AMTD website, the text on Figure 2 ("Example MISR scene of dust over the Atlantic. . .") appears to be completely legible.

Pages 1596-1597: Thinking about what is plotted and discussed related to Figs 3-4. Really what we care about is "nonspherical AOD", not total AOD or non-spherical fraction. Who cares about nonspherical fraction when AOD is low? (Of course later discussion illuminates, but I would like to see a combined Fig 3-4 plot. Plus, since all panels look so similar (and are so small), maybe four seasons for each plot instead of 12 months.

The problem with plotting non-spherical AOD alone (non-spherical fraction $\times$ AOD) is that, due to the weighting by AOD, the maps look generally correct and the artifacts that are the central focus of this study are difficult to discern. For example, even if the retrieved non-spherical fraction were low off the western coast of Africa, because of the large AOD in that region, the non-spherical AOD would still appear high relative to other regions. The obvious thing to do in this case is to "normalize" by AOD, which leads back to the non-spherical fraction. We also felt that the latitudinal change in the location of the non-spherical bands in Figure 4 was better captured in monthly plots. However, we will replot the data seasonally to see if the salient features are retained. If so, we will replace the monthly plots with larger seasonal plots.

Page 1597: Line 14: The word "true" bothers me. Either remove it, or use "expected".

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The sentence has been rewritten as: "Superimposed on these bands are the expected dust transport regions dominated by equatorial Africa, the Middle East, and eastern Asia, with contributions from southern South America, southern Africa, and Australia (see, for example, Mahowald et al., 2009, Fig. 1b)."

Page 1599: Lines 16:20: I don't follow this discussion. What about East/West position of sun? it will definitely change azimuth angles, and thus scattering angles.

The sun-synchronous nature of the Terra satellite orbit has two important consequences for the analysis described here. First, the sun moves primarily north-south through the year, due to the tilt of the Earth's axis and the motion of the Earth around the sun. There is relatively little east-west motion. Second, as the satellite completes its fifteen or so orbits around the Earth each day, the location of the sun within each one of these orbits (called swaths) is essentially identical, which is why we state that "the structure of an individual swath does not vary with longitude." However, the relative location of the sun within the swath is important, as the reviewer notes, which is why the plots also depict the variability of the scattering angle across the swath instead of averaging this information longitudinally, which is done in a classic Hovmöller diagram.

Page 1599: This is an example where I would like some foreshadowing. Range of scattering angle is important, but so is where within the angle range. There should be difference whether measuring $130^o - 155^o$ *as compared to* $110^o - 135^o$*, as you wait three pages before getting to this.*

In this particular section we are introducing the concept of scattering angle range (as opposed to specific scattering angles) to anchor the discussion relative to previous sensitivity studies that have been performed for the MISR instrument, referenced on page 1601. After introducing the concept, we extend the analysis to consider the specific set of scattering angles observed by the instrument in operation. We feel that this approach allows one concept to build logically upon the previous one. Especially sharp readers, like the reviewer, are more likely to "jump ahead" to more complicated

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concepts, but, in fairness, the wait is only one and half standard pages, or so.

Page 1600: Lines 5-10: Talking about sunglint. Both glint and scattering angles should be important. They are related, and are easily confused. Maybe plot of glint angle (nadir viewing) would help.

For MISR retrievals, the glint angles are important with regard to exclusion of cameras. We feel that the explanation in the text of the glint should be sufficient to distinguish the scattering angle (related to the viewing geometry independent of the specular direction) from the glint angle (related directly to the specular direction). Plotting the glint angle for a single camera seems more likely to confuse rather than illuminate the issue, especially since the glint angle is different for each of the nine MISR cameras.

Page 1603-1604: Small spheres "looking" like large non-spheres has been a problem forever (known by AERONET, MODIS, etc).

We agree with is statement, which is the reason for performing the analysis based on both the size-equivalent and backscatter-equivalent sphere in this section.

Page 1606: Lines 5-16: This paragraph has redundant thoughts, and does not need so many repeated citations.

The reviewer is correct. The paragraph has been shortened to read: "This discussion extends the work of Kahn et al. (1997), Kalashnikova et al. (2005), Kalashnikova and Kahn (2006), and Pierce et al. (2010), which were primarily sensitivity studies carried out over a limited but representative range of conditions. In this work we consider the performance of the Dark Water retrieval algorithm as it is implemented operationally, the influence of the changing MISR viewing geometry over the orbit and throughout the year, and the impact of excluding different cameras due to potential contamination by sunglint."

Page 1607: Thinking about MISR wavelength/channel/"bands" versus "bands" of retrievals on your hovemuller diagrams. Maybe use "channel" here (and furthermore) *instead of "bands".*

This is a good suggestion. We have change the text to use "wavelength" (rather than "band") throughout the manuscript, where appropriate, to refer to the particular spectral band of the MISR instrument to help distinguish the spectral content from the apparent "banding" in the figures.

Page 1607: What is physical reason for channel weightings and not using blue or green bands in retrieval? Also noting equation (2), if for some reason instrument uncertainty was to approach zero.

Equation (2) is written in its most general form, allowing weighting by wavelength (which is done) and weighting by camera (which is not currently done operationally). We have added the clarification in the following manner: "For AODs less than 0.5, only the red and NIR wavelengths, where the water surface is assumed to have negligible water-leaving radiance, are used in the V22 Dark Water retrieval (Martonchik et al., 1998). In Eq. (2) the weights for these wavelengths are always set to 1."

As discussed later in the paper, the instrument uncertainty, σ_{abs}, is an important parameter in the performance of the MISR Dark Water retrieval algorithm. However, σ_{abs} is constructed so as to never return a value of zero, as shown in Eq. (10).

Page 1608 : (line 20). In other words, statistically significant at 95% level.

The reviewer is correct in noting that the values of z are related to the statistical significance of the result. This conclusion is implied in the discussion, however.

Page 1609-1610: Would like some physical explanation for these chi-squared metrics. Also, why not use $l = 3$ and $l = 4$ for equations (4) and (5) like for equation (2)?

χ^2_{spec} is strictly a comparison between the red and NIR wavelengths, rather than a generic comparison among multiple wavelengths, so we felt it was clearer to list the wavelengths explicitly in this case. The physical explanation underlying ${\chi^2}_{spec}$ is presented in the text as "${\chi^2}_{spec}$ compares the spectral behavior of the observations in the NIR band to the red band observations, taking advantage of the relatively better band-to-band calibration of the MISR instrument compared to the absolute calibration (Martonchik et al., 1998; Kahn et al., 2001)." Similarly, the explanation for $\chi^2{}_{geom}$ is that it "is intended to take advantage of MISR's multiangle observation strategy and emphasizes angular differences in the way different aerosol models scatter light (Kahn et al., 1997, 2001; Martonchik et al., 1998)." Greater detail can be found in the references provided in the paper.

Page 1611: Equation (4). This 0.04 seems like a large number over black ocean surface. Should it be at least be dependent on wavelength? I understand that this is part of the discussion in this section, but the 0.04 seems wrong to begin with.

We assume the reviewer means Eq. (10). While there has been no strong justification for the use of the value of 0.04 in the MISR retrieval algorithm itself, consulting the literature, it appears that Mobley (1999) recommends a value for the ocean surface reflectance of 0.028 for a viewing geometry that minimizes the effects of sun glint and nonuniform sky radiance. The 0.04 value adopted by the MISR team is not too far from this value and must account for a broader range of viewing geometry. Of course, as explained in the text, this value plays a significant role in the performance of the operational MISR aerosol retrieval algorithm and should be reassessed given the true performance of the MISR instrument.

Page 1618: Lines 16-18. This sentence makes no sense.

The offending sentence reads: "This result suggests that naturally occurring spherical particles missing from the MISR SMART are unlikely to be the cause of the bands of enhanced non-sphericity observed in the global MISR V22 aerosol retrievals." Although clear (to us) this sentence has be rewritten as: "Based on this analysis, it is unlikely that some spherical aerosol particles present in nature, but not included in the MISR aerosol LUT, are being fit by the non-spherical particles in the LUT, thus producing the bands of enhanced non-sphericity."

Page 1621: Good idea to use MODIS to identify cirrus. There really should be a joint MODIS/MISR retrieval. Can MISR stereo help define cirrus (which is presumably even higher in altitude than dust)?

If the cirrus clouds have enough contrast to be retrieved by the stereo algorithm (optical depth > 0.3), then it is likely they will already be screened by the existing cloud masking algorithm. The existence of the non-spherical artifacts in the V22 MISR aerosol retrievals suggests they are not being screened. It is the optically thin cirrus that are the issue, see Pierce et al. (2010) for a detailed discussion.

Table 1: Of course wondering about the rest of the MISR aerosol models. Which ones are $\#19$ and $\#21$? Finally, seems like super non-absorbing particles. What happens if the dust is a little "dirtier"?

As mentioned above, the complete table of MISR aerosol models can be found in the Kahn et al. (2010) paper referenced here. The sensitivity of the MISR Dark Water aerosol retrieval to different amounts of dust absorption was tested in Kalashnikova and Kahn (2006), who found that the models shown in Table 1 provided the best overall fit to the observed MISR radiances. These models were subsequently included in the operational aerosol retrieval.

Fig 6: (And many others). This color scale does not show dynamic range well. Maybe a standard EOS color scale would be better (or at least scale used by Fig 10). For aerosol 90^o is not an important value.

All of the color scales in this paper are based on the color scales discussed in Light and Bartlein (2004) regarding the overuse and misuse of the rainbow color scale. In each case, consideration was made to select a color scale that best represented the important content of the image in an easily interpretable manner. Taking Fig. 6 as an example, the point is to represent the annual change in the location of the minimum and maximum scattering angle range, not to invite readers to try to deduce the specific scattering angle range for a specific latitude and time. This is why the dynamic range is relatively poor. While it may be true that a scattering angle range of 90^o is not particularly important for aerosol scattering, it is a useful mental reference for our readers. Magenta colors correspond to a range less than 90^o and green colors correspond to a range greater than 90^o.

Fig 11 (panel A): Why are the cameras overlapping?

The overlap of the cameras in scattering angle space is a consequence of the particular summertime viewing geometry, which happens to yield nearly symmetric scattering angles because the subsolar point is essentially located in the center of the nadir camera view for this scene.

Figs 13-18: Colorscale is not monotonic. Again suggest EOS of blue to green to yellow to red.

The whole point of the color scale is to not be monotonic. Instead, it is designed to represent gross categories (χ^2 values), then gradations within these categories. At a glance, readers should be able to determine what the overall χ^2 value, which determines whether or not the metric will "pass" given the V22 operational thresholds. The within-category values provide insight into how "close" the value may be to the next category and possibly crossing the threshold.

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