RESPONSE To Carol Bruegge

Paper summary

This paper notes that there is a bias of 0.01 in Aerosol Optical Depth (AOD) over dark ocean, between MISR aerosol products and AERONET. This is found to be the case where AOD < 0.10. The authors have studied a specific scene type, where a well-defined bright area is adjacent to a dark-water target. For this they have quantified the amount of "ghosting" from the bright area into the dark area. An empirical correction algorithm is then developed, used to correct for three hypothesized stray-light mechanisms. Once the correction is applied and the MISR data processed using their research algorithm, the AOD bias is reduced to 0.003.

In their development, the authors have made the following adjustments to the MISR radiances, before processing the data in their research algorithm (RA): 1) converted radiances to in-band reflectances 2) included a 1.06 gain adjustment in the An-Red band, and a gain 1.05 adjustment in the An-NIR band. 3) added a correction for a primary ghost image 4) added a correction for a secondary ghost image 5) added a correction for spatial smearing (point-spread-function effect)

Questions to the authors

1) The gain adjustments to the red and NIR bands are not corroborated by the validation done in Bruegge et al. (2014). Since the primary focus of this paper is the ghosting correction, how significant is the band-relative corrections? What reduction in AOD bias is found, if only the ghosting correction is applied?

First, we would like to thank Carol for her review. We have since removed the AN gain adjustments (as this was really not the primary focus of the paper) and have replaced the gain adjustments with a +0.5% red and -0.5% NIR adjustment. This is necessary to bring the Angstrom Exponent into agreement with AERONET/MAN, and is within the calibration uncertainties reported in Bruegge et al. (2014).

2) Considering the MISR aerosol product already meets the required ±0.05 uncertainty in AOD, what are the science drivers for improving the residual bias of 0.01?

*The MODIS instrument, which has 3-4 times more coverage of MISR, now reports better than ± 0.03 ± 10% over water, and MISR *should* provide at least better accuracy, given the greater information content of the multi-angle data. (And otherwise, why bother with MISR at all?) Having greater accuracy makes the AOD product itself more useful for direct-forcing calculations and for model validation, and it is *essential* for obtaining good aerosol type retrievals over a broad range of retrieval conditions [Kahn and Gaitley, JGR 2015; Limbacher and Kahn, AMT 2014], especially at low AOD. Aerosol type is a unique contribution to aerosol science that MISR can make. Also, given the magnitude of the effort involved in building and flying the instrument, creating the data products, documenting, storing, and distributing them, the incremental effort in implementing a correction that we have now developed is minuscule.*

3) The MISR instrument makes use of four different camera designs, suggesting that the "one size fits all" set of parameters is not desirable. Coefficients computed for the nadir-camera are likely not applicable to the off-nadir cameras. Although the lens designs have some characteristics in common, the lens spacings and prescriptions are different. What future work will you pursue? For example, will you examine the off-nadir camera imagery for ghosts and investigate the impact of applying the nadir camera corrections to the images to ensure that artifacts are not introduced?

We agree that the off-nadir cameras present a challenge that we cannot address directly with our image-analysis approach because MODIS is only nadir-viewing. The best we could do in the context of the present study is to compare the resulting AOD retrievals with a large set of AERONET coincidences; we find that the current empirical corrections improve these comparisons, as illustrated in Figures 9 and 10, and Tables 2 and 3. However, we also agree that more work has to be done for the off-nadir cameras. Future plans include using the MISR lunar data (which provides a bright target with a black background) and Parasol data (for an off-nadir analysis) to compliment the nadir analysis done in this paper.

4) A previous publication, Bruegge et. al (2004) has quantified the MISR ghosting problem for the Bf camera to be on the order of 0.3%, that is, the magnitude of a structured ghost of iceberg in a dark ocean was found to be 0.3% of the brightness of the actual iceberg. How do the magnitudes of structured ghosts in your study compare to this value?

It turns out that the magnitude of the reflection is strongly dependent on the location within the swath. If right near the middle of the scene, we would expect to see a 1.3% reflection in the NIR, dropping to <1% for some parts of the swath. The ghosting response drop is even sharper for the other bands and you may end of with ~0.2% in the blue towards the edges of the swath.

5) The secondary mirroring about points one-quarter and three-quarters across the field of view is not consistent with physical optics behavior. The term has a very large blur diameter and lower gain coefficient, giving it less of a structured character and smaller magnitude than the primary mirroring term. What is the magnitude of AOD improvement if this term is not included? (see suggestion 3 below)

All of these corrections are empirical corrections. The features in question show up clearly, for example, in the green contoured areas of Figures 1d, 2d, and 3d. If we do not include it in the analysis, we would be unable to correct these anomalies.

Editorial suggestions

1) Clarify Figure 6; label (or at least define) the axes. The text is difficult to follow.

We have modified this figure (now Figure 7) significantly. All axes are clearly labeled, and we now include results for all four spectral bands. We mention that the MISR-MODIS reflectances correspond to the left half of the scene in question.

2) With respect to the 4 bullets on page 2537: * the first might be called "stray-light" –then you could elaborate that these include ghosting, due to camera internal reflections, and veiling light, due to scattering within the camera. * "3D effects" – this is not a camera stray-light phenomena and should not be in a list of MISR camera artifacts. If there were a 3D effect, this would be due scattering within the vertical structure of the atmosphere, and would have to be accounted for in the Level 2 (aerosol retrieval) algorithm. * I would add PSF effects, since you include such a term in your correction equation. * rank the effects having the most significant effect on AOD (as opposed to cost function), vs. those with no effect. (i.e. move latency last), or maybe in the order you later apply a correction. These suggestions might strengthen the connection between this list, and what data manipulations are done later in the paper; that is, will make the paper flow better.

We have changed the first bullet to be stray-light, which for our definition includes the PSF effect, and we have removed 3d effects, as we would not be able to resolve such effects with our analysis anyway. The impact of these effects on AOD is really scene dependent, so there is no meaningful way to rank them based on this criterion.

3) I agree with Reviewer #1, that "calibration" may not be the best descriptor for the title. Perhaps a better title would be: "The impact of stray-light in high-contrast scenes on MISR aerosol retrievals over dark water"

We agree that we should add stray-light into the title. This has been added.

Summary

This paper has shown that stray light in the MISR cameras can affect the retrieval of AOD. An empirical algorithm is developed that has reduced the bias between AOD derived from their Research Algorithm and AERONET. It demonstrates that improvements in the derived products that can be made, if a stray-light correction algorithm were to be implemented.