Dear Authors,

Thank you for this well-written and detailed manuscript describing this large-scale experiment to attempt to understand the offset in retrieved AOD between the morning and afternoon MODIS instruments. You have presented some analysis to examine the expected magnitude of certain effects and the implications of recent re-examinations of the MODIS L1B calibration, through the lens of the persistent AOD and Angstrom Exponent biases in the MODIS-Terra MOD04 Dark Target (DT) aerosol product compared with the identical product produced from MODIS-Aqua.

I applaud your support for the community in preparing this publication to summarize your results even though the outcome is unsatisfying because the discrepancy is not resolved.

There are always more tests to be done, but my purpose is not to demand that you add multiple papers' worth of analysis (though I hope you will continue to pursue this question and publish more papers about it!). In preparing the final version of this current paper, I think care should be taken to present the outcome of the experiments in terms of what is known, and to separate findings into the categories of "constructive recommendations for analyses combining Terra and Aqua MODIS" and "directions for resolving the discrepancy in MODIS retrieved aerosol properties."

You present AERONET comparisons indicating that the global offset between Terra and Aqua is reproduced when sampled to times and locations of AERONET data, and that the Terra-Aqua differences do not correspond to differences between morning and afternoon AERONET AOT. This is consistent with analysis of AERONET morning and afternoon retrievals (without pairing to MODIS, Figure C1); AERONET also shows no systematic trend of Angstrom exponent between morning and afternoon (Figure C2). These results are consistent with literature e.g. [*Smirnov et al.*, 2002], but an update to Figure 17 from Levy et al. (2013) would be relatively easy and a welcome addition to your Figure 2.

In light of the AERONET results, the MERRA model experiment does not add much additional weight. MERRA is constrained by MODIS radiances tuned to AERONET, and from that perspective would be expected to show the same trends as AERONET. MERRA assimilation does not provide information on aerosol diurnal variation outside the Terra and Aqua overpass times. Aerosol sources in MERRA introduce sub-daily variation according to the source functions used, some of which are dependent on meteorology (e.g. dust) and some of which are climatological (e.g. diurnal cycle of smoke) or inventory-based (e.g. anthropogenic pollution). The sub-daily variation in aerosol sources in MERRA cannot be considered definitive. Thus neither the aerosol sources nor the data assimilation contribute a large amount of validated information on subdaily variation.

From the perspective of this reviewer, it seems the strongest case made by your results is that calibration is unlikely to be the cause of the observed differences. The four different L1B calibrations tested (C6, C6+, C6- Doelling, C6.1) are relatively independent, and might as an ensemble be taken to represent the current state of knowledge about how to calibrate a multispectral sensor such as MODIS. None of these calibrations eliminate the Terra-Aqua offsets in retrieved aerosol properties. The observed AOD offsets are at least double the magnitude over land than can be explained by the C6/C6+ difference, and many times larger than the C6/C6+ difference over ocean (Figure 11). In order for L1B

radiance calibration to be responsible for the discrepancy, the correct radiance calibration would have to be different from all of variants considered in your paper by considerably more than the difference between them. In the absence of other evidence that these calibrations are systematically flawed, we must consider this unlikely.

If the small residual Terra-Aqua offset cannot be explained by current state-of-the-art work on L1 radiance calibration and is not consistent with our current understanding of aerosol sources, we must consider other possibilities. These are outside the scope of your current paper, but I think you should include some discussion of the potential explanatory power of some other possibilities. For instance:

1) The MODIS retrieval makes simplifying assumptions about particle optical properties because the retrieval is underdetermined. The discrepancy between the single scattering albedo (SSA) assumed in the MODIS-DT retrieval and the actual particle properties has been shown to be a significant source of bias in MODIS retrieved AOT [*Eck et al.*, 2013]. Is there a set of optical properties consistent with the MODIS-Terra bias vs AERONET? Can this be falsified using other data from AERONET?
2) It is documented that cloud types and cloud properties show significant diurnal variation in the climatological mean [*Eastman and Warren*, 2014]. Eck et al. [2012] diagnosed how cloud processing affects aerosol particle size distributions. Can an envelope calculation be made of the expected magnitude of diurnal differences in particle optical properties related to cloud processing? Hypothetically, if the MODIS-DT assumed particle properties were assumed to match the real atmosphere for MODIS-Aqua observations, what magnitude of difference in optical properties could account for the MODIS-Terra AOD offset?
3) The distribution of observation angles is different for MODIS-Terra and MODIS-Aqua. Numerous analyses have shown that MODIS-DT retrievals have some sensitivity to observation geometry (e.g. [*Hyer et al.*, 2011]). I believe that the pole-to-pole uniformity of the Terra-Aqua bias argues against this as a contributing factor, but with some simple additional tests it might be possible to rule it out entirely.

I think the analysis you have done is solid. I would like to see the discussion at the end of this paper expanded to:

1) Include a quantitative description of how Terra-Aqua offsets compare to the magnitude of sub-daily variation as observed by AERONET. This is the clearest expression of the where we would need to get to in order to use Terra-Aqua to diagnose diurnal processes.
2) Include a hypothetical discussion of other differences in the atmosphere that could cause Terra and Aqua to report different answers, drawing on existing literature to estimate the magnitude of different effects.

Eastman, R., and S. G. Warren (2014), Diurnal Cycles of Cumulus, Cumulonimbus, Stratus, Stratocumulus, and Fog from Surface Observations over Land and Ocean, *Journal of Climate*, *27*(6), 2386-2404, doi:10.1175/jcli-d-13-00352.1.
Eck, T. F., et al. (2012), Fog- and cloud-induced aerosol modification observed by the Aerosol Robotic Network (AERONET), *J. Geophys. Res.-Atmos.*, *117*, 18, doi:10.1029/2011jd016839.
Eck, T. F., et al. (2013), A seasonal trend of single scattering albedo in southern African biomass-burning particles: Implications for satellite products and estimates of emissions for the world's largest biomass-burning source, *J. Geophys. Res.-Atmos.*, *118*(12), 6414-6432, doi:10.1002/jgrd.50500.
Hyer, E. J., J. S. Reid, and J. Zhang (2011), An over-land aerosol optical depth data set for data assimilation by filtering, correction, and aggregation of MODIS Collection 5 optical depth retrievals, *Atmospheric Measurement Techniques*, *4*(3), 379-408, doi:10.5194/amt-4-379-2011.
Smirnov, A., B. N. Holben, T. F. Eck, I. Slutsker, B. Chatenet, and R. T. Pinker (2002), Diurnal variability of aerosol optical depth observed at AERONET (Aerosol Robotic Network) sites, *Geophys. Res. Lett.*, *29*(23), 4, doi:10.1029/2002gl016305.

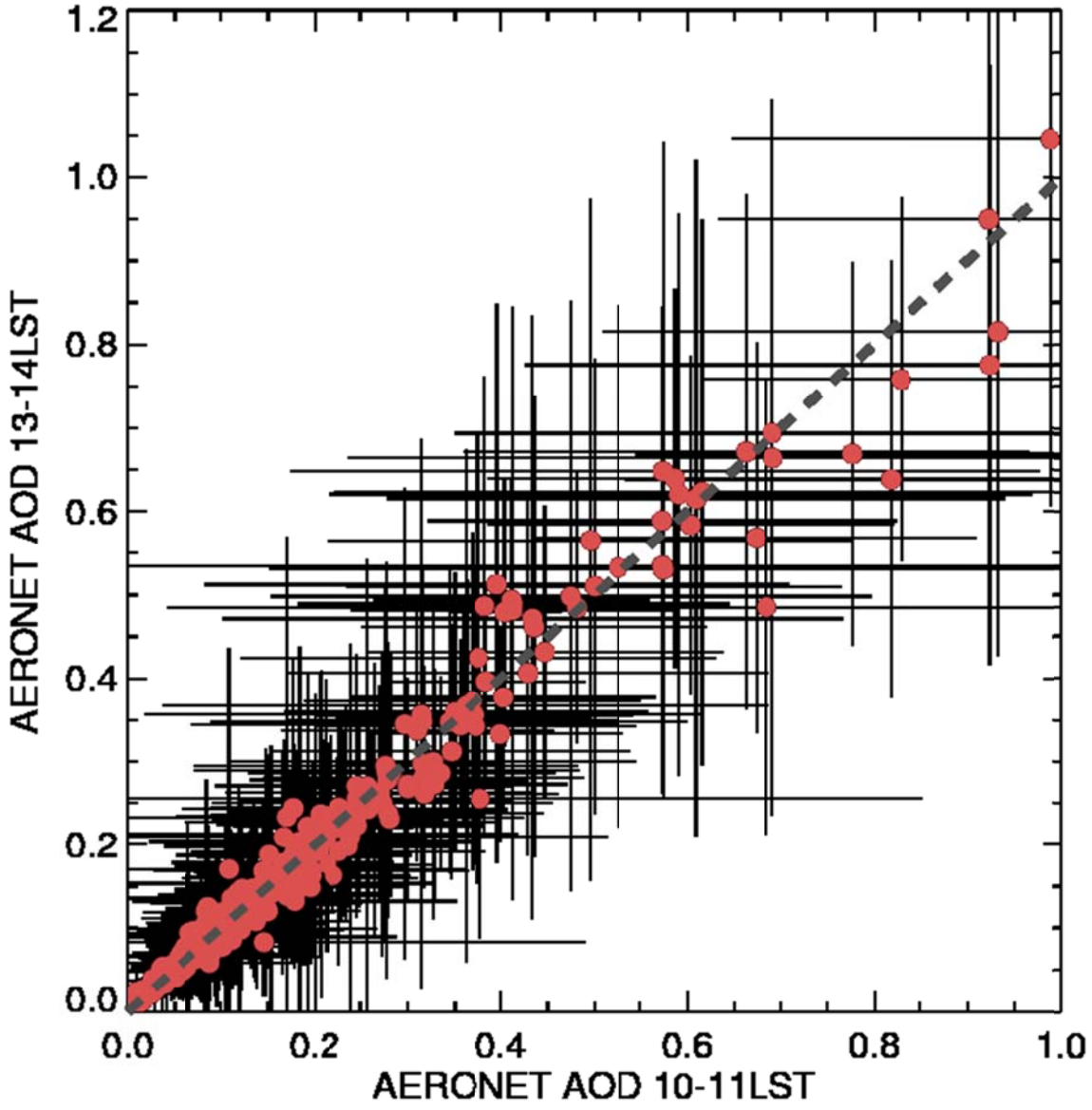

Figure C1. Each point represents AERONET AOD (Version 3, Level 2.0, interpolated to 550nm) from one AERONET station during one month of 2008, with a minimum of 50 observations during the 10-11LST hour and 50 observations during the 13-14LST hour. Vertical and horizontal bars indicate +/-1 standard deviation from the mean. The 1:1 line is shown in gray.

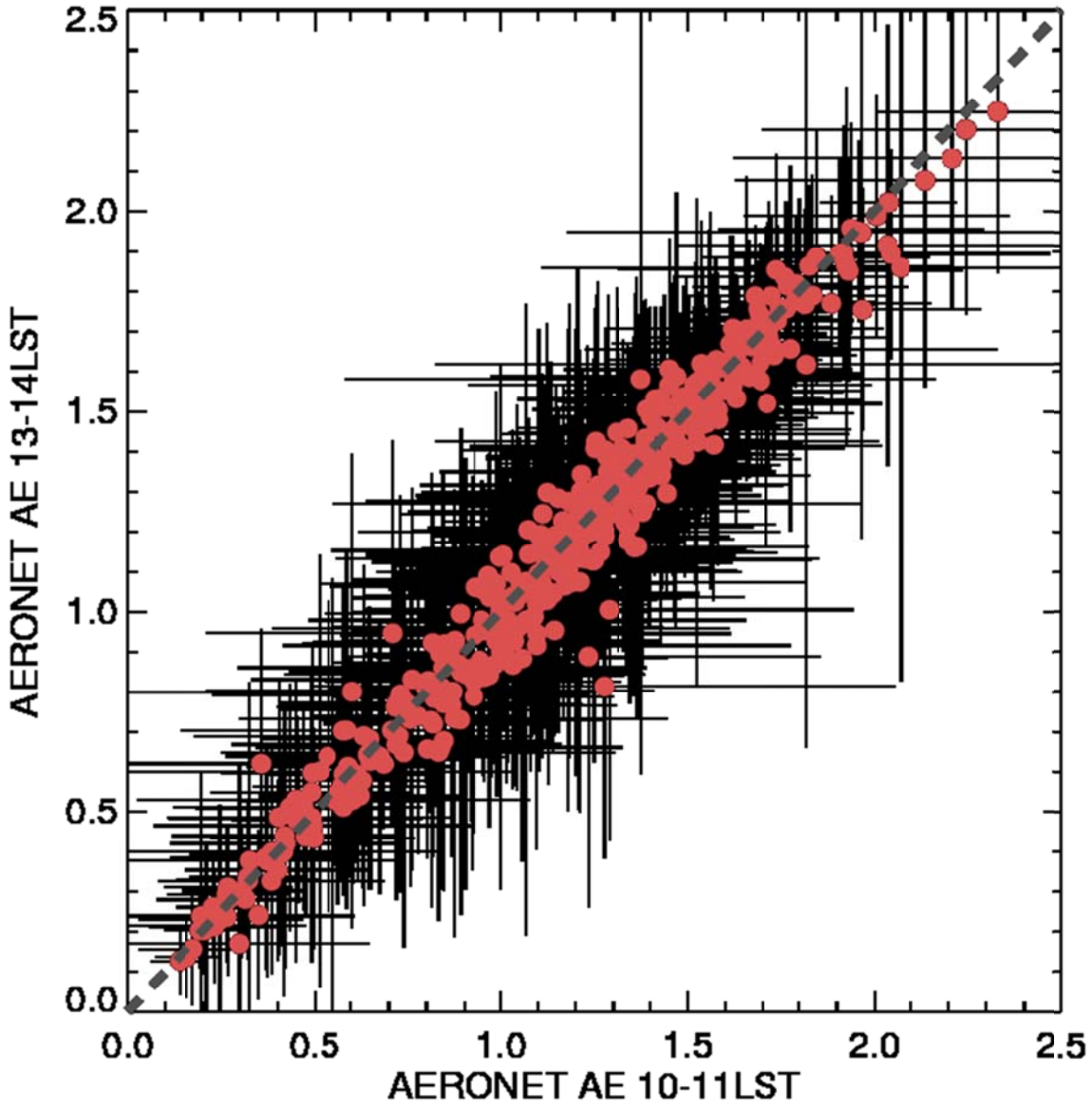

Figure C2. Same as Figure C1 but for AERONET retrieved 440-870 nm Angstrom exponent.