Interactive comment on “Impact of satellite viewing swath width on global and regional aerosol optical thickness statistics and trends” by P. R. Colarco et al.

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Review of Colarco et al., “Impact of Satellite Viewing Swath Width on Global and Regional Aerosol Optical Thickness Statistics and Trends”

Reviewer: Mike Fromm

In my report I use “auth” to refer to Colarco et al.

Auth focus their study on satellite observations of aerosol optical thickness (AOT), particularly the question of strategic spatial sampling reduction, with respect to a MODIS-like full swath, and its impact on the value of the resultant AOT data for climate studies.
They choose AOT for its relevance as a primary metric in the assessment of direct aerosol radiative forcing (DARF) of climate. They adopt MODIS as the standard for global satellite remote sensing of AOT because of the existing decade-long data set, large swath width (synonymous with global spatial coverage), and the maturity level of aerosol retrieval. Auth undertake a statistical analysis of 10 years of Aqua MODIS level 2 AOT data aggregated onto regular lat/lon grids of various size. From those grids they are able to perform global/regional 1-year (2010) analyses, time series, and trend analyses for defined regions. The limited-area swaths they test are intended to mimic MISR-like narrow swaths or to approximate the real estate covered by CALIOP (what they refer to as “curtain” mode). Auth conclude that spatial sampling matters in the qualification of an AOT data set for DARF assessment. In particular they conclude that a MODIS-like AOT in curtain mode is inadequate for climate studies, however they’re less definitive on the limitations imposed by MISR-like narrow swaths.

Spatial sampling of AOT is without doubt an important consideration for qualification as a climate data record. Hence it is an appropriate topic for AMT. Moreover, considering the remarkable MODIS record dating to 2000, it is compelling to evaluate its position as a possible standard for global AOT data. However, my assessment is that this paper has approached their science question in a largely unsupportable way, significantly limiting its value. Unfortunately, I cannot recommend publication of this paper in its present form. My major reasons are given below.

Additional comments and suggestions are provided as comment bubbles in the pdf of the manuscript.

Motivation of Study

A singular motivation for auth’s paper is explicitly given in the introductory paragraph starting on line 57. “Spatial coverage is among the primary considerations for any future satellite instrument designed to measure aerosols. Given technological and budgetary constraints, trade-offs are made between spatial coverage (i.e., measure-
ment swath width) and other instrument measurement characteristics, including the number of spectral and polarized channels, relative precision and accuracy, angular and temporal coverage, and pixel size.” Since the entire justification of this research flows exclusively from this statement, auth are obligated to reinforce this statement with citations. Without objective reinforcing information, this statement amounts to informal speculation. I.e. auth need to build a compelling case here, identifying real assessments of future satellite concepts w.r.t. spatial sub-sampling as a “primary consideration” for decision-making. If indeed they cannot cite firm evidence of swath width as an acknowledged trade-off against other instrument factors, the sole motivation for this research evaporates.

Even if auth can convince that spatial coverage is a factor in competition with other instrument design elements, they must acknowledge that the trade-offs add value to the whole content of aerosol measurement (e.g. MISR’s stereographic views of scattering and aerosol height). This fact further diminishes the motivation to study only swath width and the importance of any results so derived.

Auth need to strengthen their stated motivation and add additional background to justify the research plan and results restricted to swath-width considerations. Otherwise this work comes across as an arbitrary exercise with results having minimal impact.

Method

Auth are looking strictly at artifacts introduced via reduced spatial sampling of AOT. In the Introduction they state: “If spatial sampling artifacts introduce sufficient uncertainty in the satellite-derived AOT, we will not be able to meaningfully improve estimates of DARF.” So they undertake to isolate this factor (narrower swaths with respect to a full MODIS image) to answer the question of whether certain image-swath subsets are insufficient for climate sensitivity studies. They test the subsamples on actual MODIS AOT, with all of its well documented issues. An example of just one issue is illustrated in their Figure 1c. Ms. Lisa’s picture is significantly disfigured by clouds. The ubiquitous
issue of clouds adds a large unknown to the puzzle of true AOT and trends thereof. As far as I can tell from what is presented here, auth do not acknowledge that the grid-point AOT averages are only representative of the clear-sky areal fraction (as do Remer and Kaufman (2006)). With or without this acknowledgement, it is essential (in my assessment) to discuss the implications of cloud cover and regional/temporal changes thereto in the context of the “true” vs. MODIS areal/temporal AOT variations. This and the many other MODIS issues, some discussed by auth, impose a high level of uncertainty regarding a true representation of AOT that may well dominate spatial sampling considerations.

It is fundamental from a statistical standpoint that reduced sampling will increase uncertainty. This can be formulated and demonstrated one theoretical grounds.

Auth have already decided that they are basing their work on an imaging instrument identical to MODIS. MODIS by no means has been established objectively as a satisfactory AOT data set either for short-term, regional, or climate applications. The strongest defendable affirmation is that MODIS AOT is the best we have (and there might not even be consensus on that point). As valuable as MODIS aerosol data are, they can by no means be generalized as “high quality” as auth claim in the Discussion and Conclusion section (line 632). Their own discussion, and papers they cite, fully reveal the several weaknesses inherent in the MODIS data; scan-angle systematics, cloud contamination, cloud clearing, minimal diurnal sampling, land/ocean differences to mention some. Hence, to achieve auth’s stated goals, applying a statistical technique to real MODIS data does not produce convincing results. To illustrate that contention I refer to the discussion of Figure 12 after line 445. Here auth compare their map of AOT trends with Figure 7a of Zhang and Reid (2010). Auth point to only one region of differing result (lines 449-451), the Pacific Ocean west of Mexico. However, there is a much larger area of opposite sign of AOT trend in the region encompassing Indonesia, New Guinea, and the western Pacific northeast to Japan. This is not meant to criticize their focus, but rather to point out that indeed large, coherent regions have
full-swath-derived MODIS AOT trends of opposite sign between two thoughtful, rigorous, independent AOT analyses. My conclusion, after comparing auth’s and Zhang and Reid’s maps, is that factors other than swath width likely dominate an analysis of AOD trends, regional and global.

In my view, this type of approach to answering the science questions auth pose would be substantially more convincing if it invoked synthetic MODIS data. Here all the unknowns and hard-to-disentangle issues (like scan-angle AOT artifacts) could be eliminated, and replaced with a synthetic model of AOT that replicates regional sources and introduces a specified trend (regional or global). This model AOT atmosphere, sampled by real MODIS swaths (and strategic subswaths), would give the analyst the most defendable tool for making a convincing assessment of spatial sampling artifacts on AOT patterns/trends.

Results

My perception of auth’s results is that there is one clear signal: curtain measurements won’t cut it for DARF applications. However, their rendition of curtain measurements is nothing more than MODIS AOT along a very narrow swath. They argue against some hypothetical curtain measurement techniques with presumptive statements about a lack of information on surface reflective qualities (line 630). Referring back to the above-mentioned concern about unsubstantiated future satellite missions, statements like the one on line 630 echo as empty speculation/argumentation. This and other curtain-centric concerns are already seen to be mitigated when considering that an existing curtain instrument, CALIOP, has synchronous visible and IR imagers, and also makes aerosol measurements day and night, twice as often as a MODIS curtain would. Hence the simple conclusions stated online 630 come across to me as prejudicial and speculative.

As elaborated on in the comment bubbles imbedded in the manuscript, there is also some unnecessary difficulty in evaluating curtain-analysis map panels in Figures 4 and
13. Auth’s interpretation of these figures suggests that the curtains completely miss large or numerous areas. However, close-up viewing shows that these findings are not accurate. It still may be true that the curtain sampling considerably degrades the detection of regional/temporal AOT features, but it is also true that the color schemes employed and the representation of the whole globe in a small plot area smears out features that argue against the written interpretation. I suggest that auth experiment with zoom views and other color schemes to give more contrast and detail than is presented here. In addition, I suggest that a clear and objective test be applied, over and above eyeballing maps, to evaluate whether or not curtain sampling sufficiently captures regional/temporal AOT variations.

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/6/C4495/2014/amtd-6-C4495-2014-supplement.pdf