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Interactive Comment

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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The paper attempts to address the important question of the influence of sampling on aerosol retrievals from space. As explained below, this study appears to have major drawbacks which significantly reduce its scientific value.

General comments

It is known from statistics that a random sampling estimate of a dataset's mean is always unbiased (i.e., the expected value of the estimate equals the mean of the dataset) and consistent (converges to the dataset's mean as sample size increases). The vari-

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ance of such an estimate depends on the sample size, and is proportional to the inverse of the number of measurements (pixels) in a typical sample. AOT values at each pixel of a track crossing a certain region can be considered a random sample and used to estimate the regional mean. In order for this estimate to be sufficiently accurate the “region” should include a number of pixels large enough to reduce the estimate’s variance (i.e., the “region” should not be too small relative to the sampling spacing). Quantitative evaluation of the relationship between the region size and the sampling spacing can be done easily using existing statistical techniques, but this is not among the authors’ goals.

One may be concerned whether the AOT sampling by, e.g., a curtain track is sufficiently random for the above-mentioned statistical methods to be applicable. Indeed, too sparse a set of orbits can systematically miss significant localized features (such as, e.g., dust or pollution plumes). However, the curtain track spacing used in the paper appears to be sufficient to study AOT, which is known to have large variability scales (hundreds of km). This can be seen in Figs. 9 and 10 as each high-AOT region is crossed by multiple curtain tracks (so nothing significant “falls through the net”). Also, the AOT values in “observed” pixels are not so different from those in “not observed” nearby pixels (except for the glint-affected C3 case). We should also note that if the regional biases due to non-random sampling indeed existed they would have led to a global bias, since all AOT features have higher than average value (so they cannot cancel each other). However, no global bias is seen in Fig. 14c.

It follows from the above discussion that any reasonable sub-sampling strategy is expected to provide an unbiased AOT climatology, spatial and temporal resolution of which depends on the sampling density (less frequent sampling yields a coarser-resolution AOT map and/or seasonal time series). This means that the sampling density cannot be "good" or "bad", but is a quantitative parameter that should be chosen depending on the given climatological resolution requirements. Thus, the authors estimate that a perfect along-track instrument that “could retrieve aerosol properties with no cloud exclusions... would still be sampling only about 10% of the globe" is arbitrary as it depends crucially on the required climatological resolution.

For their study of "observability" the authors chose a 0.5o×0.625o grid essentially studying the observability of each grid cell. These cells are too small for curtain-track sampling, so one would expect the lack of statistical significance of the results. However the findings are presented as applicable to regions which are orders of magnitude larger than the cell size.

Finally, the paper's main conclusion that sub-sampling results in "significant regional and seasonal biases" is not supported by the data at all. There is not a single plot comparing regional seasonal means from a sub-sample to that from the full swath. Instead, the authors show plots of their own non-standard metric delta-AOT, which does not have a precise mathematical meaning.

The "test" MODIS dataset itself has significant gaps and uncertainties

The authors use MODIS level 2 aerosol product to evaluate the influence of sampling on the accuracy of narrow band and curtain-like instruments. The choice of this dataset is less than optimal, since the retrieval errors in MODIS aerosol product are an order of magnitude larger than the reported sampling uncertainties (and hence contribute much more significantly to the total uncertainties in the mean AOT values). The sampling of the aerosol field by MODIS itself is limited. Only around a quarter of all available MODIS Aqua pixels over ocean between 60oS and 60oN are actually used to retrieve aerosol properties, and this fraction has a pronounced seasonal dependence. Over land the fraction of pixels suitable for AOT retrievals is even less: 10%. Clouds, sunglint, bright or variable surface may lead to gaps in MODIS retrievals. It has been shown using a representative set of model aerosol fields that full Dark target MODIS dataset may produce negative biases in global monthly mean AOT as large as 0.07-0.12 (30% – 45% of the long-term mean) during boreal summer over land and 0.015-0.03 (10% - 20%) over ocean (Model-based estimation of sampling-caused uncertainty in aerosol remote sensing for climate research applications, I. Geogdzhayev, B. Cairns, M. I. Mishchenko, K. Tsigaridis,T. van Noije, QJRMS, in press). In large part these biases are caused by the gaps in coverage of the MODIS dataset. Regionally these biases may be significantly greater. Compared to these deficiencies the effect of reduced sampling of pixel-wide along track instrument is small for global mean AOT.

Real narrow-swath instruments can retrieve AOT where MODIS fails

Given the limitations of the original dataset any conclusions drawn from sub-sampling of it may at best be applied to narrow-band or pixel-wide along track sampling instruments which have the same measurement accuracy and limitations as MODIS itself. This fact is disregarded by the authors who extend the conclusions from sub-sampling MODIS data far beyond their applicability to include any narrowband or pixel-wide along track sampling instrument. Yet the whole purpose of designing and flying such instruments is to include advanced capabilities, which would allow more accurate retrievals in places where MODIS fails. For example the CALIOP lidar has a much higher spatial resolution making many measurements for each MODIS footprint. This makes it possible to observe aerosols in scenes with broken cloudiness where no MODIS retrievals would be possible. Unlike MODIS, a lidar can observe aerosols above clouds. Consider Sahara or Asian dust outflow regions where MODIS has difficulties because of glint, underlying clouds and particle non-sphericity. These problems, however, can be addressed by an APS-like instrument with high accuracy polarization channels and multi-angle viewing capabilities.

MODIS cross-track bias is not adequately addressed

In his recent presentation at the 2013 AGU Fall Meeting, the lead author admitted that along-track sampling results are affected by the MODIS cross-track bias and crossed over Fig. 5 as no longer valid. However, in the paper this figure and along-track sampled data are still present. This especially concerns the C3 sample, which is also affected by sun glint. Fig. 9cd is particularly misleading since neither Sahara dust nor

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equatorial biomass burning regions are "observed" in C3 track. The authors also claim that MODIS “scan angle biases in the AOT field ... will not affect the statistical significance of the derived trends”. This is wrong: such biases will increase the apparent variability of the aerosol load above its actual natural level reducing the statistical significance. Since these biases are likely to depend on aerosol composition and height, cloud cover frequency, and season, their effect may be more pronounced for narrow scan samples as they view a given location less frequently.

Use of uncommon statistical methodology

The delta-AOT metric used by the authors is a non-standard statistic which is misleading since it conceals the difference between bias and noise contributions to the sub-sampling estimates. The authors should instead use the standard statistics accepted in sampling techniques, such as PDF of the sampling estimate of the regional mean AOT (with the expected value and variance of this estimate).

Misinterpretation of decadal trends

The authors’ choice of the 0.5ox0.625o grid-cell size to assess statistical significance of the AOT trends is highly questionable. Calculating trends independently in each grid-cell puts reduced sampling strategies at a disadvantage, while there is no compelling physical reason for the decadal AOT trends in two points 600 km apart to be wildly different. In fact Fig. 12 clearly shows that the trend patterns exhibit features of a regional scale, which are spatially much larger than the 0.5ox0.625o grid. This suggests that considering a few regions instead would improve the confidence for all types of sampling. This conclusion is confirmed by Figs. 17 and 18, where the use of coarser 10ox10o resolution significantly improves the agreement between various subsamples and the confidence levels.

Yet the authors chose to refer to the higher resolution Fig. 13 to state that “our subsamples could not assign significance at the 95% confidence level to any decadal-scale trends over Amazonia or the central United States, and had reduced confidence

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in western Africa and India" inconsistently switching from local to sub-continental scale.

Mixing land and ocean MODIS pixels

It is unfortunate that many of the selected aerosol regions mix over land and over ocean pixels in different proportions as the MODIS retrieval approaches and coverage are completely different over land and ocean. Combining them obscures the biases and gaps of the land and ocean retrievals. Also, the authors' statement that "DARF depends strongly on the reflective properties of the surface over which the particles reside, most of which would be unobserved by the curtain instrument" is irrelevant to the study of climatological effects of aerosols, which require statistical properties of aerosol composition and load – tasks for which advanced along-track aerosol sensor is well suited. In addition, ocean surface reflectivity can be modeled and extensive observational data exist on the statistical properties of land surfaces.

Interactive comment on Atmos. Meas. Tech. Discuss., 6, 10117, 2013.