Response to Anonymous Referee #1

Collocation Mismatch Uncertainties in Satellite Aerosol Retrieval Validation

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We thank the Referee for the positive feedback and constructive comments. The numbered comments are answered below and the changes to the manuscript are indicated in a separate pdf file.

1. *The paper focuses on the DRAGON campaign area and mostly provides composite results for all sites. I wonder if how different is the CMU for different sites, especially between urban and rural sites?*

   It was briefly mentioned in the manuscript (p. 5, line 4) that unlike Munchak et al. (2013), we did not find any significant difference in the performance of the satellite AOD retrieval between urban and rural areas. The same is true for CMU; we did not find any systematic difference between urban and non-urban sites in the spatial (AATSR) or temporal (AERONET) standard deviation of AOD. We went through the collocated cases (matches) for each site individually (Fig. 1 and Table 1 below). The CMU and AOD correlation vary from site to site, but none of the sites stands out as particularly peculiar, when the full range of sampling parameters is considered. We note that the low number of matches for individual sites limits the analysis; more data would be required to study the CMU in greater detail for individual sites. We have added the enclosed Fig. 1 and Table 1 to the Supplement (as Fig. S2, and Table S4), and a brief discussion of this to the manuscript (p. 12, after line 11).

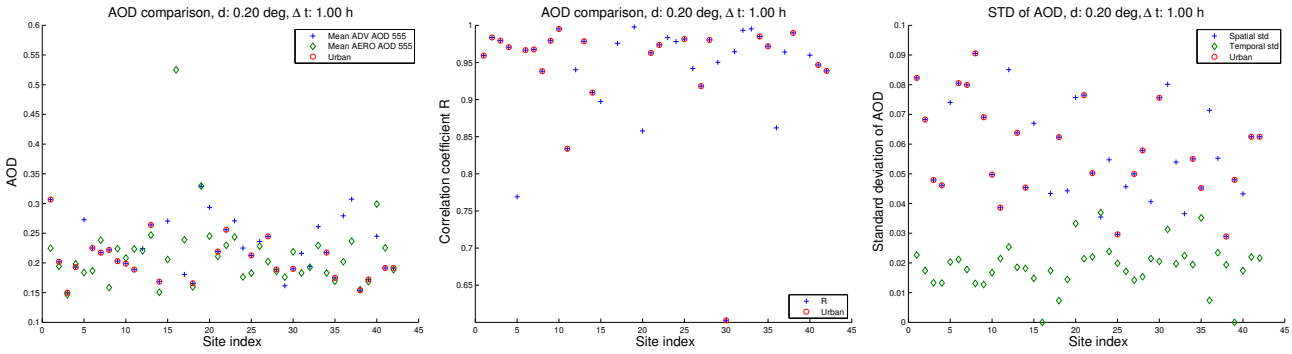

Figure 1: Comparison of AOD and standard deviation of AOD between AATSR and AERONET does not differ systematically between urban and rural sites. The urban sites are marked with red circles. **(a)** Average AATSR and AERONET AOD for individual sites over the study period. **(b)** The correlation coefficient R between AATSR and AERONET AOD for individual sites. For one of the sites (DRAGON_Padonia) the AOD correlation coefficient is particularly low (0.6) for the selected sampling parameters (d=0.2°, $\Delta t = 1$ h), but not necessarily for other sampling parameters. **(c)** The average spatial standard deviation of AOD for AATSR and the corresponding temporal standard deviation of AERONET AOD for individual sites.

2. *The 'collocated area' between satellite and ground measurements is defined as a symmetric circle around the AERONET site. I understand this is conventional practice for satellite data evaluation. But due to factors such as aerosol transport, cloud and topography, etc, the distribution of AOD spatial variability is usually not symmetric. I wonder if the authors have examined the specific AOD spatial variability for each site?*

   It is understood that the spatiotemporal mismatch between the airmass sampled by the satellite and by the sun-photometers depends on the trajectories, i.e. wind direction and local topography. Although the use of AOD gradients (following Ichoku et al. 2002) was initially considered, we decided to focus in this study on CMU estimation methods that could be easily implemented in the global aerosol retrieval algorithm without the need for external data (such as wind directions). For the individual sites, see the response to the previous comment above. We have added a brief discussion of the matter to the manuscript (p. 12, after line 11).

   The effect of clouds on the collocation mismatch can be large even though both satellite and ground based data are cloud screened, as discussed in the manuscript (p. 9). A more detailed study taking into account the cloud proximity effects would be interesting, but is beyond the scope of this study.

3. *In this work and in all collocation works the CMU actually combines both spatial and temporal variability, as both a space and time window is needed. It would be more precise if the space and time CMU could be separated. I understand this is a difficult practice, but could the authors offer some discussion?*

   In this study we concentrate mainly on the spatial AOD variability, since that is available from the satellite data and the goal is to provide the uncertainty estimate for the global satellite product. However, information on the temporal variability is available from the AERONET observations, as discussed in the manuscript (p. 7, line 10, and p. 10, line 20). The temporal variability and the correlation between spatial and temporal variability is shown in Fig. S1 in the supplement, and discussed on pp. 10-11 in the manuscript. While the spatial and temporal variability from the AERONET data are of the same order of magnitude (~ 0.02, depending on the sampling parameters), the spatial variability obtained from the satellite data (~ 0.08) dominates CMU.

4. *The results indicate some difference between the CMU estimated using AATSR and MODIS data. Since AATSR is not as popular a dataset as MODIS. It would be helpful to offer some intercomparison results between these two datasets, e.g., any disagreements in their absolute magnitudes and spatial variability.*

   Comparison of AATSR and MODIS AOD products (on a global scale) has been done elsewhere (e.g. de Leeuw et al. 2015), and the results are in agreement in general. In this study, the correlations between collocated AOD values of AATSR and AERONET are similar to those of MODIS and AERONET for most of the sampling parameters (Figs. 4 and 9). The spatial variability of AERONET AOD correlates slightly stronger with the corresponding values from MODIS than from AATSR (Figs. 6 and 9).

   We can also compare the AOD values from AATSR and MODIS for the study area and period by regridding the MODIS 10 km product data to the AATSR ADV 0.1 degree grid. We find that the collocated AOD values of AATSR and MODIS agree well with R=0.89 (Fig. 2 below, now added to the Supplement as Fig. S10). The day-to-day changes in AOD variability for the full study area are tracked in a similar fashion by both AATSR and MODIS, as shown in Fig. 3 below. We have replaced Fig. 7 in the manuscript by this figure, so that MODIS is included in the comparison. We have also updated Table S3 in the Supplement to include MODIS data. MODIS overestimates the variability less than AATSR and has slightly better correlation with AERONET. We have added a brief discussion of the inter-satellite comparison to the manuscript (Section 4.3, p. 15). We note that to properly compare the spatial variability of AOD between the two satellite instruments would require more careful sampling, and is beyond the scope of this study. Here we mainly wanted to demonstrate that the methods applied to the AATSR data are in principle applicable to other satellite instruments as well.

   Please note that while reproducing Fig. 7, a small error in calculating the temporal collocations was discovered and corrected. This changes the daily collocated AERONET values and the corresponding correlation coefficients slightly, as can be seen in the updated Fig. 7 and Table S3. This error only affected the daily collocation for the whole study area (time series), and has no effect on the other results shown in the manuscript.

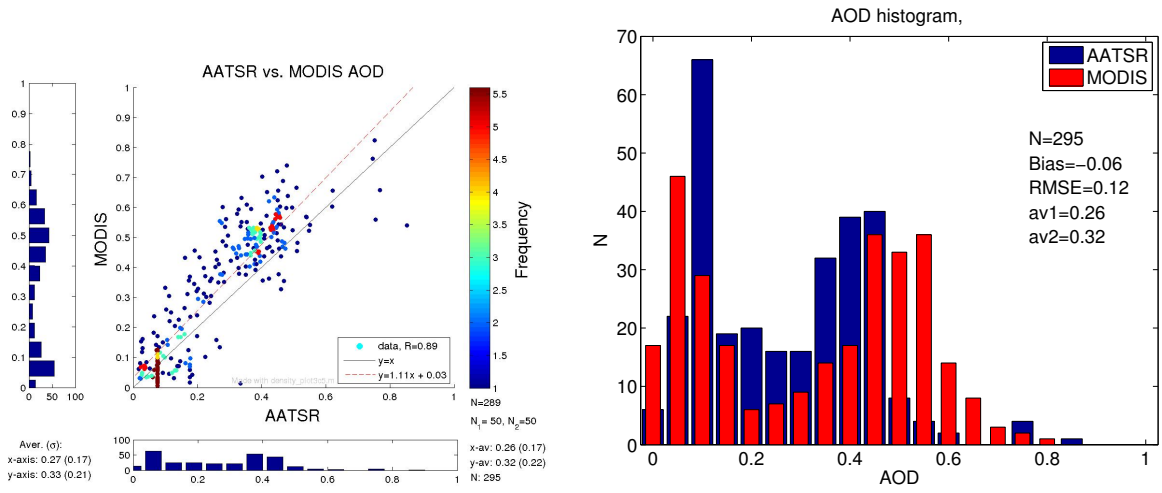

Figure 2: Comparison of collocated AATSR ADV and MODIS 10 km AOD values at 555 nm for the DRAGON 2011 campaign.

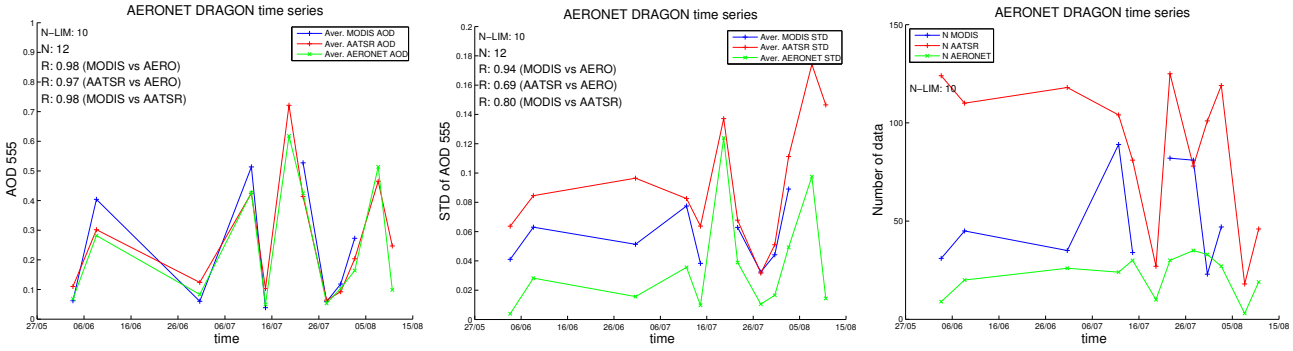

Figure 3: Day-to-day changes in AOD and spatial AOD variability for the full study area for AATSR, MODIS and AERONET. Note that here we limit the consideration to days when AATSR has data over the area; for MODIS there is data for more days than shown here.

5. *Figures 4, 6, and 7-9 seem a bit difficult to read. I suggest increase the line weights and fond sizes a little bit for clearer presentation.*

   We have increase the font sizes and line widths, and will consult the Editor about options for increasing the image sizes.

Ind	Site name	URB	N_m	AATSR		AERO		R	$\Delta\tau$
				AOD	σ	AOD	σ		
1	DRAGON_ABERD	1	9	0.31	0.08	0.22	0.02	0.96	0.08
2	DRAGON_ANNEA	1	8	0.20	0.07	0.19	0.02	0.98	0.01
3	DRAGON_ARNCC	1	10	0.15	0.05	0.15	0.01	0.98	0.00
4	DRAGON_ARNLS	1	7	0.19	0.05	0.20	0.01	0.97	-0.01
5	DRAGON_Aldino	0	13	0.27	0.07	0.18	0.02	0.77	0.09
6	DRAGON_BATMR	1	10	0.23	0.08	0.19	0.02	0.97	0.04
7	DRAGON_BLDND	1	11	0.22	0.08	0.24	0.02	0.97	-0.02
8	DRAGON_BLLRT	1	8	0.22	0.09	0.16	0.01	0.94	0.06
9	DRAGON_BLTCC	1	8	0.20	0.07	0.22	0.01	0.98	-0.02
10	DRAGON_BLTNR	1	8	0.20	0.05	0.21	0.02	1.00	-0.01
11	DRAGON_BOWEM	1	11	0.19	0.04	0.22	0.02	0.83	-0.03
12	DRAGON_BTMDL	0	9	0.22	0.09	0.22	0.03	0.94	0.00
13	DRAGON_Beltsville	1	10	0.26	0.06	0.25	0.02	0.98	0.02
14	DRAGON_CLLGP	1	10	0.17	0.05	0.15	0.02	0.91	0.02
15	DRAGON_CLRST	0	10	0.27	0.07	0.21	0.01	0.90	0.06
16	DRAGON_CPSDN	0	1	NaN	NaN	0.53	0.00	NaN	NaN
17	DRAGON_EDCMS	0	14	0.18	0.04	0.24	0.02	0.98	-0.06
18	DRAGON_ELLCT	1	3	0.17	0.06	0.16	0.01	NaN	0.01
19	DRAGON_EaglePoint	0	4	0.33	0.04	0.33	0.01	1.00	-0.00
20	DRAGON_Edgewood	0	14	0.29	0.08	0.25	0.03	0.86	0.05
21	DRAGON_Essex	1	13	0.22	0.08	0.21	0.02	0.96	0.01
22	DRAGON_FLLST	1	12	0.26	0.05	0.23	0.02	0.97	0.03
23	DRAGON_FairHill	0	13	0.27	0.04	0.24	0.04	0.98	0.03
24	DRAGON_KentIsland	0	10	0.22	0.05	0.18	0.02	0.98	0.05
25	DRAGON_LAUMD	1	5	0.21	0.03	0.18	0.02	0.98	0.03
26	DRAGON_MNKTN	0	10	0.24	0.05	0.23	0.02	0.94	0.01
27	DRAGON_OLNES	1	12	0.24	0.05	0.20	0.01	0.92	0.04
28	DRAGON_ONNGS	1	10	0.19	0.06	0.19	0.02	0.98	0.00
29	DRAGON_PATUX	0	9	0.16	0.04	0.18	0.02	0.95	-0.01
30	DRAGON_Padonia	1	7	0.19	0.08	0.22	0.02	0.60	-0.03
31	DRAGON_Pasadena	0	8	0.22	0.08	0.18	0.03	0.96	0.03
32	DRAGON_PineyOrchard	0	7	0.19	0.05	0.19	0.02	0.99	0.00
33	DRAGON_Pylesville	0	9	0.26	0.04	0.23	0.02	1.00	0.03
34	DRAGON_SPBRK	1	12	0.22	0.06	0.18	0.02	0.98	0.03
35	DRAGON_UMRLB	1	8	0.17	0.05	0.17	0.04	0.97	0.01
36	DRAGON_WSTFD	0	8	0.28	0.07	0.20	0.01	0.86	0.08
37	DRAGON_Worton	0	8	0.31	0.06	0.24	0.02	0.96	0.07
38	GSFC	1	9	0.15	0.03	0.15	0.02	0.99	-0.00
39	MD_Science_Center	1	3	0.17	0.05	0.17	0.00	NaN	0.00
40	SERC	0	6	0.24	0.04	0.30	0.02	0.96	-0.05
41	UMBC	1	10	0.19	0.06	0.23	0.02	0.95	-0.03
42	UMBC_temp	1	10	0.19	0.06	0.19	0.02	0.94	0.00
	Average	0.6	9.0	0.22	0.06	0.21	0.02	0.94	0.03
	Aver. (urban)	1.0	9.0	0.20	0.06	0.20	0.02	0.94	0.02
	Aver. (non-urban)	0.0	9.0	0.25	0.06	0.24	0.02	0.94	0.04

Table 1: AOD comparison between AATSR and individual AERONET sites in the study area for the study period. Column 'URB' is 1 for urban sites, 0 for non-urban sites. Column 'N_m' gives the number of matches i.e. the number of AATSR overpasses in cloud-free conditions. The averages over the columns are calculated for all sites, for the 25 urban sites, and for the 17 non-urban sites, respectively. The sampling parameters used in this comparison are d=0.20 °, Δt=1.00 h.