Digital Supplement to Manuscript

Coherent uncertainty analysis of aerosol measurements from multiple satellite sensors

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Description

This digital supplement to the paper 'Coherent uncertainty analysis of aerosol measurements from multiple satellite sensors' presents additional statistics and figures that were not included in the main paper to avoid overcrowding. While the main paper focuses on the analysis of the **mean** AOD values of the spatial subsets of the satellite data within 55-km diameter circles centered over the ground-based AERONET sites and coincident 1-hour AERONET data segments centered at each satellite overpass time (i.e., the spatially-averaged spaceborne aerosol observations were compared to the time-averaged ground-based observations from AERONET), this supplement replicates the analysis of Sect. 6 and Sect. 7 by using the central (**cval**) AOD values instead of the mean. For the spaceborne data, the central value is the value of a pixel in the subset that has the smallest distance to the ground station. For the ground-based data, this is the value of a measurement in the subset that is the closest in time to the satellite overpass. To facilitate cross-referencing between the main paper and this supplement, the **cval**-based figures and tables in the supplement are numbered similarly to the corresponding **mean**-based figures in the main document, e.g., Fig. 6b. in the supplement corresponds to Fig. 6 in the main document.

Table 3b. Statistics of the studied aerosol data sets based on all AERONET stations during the period of 2006-06-07 and 2010-12-11. 'Ntot' indicates the total number of the collocated Spaceborne AOD - AERONET AOD data points, while 'Nfilt' indicates the number of data points after filtering (screening) the spaceborne data by QA as described in Section 4 and Table 2. 'Nout' is the total number of the possible data outliers determined as explained in Section 5. The last 8 columns present the statistics on the collocated data based on regression fits also plotted in Fig. 6b.

Dataset	Nfilt	Nfilt /Ntot (%)	Nout	Nfilt/ Nout (%)	Complete data				Outliers removed			
					R^2	RMSE	Slope	Intercept	R^2	RMSE	Slope	Intercept
All seasons												
TMODIS DT	26162	56.3	840	3.2	0.81	0.11	1.00	0.00	0.86	0.08	0.99	0.00
TMODIS DB	1363	18.9	85	6.2	0.73	0.21	0.76	0.09	0.81	0.13	0.91	0.04
TMODIS O	1696	99.6	99	5.8	0.88	0.10	1.14	0.00	0.92	0.05	0.97	0.02
AMODIS DT	20644	51.9	792	3.8	0.80	0.11	0.99	0.01	0.85	0.08	1.00	0.00
AMODIS DB	3672	17.7	184	5	0.76	0.20	0.87	0.03	0.84	0.14	0.93	0.01
AMODIS O	1827	99.7	111	6.1	0.81	0.10	1.06	0.01	0.92	0.04	0.95	0.02
MISR	8517	87.8	464	5.4	0.78	0.12	0.66	0.06	0.85	0.06	0.85	0.03
OMI	39600	95.6	1930	4.9	0.41	0.25	0.76	0.14	0.55	0.18	0.79	0.11
CALIOP	1482	88.3	118	8	0.29	0.24	0.48	0.07	0.62	0.12	0.75	0.00
POLDER3 L	26669	74.9	3128	11.7	0.27	0.21	0.18	0.02	0.59	0.08	0.53	-0.01
POLDER3 O	4243	48.6	406	9.6	0.38	0.16	0.24	0.03	0.58	0.08	0.56	0.00
SeaWiFS L	10366	37.3	547	5.3	0.78	0.13	0.74	0.04	0.84	0.08	0.89	0.01
SeaWiFS O	3416	70.8	276	8.1	0.65	0.13	1.04	0.04	0.81	0.06	0.92	0.03
Fall												
TMODIS DT	7072	55	242	3.4	0.86	0.11	1.06	-0.02	0.89	0.08	0.98	-0.01
TMODIS DB	399	16.5	10	2.5	0.53	0.17	0.92	0.03	0.63	0.13	0.91	0.03
TMODIS O	456	99.8	24	5.3	0.89	0.06	0.98	0.02	0.93	0.04	0.96	0.02
AMODIS DT	5253	49.8	190	3.6	0.85	0.10	1.04	-0.01	0.87	0.07	0.99	0.00
AMODIS DB	1034	17.2	39	3.8	0.76	0.16	1.00	-0.01	0.83	0.12	0.99	-0.01
AMODIS O	493	99.8	33	6.7	0.85	0.06	0.81	0.03	0.92	0.04	0.89	0.02
MISR	2219	86.5	138	6.2	0.79	0.11	0.62	0.05	0.86	0.05	0.84	0.02
OMI	10124	94.3	545	5.4	0.32	0.22	0.70	0.13	0.51	0.15	0.76	0.09
CALIOP	417	88	33	7.9	0.26	0.26	0.44	0.08	0.62	0.11	0.75	0.00
POLDER3 L	8309	75.2	836	10.1	0.43	0.15	0.35	0.00	0.69	0.07	0.65	-0.02
POLDER3 O	1090	45.9	84	7.7	0.48	0.13	0.32	0.02	0.61	0.07	0.59	-0.01
SeaWiFS L	3347	40.3	141	4.2	0.83	0.10	0.81	0.02	0.86	0.07	0.91	0.01
SeaWiFS O	922	70	85	9.2	0.64	0.13	1.08	0.04	0.81	0.06	0.91	0.03

Table 3b (continued)

Dataset	Nfilt	Nfilt /Ntot (%)	Nout	Nfilt/ Nout (%)	Complete data				Outliers removed			
					R^2	RMSE	Slope	Intercept	R^2	RMSE	Slope	Intercept
					Winter							
TMODIS DT	2390	47	112	4.7	0.81	0.13	0.77	0.04	0.87	0.09	0.90	0.02
TMODIS DB	261	19.3	27	10.3	0.74	0.20	0.79	0.08	0.86	0.10	0.97	0.03
TMODIS O	219	100	12	5.5	0.90	0.05	1.07	0.01	0.92	0.04	0.95	0.02
AMODIS DT	1803	43.1	96	5.3	0.79	0.15	0.76	0.04	0.86	0.10	0.91	0.01
AMODIS DB	829	18.9	54	6.5	0.78	0.17	0.83	0.03	0.85	0.12	0.88	0.02
AMODIS O	227	100	18	7.9	0.87	0.06	0.85	0.03	0.93	0.03	0.97	0.01
MISR	1275	88.1	80	6.3	0.82	0.10	0.61	0.05	0.84	0.06	0.78	0.03
OMI	6283	94.1	266	4.2	0.47	0.24	0.68	0.15	0.58	0.18	0.72	0.12
CALIOP	242	86.7	23	9.5	0.29	0.28	0.37	0.11	0.63	0.12	0.75	0.02
POLDER3 L	4193	75.9	418	10	0.33	0.22	0.15	0.03	0.57	0.09	0.42	0.00
POLDER3 O	642	48.3	38	5.9	0.55	0.11	0.40	0.01	0.60	0.08	0.55	-0.01
SeaWiFS L	1819	40.3	94	5.2	0.68	0.16	0.63	0.07	0.74	0.11	0.76	0.04
SeaWiFS O	376	67	37	9.8	0.57	0.13	0.97	0.06	0.74	0.07	0.85	0.04
					Spring							
TMODIS DT	6213	57.6	198	3.2	0.81	0.11	0.94	0.03	0.86	0.09	0.98	0.01
TMODIS DB	246	20.9	13	5.3	0.80	0.27	0.70	0.14	0.8	0.18	0.86	0.08
TMODIS O	348	99.4	18	5.2	0.89	0.12	1.25	-0.01	0.91	0.07	1.04	0.02
AMODIS DT	4929	53.4	181	3.7	0.81	0.12	0.97	0.03	0.86	0.09	1.00	0.02
AMODIS DB	892	18.9	27	3	0.75	0.24	0.80	0.08	0.79	0.19	0.87	0.04
AMODIS O	366	99.7	22	6	0.82	0.16	1.30	-0.03	0.93	0.05	0.98	0.02
MISR	2189	88.4	135	6.2	0.76	0.14	0.66	0.07	0.86	0.07	0.86	0.03
OMI	9474	96.3	445	4.7	0.47	0.29	0.81	0.15	0.59	0.21	0.83	0.11
CALIOP	349	88.6	32	9.2	0.38	0.24	0.61	0.04	0.62	0.13	0.74	-0.01
POLDER3 L	6648	77.1	963	14.5	0.25	0.28	0.12	0.03	0.50	0.10	0.41	-0.01
POLDER3 O	1130	50	123	10.9	0.38	0.18	0.23	0.04	0.52	0.09	0.49	0.01
SeaWiFS L	2458	39.2	157	6.4	0.83	0.15	0.75	0.05	0.89	0.08	0.92	0.02
SeaWiFS O	763	69.9	64	8.4	0.66	0.16	1.05	0.04	0.82	0.07	0.95	0.03
					Summer							
TMODIS DT	10487	59.1	277	2.6	0.79	0.11	1.10	-0.02	0.82	0.08	1.03	-0.01
TMODIS DB	457	20	32	7	0.72	0.22	0.76	0.09	0.80	0.13	0.90	0.03
TMODIS O	673	99.6	28	4.2	0.86	0.11	1.15	0.00	0.91	0.06	0.98	0.03
AMODIS DT	8659	54.8	276	3.2	0.80	0.10	1.12	-0.01	0.80	0.08	1.04	0.00
AMODIS DB	917	16.5	49	5.3	0.74	0.20	0.90	0.03	0.83	0.14	0.95	0.00
AMODIS O	741	99.5	43	5.8	0.84	0.09	1.05	0.01	0.91	0.05	0.95	0.02
MISR	2834	88.3	121	4.3	0.77	0.11	0.72	0.05	0.84	0.07	0.88	0.03
OMI	13719	96.8	617	4.5	0.33	0.26	0.74	0.16	0.48	0.19	0.79	0.12
CALIOP	474	89.3	32	6.8	0.26	0.20	0.54	0.05	0.58	0.12	0.73	0.00
POLDER3 L	7519	72.4	876	11.7	0.22	0.19	0.17	0.02	0.53	0.07	0.54	-0.01
POLDER3 O	1381	49.9	152	11	0.31	0.19	0.19	0.04	0.59	0.07	0.59	0.00
SeaWiFS L	2742	31.5	116	4.2	0.72	0.13	0.71	0.03	0.77	0.08	0.86	0.00
SeaWiFS O	1355	73.1	97	7.2	0.68	0.10	1.02	0.03	0.82	0.06	0.94	0.03

Table 4b. Linear fit correlation coefficient (R2) between the collocated spaceborne and ground-based observations of AOD estimated at the stations that coincide with different IGBP land cover types. Empty cells indicate no collocated data available from a specific sensor over a specific land cover type. No AERONET stations are available at the areas occupied by Deciduous needleleaf forest. The statistics were calculated based on the data that was pre-filtered by QA and screened of outliers as described in Sections 4 and Section 5. A graphical representation of this table is in Figure 13b.

	TMODIS DT	TMODIS DB	TMODIS O	AMODIS DT	AMODIS DB	AMODIS O	MISR	OMI	CALIOP	POLDER3 L	POLDER3 O	SeaWiFS L	SeaWiFS O
Water			0.87			0.88	0.78	0.47	0.53		0.56		0.65
Evergreen needleleaf forest	0.80			0.82	0.87		0.76	0.38	0.60	0.59		0.58	
Evergreen broadleaf forest	0.77			0.87			0.69	0.49	0.15	0.94		0.91	
Deciduous broadleaf forest	0.85			0.89			0.82	0.58	0.35	0.72		0.75	
Mixed forests	0.79			0.83			0.74	0.39	0.62	0.71		0.70	
Closed shrubland	0.73	0.86		0.78	0.77		0.77	0.48	0.64	0.40		0.79	
Open shrublands	0.54	0.61		0.64	0.75		0.69	0.28	0.70	0.38		0.60	
Woody savannas	0.76	0.90		0.84	0.87		0.79	0.52	0.60	0.55		0.83	
Savannas	0.76	0.65		0.86	0.61		0.81	0.53	0.46	0.67		0.74	
Grasslands	0.62	0.88		0.68	0.75		0.70	0.40	0.48	0.36		0.61	
Permanent wetlands	0.79			0.90			0.84	0.33	0.57	0.33			
Croplands	0.77	0.70		0.79	0.57		0.77	0.49	0.56	0.47		0.67	
Urban and built-up	0.75	0.67		0.74	0.70		0.73	0.44	0.46	0.42		0.69	
Cropland / natural veget. mosaic	0.77			0.81	0.53		0.81	0.56	0.57	0.59		0.73	
Snow and ice	1.00						0.73		1.00	0.54			
Barren or sparsely vegetated	0.72	0.71		0.72	0.48		0.72	0.21	0.54	0.32		0.53	

Table 5b. Root mean square error (RMSE) between the collocated spaceborne and ground-based observations of AOD estimated at the stations that coincide with different IGBP land cover types. Empty cells indicate no collocated data available from a specific sensor over a specific land cover type. No AERONET stations are available at the areas occupied by Deciduous needleleaf forest. The statistics were calculated based on the data that was pre-filtered by QA and screened of outliers as described in Sections 4 and Section 5. A graphical representation of this table is in Figure 14b.

	TMODIS DT	TMODIS DB	TMODIS O	AMODIS DT	AMODIS DB	AMODIS O	MISR	OMI	CALIOP	POLDER3 L	POLDER3 O	SeaWiFS L	SeaWiFS O
Water			0.06			0.05	0.09	0.16	0.12		0.08		0.09
Evergreen needleleaf forest	0.06	0.06		0.06	0.34		0.06	0.15	0.11	0.06		0.05	
Evergreen broadleaf forest	0.11			0.10			0.15	0.25	0.36	0.08		0.18	
Deciduous broadleaf forest	0.06			0.06			0.05	0.11	0.13	0.05		0.05	
Mixed forests	0.06			0.05			0.04	0.14	0.12	0.06		0.06	
Closed shrubland	0.13	0.09		0.08	0.06		0.06	0.19	0.06	0.10		0.05	
Open shrublands	0.09	0.09		0.07	0.14		0.07	0.25	0.14	0.14		0.10	
Woody savannas	0.09	0.44		0.10	0.23		0.08	0.22	0.23	0.15		0.08	
Savannas	0.10	0.19		0.09	0.15		0.08	0.23	0.12	0.13		0.13	
Grasslands	0.08	0.22		0.08	0.13		0.05	0.19	0.13	0.11		0.07	
Permanent wetlands	0.07			0.07			0.08	0.16	0.12	0.09		0.19	
Croplands	0.09	0.10		0.09	0.12		0.08	0.16	0.16	0.11		0.09	
Urban and built-up	0.10	0.15		0.10	0.14		0.07	0.21	0.14	0.10		0.09	
Cropland / natural veget. mosaic	0.09			0.09	0.17		0.05	0.14	0.20	0.09		0.10	
Snow and ice	0.10						0.02		0.04	0.01			
Barren or sparsely vegetated	0.09	0.06		0.10	0.11		0.09	0.38	0.12	0.12		0.16	

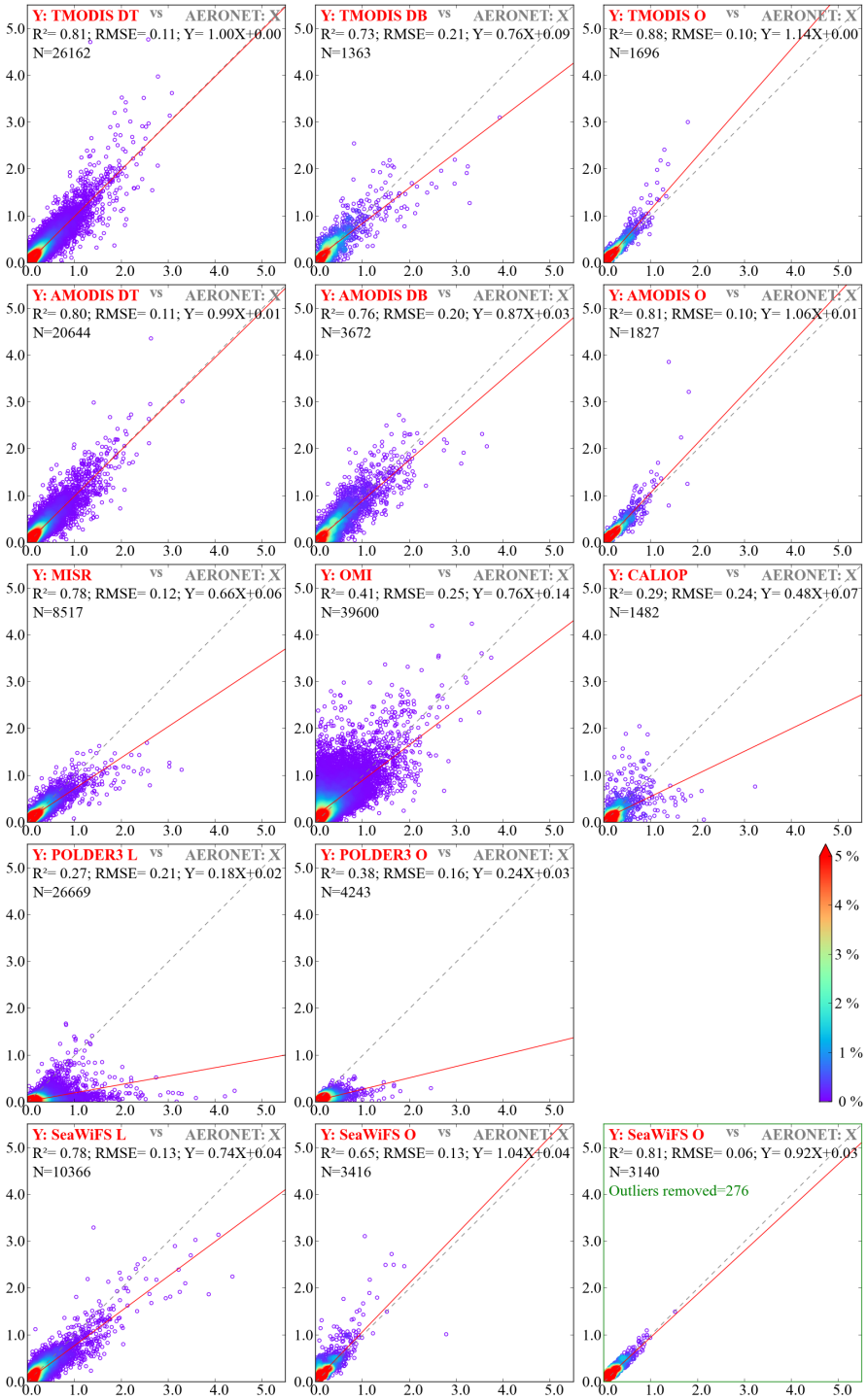

Figure 6b. Regression fits of AERONET AOD (x-axes) to AOD measured by spaceborne sensors (y-axes). Satellite data were pre-screened by QA as explained in Section 4. The color of each data point indicates the percentage of all data points on the plot that fall within 0.05 AOD of this point (in Cartesian coordinates). Scatter plot in the green frame demonstrates the results of the possible data outlier detection and removal procedure described in Section 5.

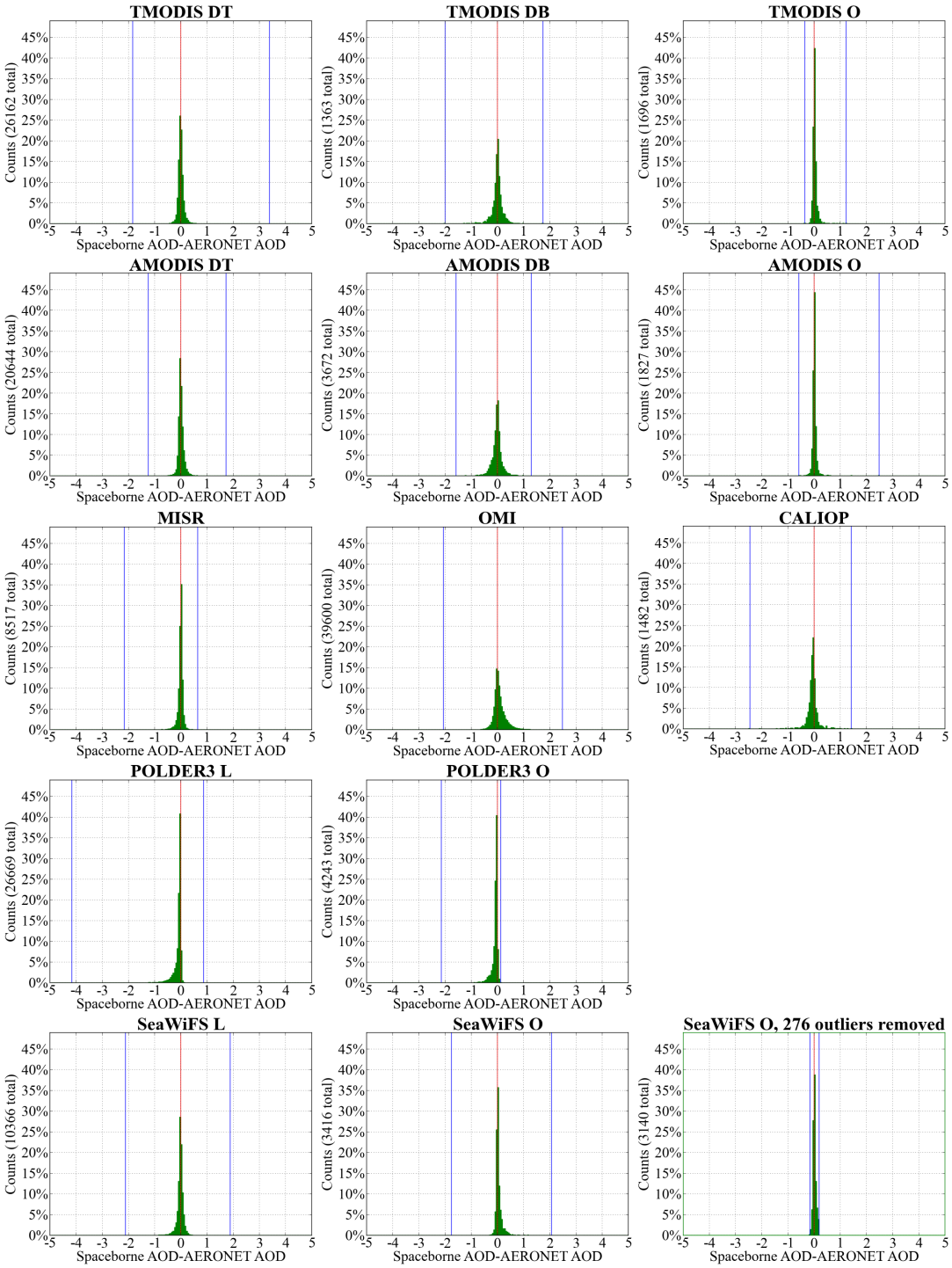

Figure 7b. Distribution of the difference (residuals) between Spaceborne AOD and AERONET AOD. Satellite data were pre-screened by QA as explained in Section 4. In each histogram, the data are split into equal-length bins of 0.05 AOD. The red vertical line indicates the residual of 0 AOD, while the blue lines mark minimum and maximum residuals of each distribution. Histogram in the green frame demonstrates the results of the possible data outlier detection and removal procedure described in Section 5.

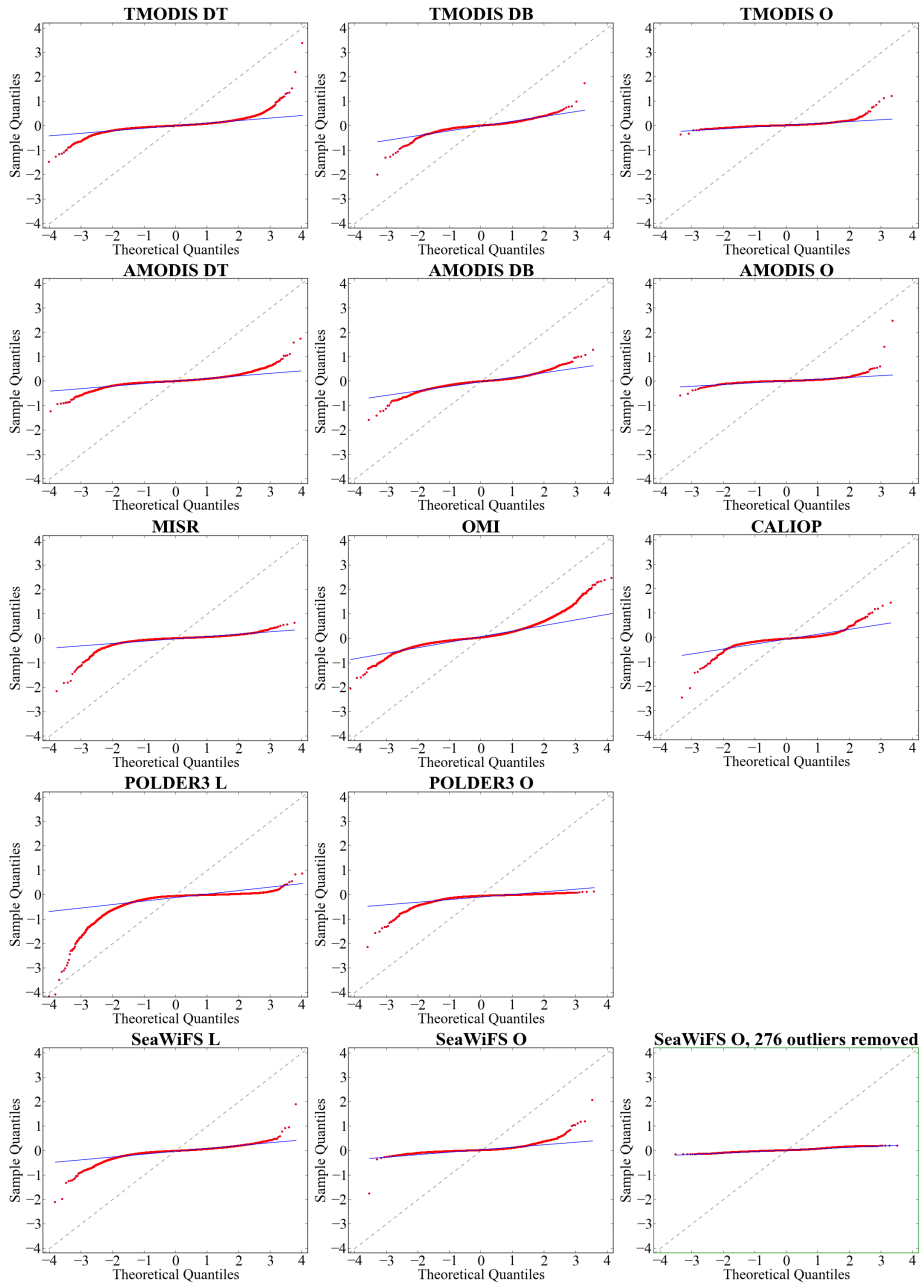

Figure 8b. Normality of the difference between Spaceborne AOD and AERONET AOD. In each plot, points closely following the blue fitted line indicate the data that are approximately normally distributed. Curvatures around the center of the straight line represent the departure from the normality and indicate a presence of possible outliers, particularly at the tails of the distributions. The difference in the slope and offset of the fitted blue line from the gray 1:1 line indicates a deviation from the standard location (i.e., mean=0) and scale (i.e., standard deviation=1) of the normal distribution. Satellite data were pre-screened by QA as explained in Section 4. Plot in the green frame demonstrates the results of the possible data outlier detection and removal procedure described in Section 5.

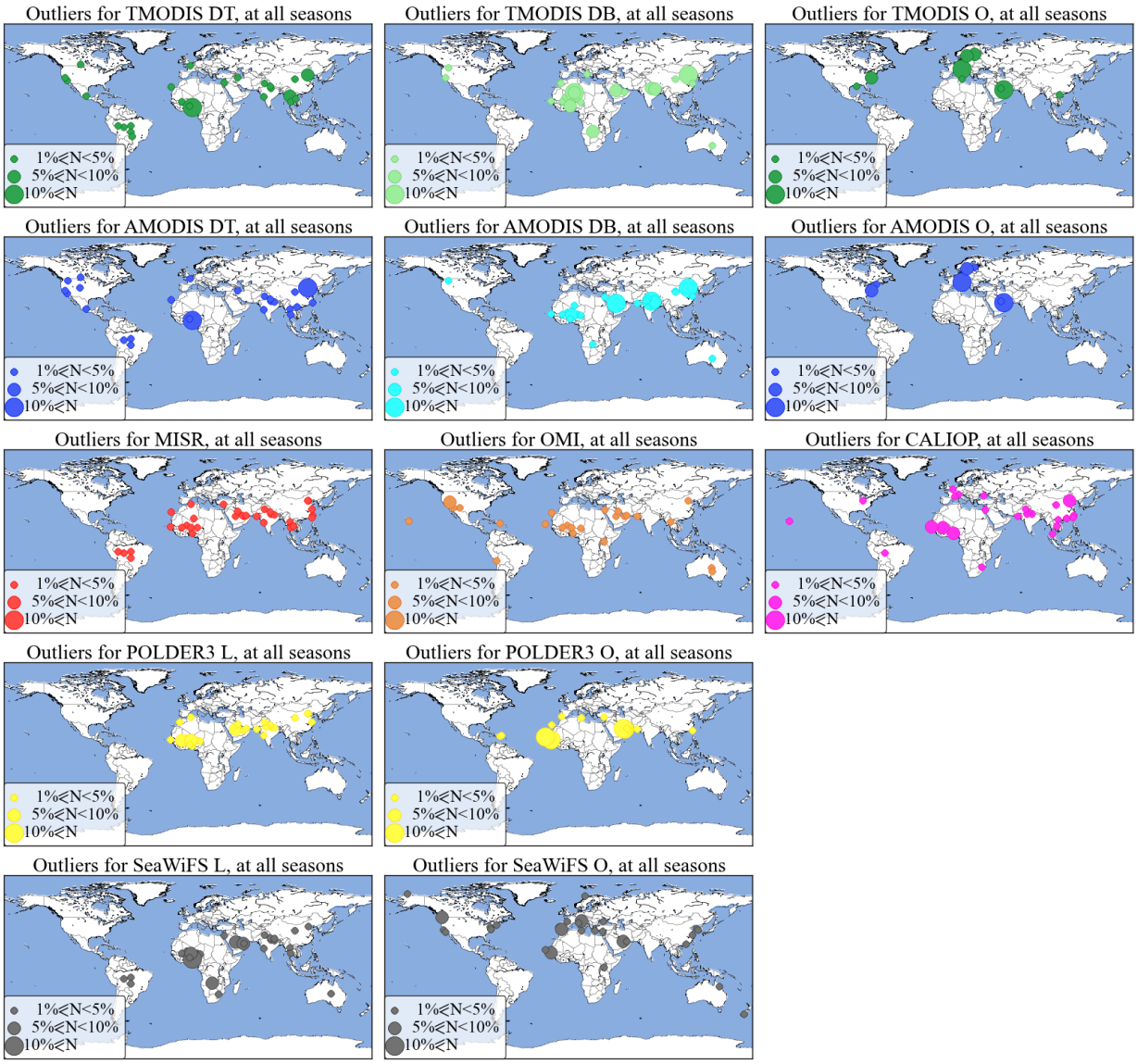

Figure 9b. Distribution of the possible data outliers for the studied spaceborne aerosol data sets. Displayed values are percentages from all outliers detected for each of the data sets as listed in the 4th column of Table 3. Stations with less than 1% from the total number of outliers are not shown. The statistical technique for detection and removal of the possible data outliers is described in Section 5.

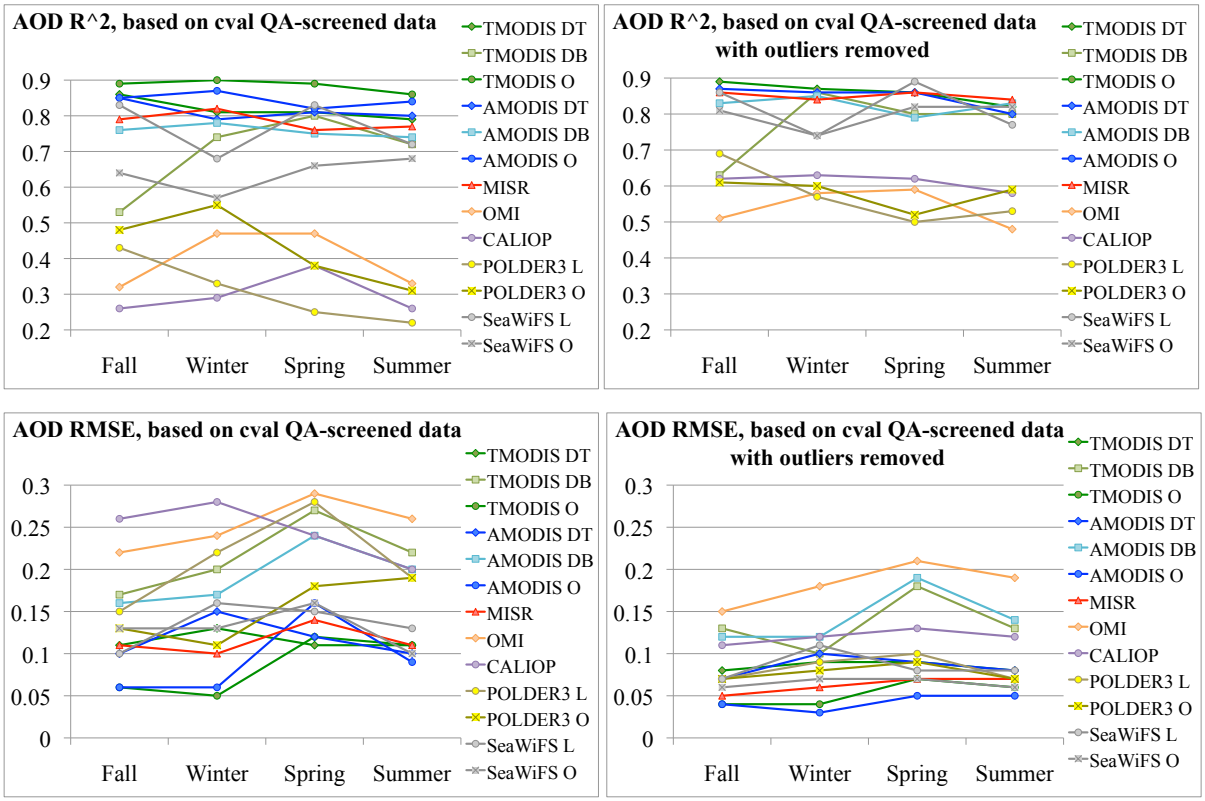

Figure 10b. Seasonal dependence of squared linear fit correlation coefficient (R^2) and root mean square error (RMSE) statistics between the collocated spaceborne and ground-based (AERONET) observations of AOD, based on the data in Table 3b.

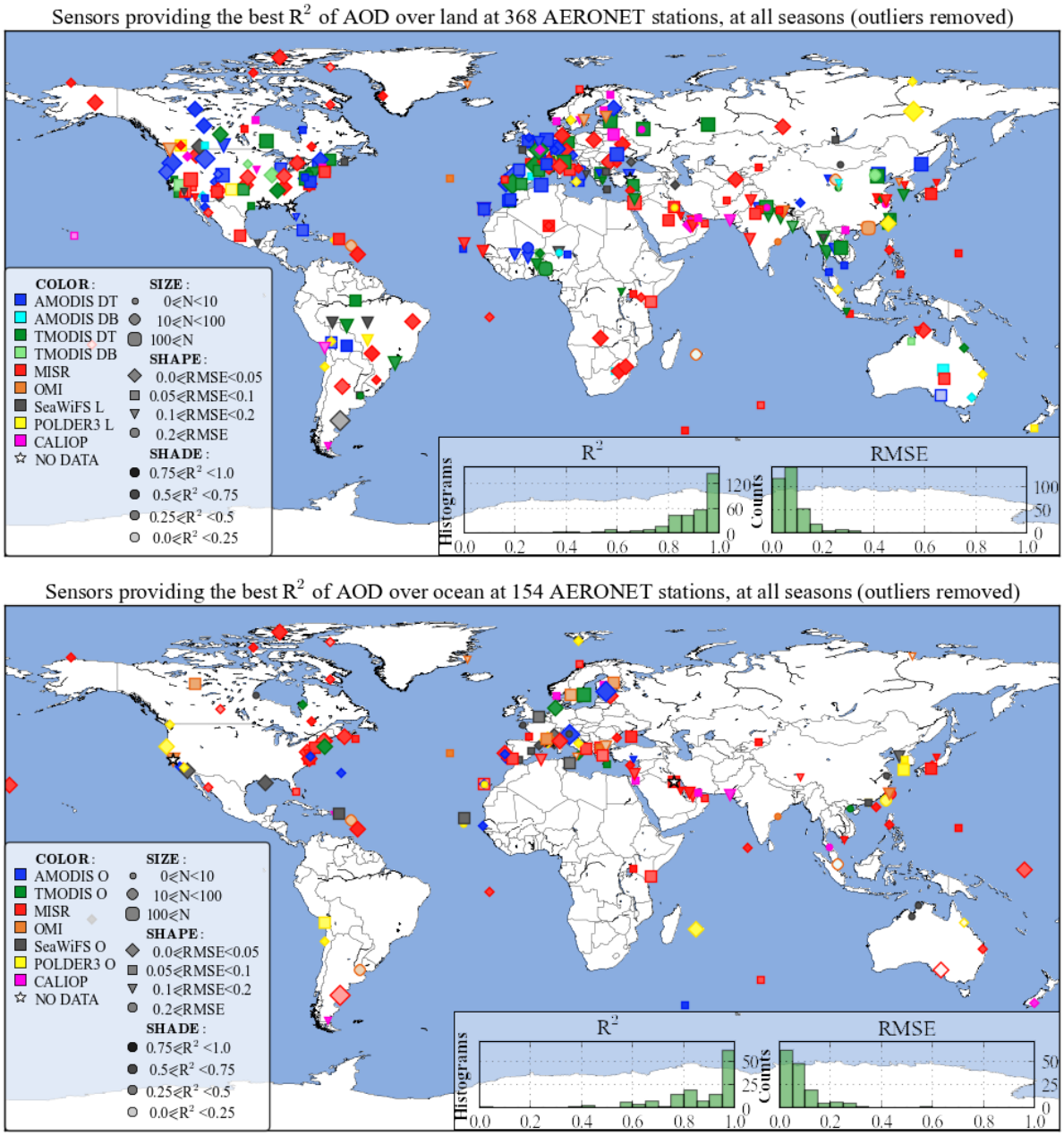

Figure 11. Spaceborne datasets with the best correlation (R^2) of the retrieved AOD to the AOD measured by inland (top) and coastal or island-based (bottom) AERONET sites. The intensity of marker shading indicates the degree of correlation. Marker shape indicates the range of root mean square error (RMSE) associated with the displayed best R^2. Finally, marker size corresponds to the number of collocated data points used to compute the displayed statistics. Histograms in the bottom insets highlight the distribution of these statistics over all sites based on bins of 0.05 AOD. The statistics were calculated based on the data that were pre-filtered by QA and screened of outliers as described in Sections 4 and Section 5.

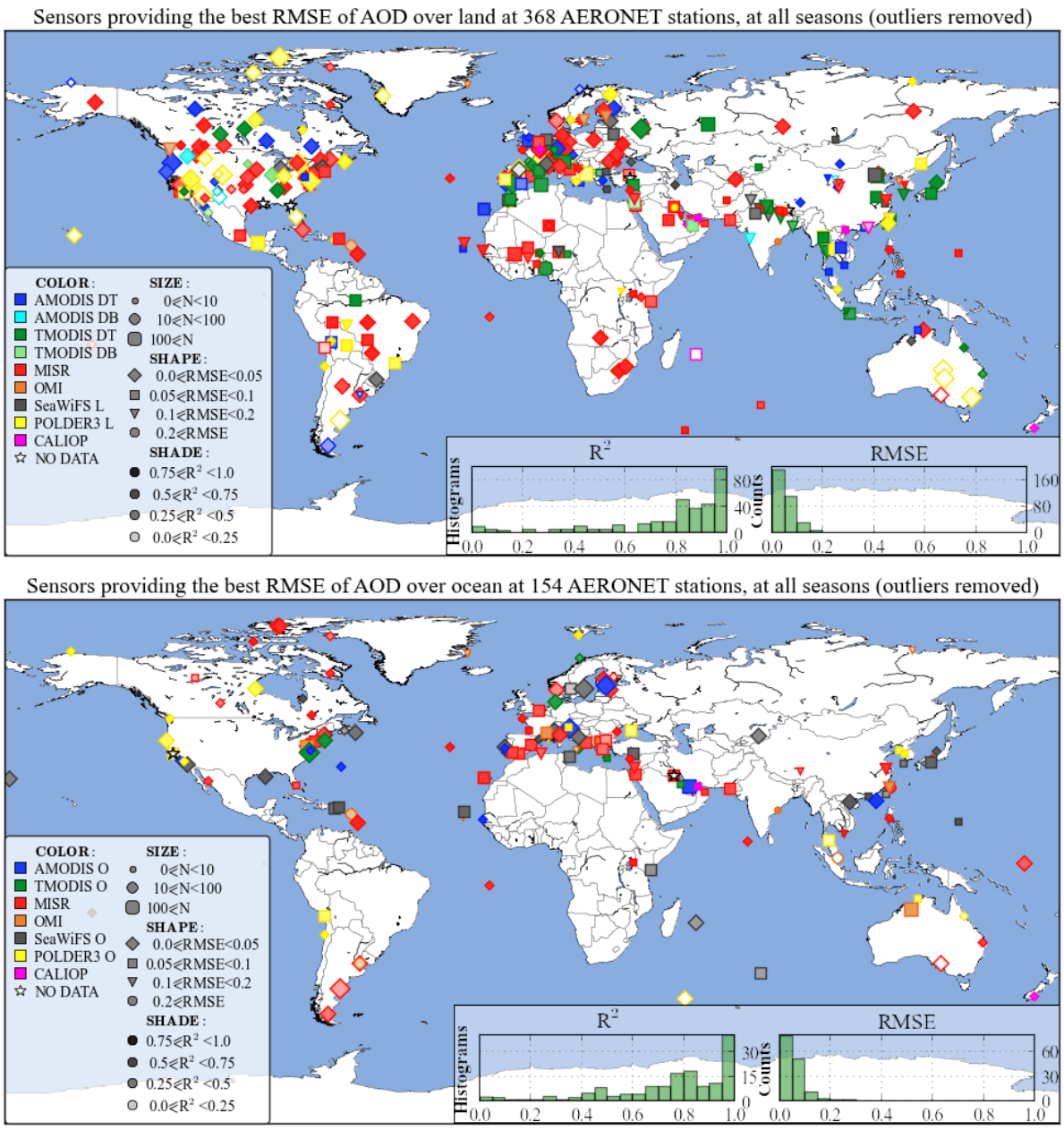

Figure 12b. Spaceborne datasets with the best root mean square error (RMSE) of the retrieved AOD to the AOD measured by inland (top) and coastal or island-based (bottom) AERONET sites. The symbols used are the same as the symbols in Figure 11b. The statistics were calculated based on the data that were pre-filtered by QA and screened of outliers as described in Sections 4 and Section 5.

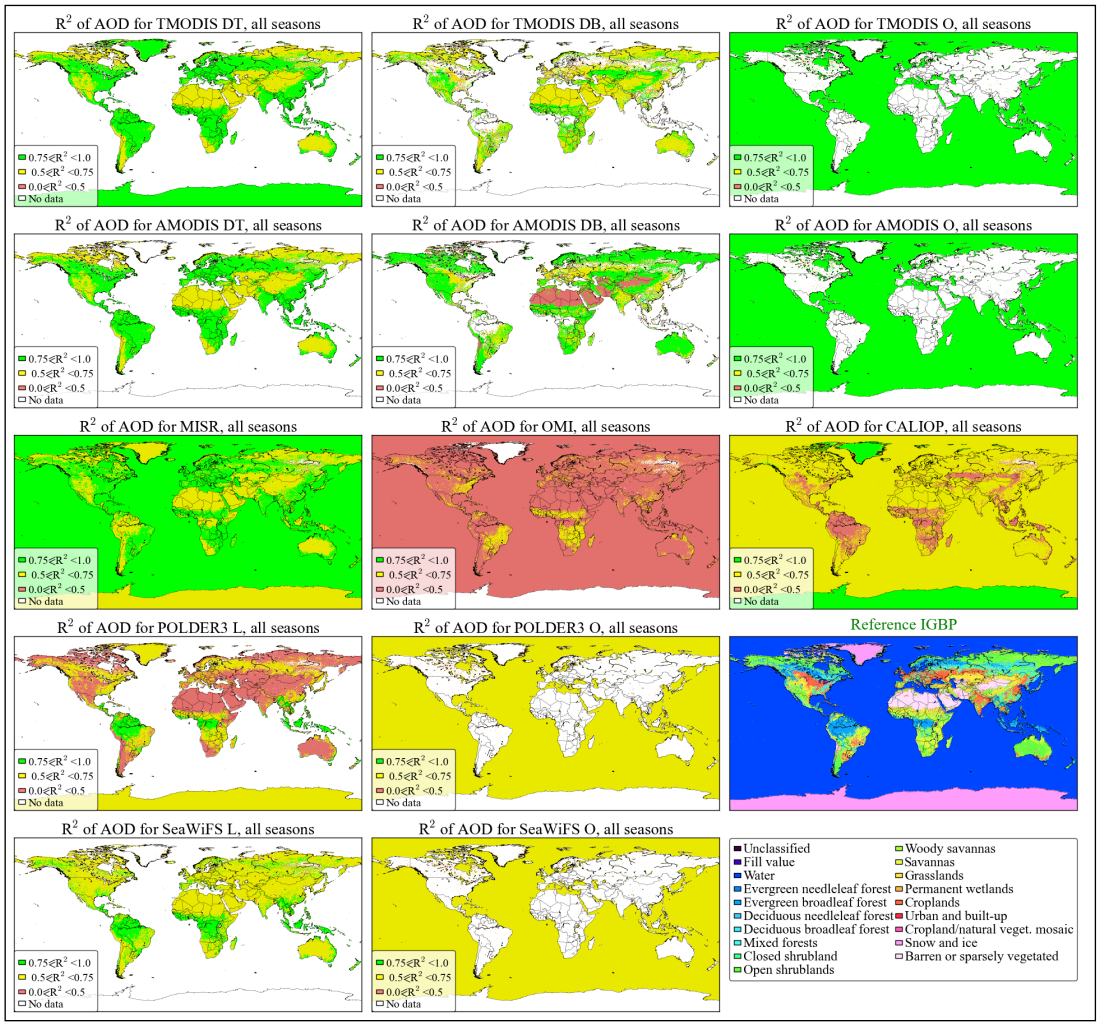

Figure 13b. Land cover type dependence of squared linear fit correlation coefficient (R2) between the collocated spaceborne and ground-based (AERONET) observations of AOD. Areas corresponding to each IGBP land cover type (bottom right inset) are colored based on the average of the data from those AERONET sites that reside in these areas. The statistics were calculated based on data that were pre-filtered by QA and screened of outliers as described in Sections 4 and Section 5.

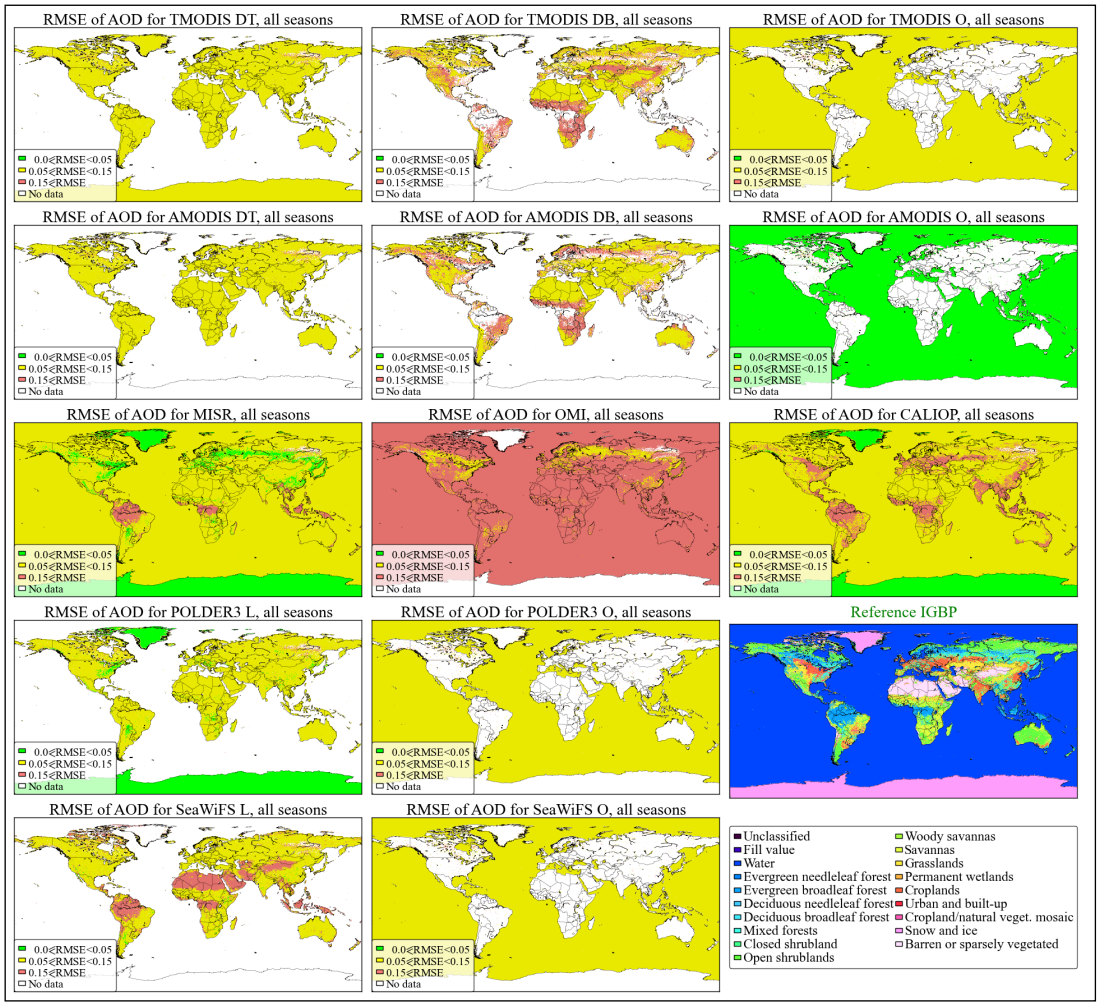

Figure 14b. Land cover type dependence of root mean square error (RMSE) between the collocated spaceborne and ground-based (AERONET) observations of AOD. Areas corresponding to each IGBP land cover type (bottom right inset) are colored based on the average of the data from those AERONET sites that reside in these areas. The statistics were calculated based on the data that were pre-filtered by QA and screened of outliers as described in Sections 4 and Section 5.