Supplement

Table S1: Statistics of the comparisons for the satellite versus MAX-DOAS or Direct-sun TROPO comparisons per station. Closest pixel within 50km, with pixel sizes <100km for GOME-2 and <40km for OMI are presented. The two lines of the linear regression statistics are the daily and monthly mean results respectively. For the biases, the mean and median monthly values are given. Intercept I and bias (SAT-GB) are in $x10^{15}$ molec/cm².

					Only pixels over station					
Station by station comparisons	Satellite and time period	R	S	I	#	Bias (SAT-GB) [x10 ¹⁵ molec/cm ²]	Bias (%)	#	Bias (SAT-GB) [x10 ¹⁵ molec/cm ²]	Bias (%)
Direct sun_TROPO										
Beijing	OMI	0.79	0.52	4.27	59			44		
	(20080703 - 20090405)	0.89	0.61	0.021	9	-13 ; -11	-39% ; -35%		-11;-7.4	-33% ; -32%
	GOME2-A	0.79	0.52	1.63	115			113		
	(20080622 - 20090416)	0.9	0.54	1.32	10	-13 ; -13	-42% ; -43%		-13 ; -13	-41% ; -42%
Boulder	OMI	0.24	0.12	1.72	210			94		
	(20131219 - 20150828)	0.19	0.16	1.70	20	-4.4 ; -3.4	-58% ; -54%		-2.9 ; -2.2	-39% ; -36%
	GOME2-A	0.49	0.40	0.47	119			93		
	(20131225 - 20150826)	0.49	0.36	0.55	20	-2.6 ; -2.7	-52% ; -47%		-2.7; -2.8	-56% ; -54%
Busan	OMI	0.41	0.30	5.88	75			45		
	(20120318 - 20150523)	0.47	0.33	5.38	25	-5 ; -4.6	-227 ; -33%		-5.9 ; -5.7	-30% ; -35%
	GOME2-A	0.49	0.28	5.84	178			166		
	(20120314 - 20150524)	0.6	0.45	3.11	24	-5.2 ; -5.7	-32% ; -32%		-5.1 ; -4.7	-31% ; -30%
FMI	OMI	0.27	0.10	1.94	47			25	0.04 ; 0.9	
	(20120210 - 20130410)	0.2	0.067	2.01	11	-1.7 ; -1.5	11% ; -31%			120% ; 90%
	GOME2-A	0.47	0.37	0.89	88			83		
	(20110910 - 20130621)	0.76	0.911	-0.98	13	-1.3 ; -1.5	-39% ; -26%		-1.3 ; -1.4	-41% ; -26%
Four Corners NM	OMI	0.51	0.41	2.62	155			129		
	(20120605 - 20150824)	0.72	0.54	1.89	28	-0.72 ; -0.62	-5% ; -17%		-0.07 ; -0.42	51% ; -6.9%
	GOME2-A	0.3	0.14	3.68	235			222		
	(20120606 - 20150827)	0.42	0.37	2.05	29	-2.8 ; -2	-35% ; -39%		-2.9 ; -2	-35% ; -45%
GSFC	OMI	0.63	0.63	1.89	293			182		
	(20090523 - 20150830)	0.75	0.61	1.95	68	-0.79 ; -0.55	-3.3% ; -8.5%		0.35; 0.55	14%; 6.2%
	GOME2-A	0.48	0.44	3.37	537			497		
	(20090601 - 20150827)	0.58	0.54	3.02	66	-0.35 ; -0.61	-0.2% ; -8.8%		-0.28 ; -0.57	1.2% ; -8.6%
Harvard	OMI	0.53	0.41	1.35	52			30		

	(20141110 - 20150827)	0.58	0.3	2.12	7	-2;-1.5	-30% ; -29%		-1.3 ; -1.4	-17% ; -12%
	GOME2-A	0.2	0.27	2.72	32			27		
	(20141110 - 20150819)	0.46	0.77	0.38	8	-1;-1.2	-17% ; -24%		-0.93 ; -1.2	-16% ; -24%
IZO	OMI	0.13	0.11	1.21	158			89		
	(20130109 - 20150713)	0.18	0.12	1.22	27	2.2;2.1	220%;190%		2.1;1.9	-180% ; -210%
	GOME2-A	0.049	0.056	0.64	221			181		
	(20130108 - 20150712)	-0.24	-0.26	0.50	29	1.4 ; 1.3	190% ; -190%		1.5 ; 1.3	240%;-200%
Langley	OMI	0.28	0.30	2.83	73			52		
	(20100127 - 20140617)	0.45	0.33	2.41	17	-0.6;-1.1	-3.1% ; -16%		-0.49 ; -5.2	-3.7% ; -16%
	GOME2-A	0.47	0.59	0.50	159			151		
	(20100204 - 20140614)	0.51	0.77	0.25	19	-0.89; -0.77	-17% ; -15%		-0.9 ; 0.9	-18% ; -19%
Mauna Loa	OMI	-0.047	-0.023	0.75	29			5		
	(20141107 - 20150508)	0.14	0.066	0.70	6	0.5;0.37	210% ; -120%		-1.2 ; -1.2	-60% ; -60%
	GOME2-A	-0.35	-0.35	0.75	33			30		
	(20141106 - 20150518)	-0.25	-0.47	0.87	6	-0.7; -0.53	-62%;-61%		-0.7 ; -0.5	-77% ; -61%
NASA HQ	OMI	0.5	0.37	2.5	116			74		
	(20120830 - 20150830)	0.34	0.20	3.45	19	-1.8 ; -0.66	-18% ; -14%		- 1; -0.6	-16% ; -14%
	GOME2-A	0.5	0.4	2.89	105			82		
	(20120830 - 20150827)	0.1	0.05	5.98	20	-2;-1.3	-15% ; -18%		-1.8 ; -0.6	-11% ; -11%
SERC	OMI	0.56	0.71	0.8	71			57		
	(20100924 - 20130105)	0.71	0.85	0.41	22	-0.31 ; -0.79	-4.1% ; -14%		-0.63 ; -0.83	-11% ; -11%
	GOME2-A	0.52	0.82	1.32	140			131		
	(20100925 - 20130110)	0.7	0.94	0.69	22	-0.28 ; -0.006	3.6%; 0.4%		0.4;0.26	6.6% ; 4.6%
Seoul	OMI	0.22	0.15	15.7	92			42		
	(20120309 - 20150828)	0.01	0.005	20.42	27	-13 ; -8.9	-27% ; -29%		-2.8 ; -0.86	-5.2% ; -3.8%
	GOME2-A	0.35	0.08	17.7	132			122		
	(20120310 - 20150828)	0.49	0.13	14.6	29	-15 ; -7.4	-31% ; -30%		-13 ; -7.1	-28% ; -29%
Thessaloniki	OMI	0.69	0.33	1.14	19			14		
	(20110415 - 20140507)	0.86	0.28	1.19	11	-5.5 ; -2.4	370% ; -51%		-4.9 ; -2.2	-430% ; -47%
	GOME2-A	0.39	0.17	1.01	114			108		
	(20110204 - 20140519)	0.52	0.24	0.98	22	-5.7 ; -4.1	-66% ; -71%		-5.6 ; -3.9	-65% ; -71%
UHMT	OMI	0.73	0.60	3.12	40			24		
	(20120316 - 20150419)	0.68	0.59	3.37	14	0.57;0.68	19%;15%		2.5;2.4	49%;43%
	GOME2-A	0.52	0.45	2.8	102			98		
	(20120322 - 20150430)	0.53	0.57	2.5	16	-0.24/-0.085	5.8% ; -1.2%		-0.21 ; -0.22	4.2% ; -3.9%
Xianghe	OMI	0.87	0.81	0.94	639			462		
	(20100321 - 20180108)	0.88	0.84	0.16	92	-2.6/-2.5	-15% ; -17%		-3.4 ; -3.1	-19% ; -18%
	GOME2-A	0.89	0.79	2.04	878			844		
	(20100309 - 20180116)	0.88	0.76	2.25	94	-3.4 ; -3.4	-13% ; -14%		-3.2 ; -3.2	-13% ; -14%

MAX-DOAS										
Athens	OMI	0.41	0.21	2	324			225		
1 millions	(20121001 - 20180815)	046	0.25	1.6	65	-3.3; -2.6	-44% ; -49%	_	-3.4 ; -2	-33% ; -38%
	GOME2-A	0.46	0.30	2.4	487			442		
	(20120928 - 20180818)	0.52	0.35	2.4	65	-1.6; -1.1	-20% ; -26%		-1.4 ; -1.1	-16% ; -18%
Beijing-CMA	OMI	0.78	0.57	3.13	429			107		
5 6	(20080809 - 20110925)	0.84	0.70	-2.54	38	-1.5; -1.4	-37% ; -35%		-14; -14	-34%; -33%
	GOME2-A	0.76	0.50	1.01	429			406		
	(20080809 - 20110925)	0.81	0.56	-1.36		-19; -18	-48% ; -48%		-19; -17	-47%; -49%
Beijing	OMI	0.66	0.36	8.10	64			44		
0	(20080712 - 20090405)	0.7	0.34	7.46	10	-15; -12	-38% ; -39%		-9.2 ; -6.1	-25% ; -24%
	GOME2-A	0.77	0.45	3.04	116			106		
	(20080622 - 20090416)	0.98	0.47	2.20	11	-16; -19	-45% ; -46%		-15 ; -16	-44% ; -45%
Bremen	OMI	0.43	0.26	2.8	265			40		
	(20050513 - 20180821)	0.59	0.26	2.7	69	-2.9 ; -2.7	-29% ; -36%		-1.7 ; -0.4	2%;-8%
	GOME2-A	0.28	0.21	2.84	496			339		
	(20071224 - 20180818)	0.1	0.05	4	81	-3.2 ; -2.6	-38% ; -38%		-3.2 ; -2.7	-36% ; -40%
Bujumbura	OMI	0.033	0.03	1.29	142			49		
	(20131215 - 20170719)	-0.07	-0.07	1.53	43	-0.59 ; -0.58	-21% ; -31%		-0.71 ; -0.91	-30% ; -46%
	GOME2-A	-0.07	-0.003	0.89	156			119		
	(20131224 - 20170722)	0.11	0.034	0.53	42	-3.8 ; -3.3	-83% ; -84%		-4 ; -3.4	-81% ; -84%
Cabauw	OMI	0.52	0.45	5.4	70			41		
	(20110304 - 20180814)	0.69	0.49	5.2	22	0.6;1.2	29% ; 20%		1.5 ; 0.8	49% ; 18 %
	GOME2-A	0.33	0.38	6	130	10.10		112	10.15	
	(20110306 - 20180804)	0.28	0.25	6.6	18	1.2;1.9	45%;28%		1.2;1.5	32%;19%
Cape Hedo	OMI	0.24	0.33	0.62	477	0.00	100/ 50/	277	0.001 0.020	
	(20070331 - 20151229)	0.27	0.43	0.56	101	0.08 ; -0.04	18% ; 5%		0.091; 0.032	28%; 5.2%
	GOME2-A	0.18	0.28	-0.02	697	0.67 0.64	770/ 750/	633	0.65 0.64	740/ 700/
~	(20070412 - 20151213)	0.17	0.22	0.16	100	-0.67;-0.64	-//% ;-/5%	a 10	-0.65 ; -0.64	-/4% ; -/0%
Chiba	OMI	0.56	0.50	4.5	358	0.65 . 1.2	0.80/ . 100/	249	0.75 . 1.1	2 10/ . 7 20/
	(20120608 - 20170708)	0.51	0.58	4.25	02	-0.05 ; -1.5	0.8% ; -10%	254	-0.75;-1.1	3.1%;-7.3%
	GOME2-A	0.51	0.42	5.9	391	22.2	0.604 + 1704	354	16.10	6 604 + 1204
	(20120607 - 20170721)	0.55	0.20	1.15	01	-2.3,-2	-9.0% , -17%	110	-1.0, -1.9	-0.0%, -13%
De Bilt	UMI (20071115 20190907)	0.5	0.37	4.8	61	$-0.44 \cdot -1.2$	$3.8e9\% \cdot -1.40\%$	112	$0.21 \cdot 0.81$	140% • 130/
	(200/1115 - 2018080/)	0.57	0.33	28	322	-0.77 , -1.2	5.007/0, -14/0	280	0.21,0.01	17/0,1370
	(20071114 20180805)	0.50	0.47	2.0	522	-2626	$2.6e9\% \cdot -26\%$	200	$-23 \cdot -22$	3-9% 22%
	(20071114 - 20180805)	0.51	0.40	2.0	00	-2.0, -2.0	2.007/0,-2070		-2.3, -2.2	50770,-2270

Fukue	OMI	0.55	0.48	1.03	260			137		
	(20090301 - 20151208)	0.43	0.49	1.02	72	-0.11/-0.18	11%;-6.8%		0.1;0.19	30%;18%
	GOME2-A	0.7	0.63	0.39	394			364		
	(20090307 - 20151213)	0.85	0.59	0.50	80	-0.73 ; -0.49	-21% ; -24%		-0.6 ; -0.49	-19% ; -23%
Gwangju	OMI	0.57	0.27	2.8	343			193		
20	(20080220 - 20151231)	0.68	0.29	2.44	73	-4.7;-3.9	-40% ; -44%		-3.6;-3.1	-28% ; -34%
	GOME2-A	0.33	0.12	3.9	417			393		
	(20080220 - 20151226)	0.27	0.11	3.93	75	-6.8;-5.8	-51%;-55%		-6.7;-5.8	-51%;-54%
Hohenpeissenberg	ÔMI	0.31	0.23	2.09	32			12		
1 0	(20120605 - 20121221)	0.8	0.66	0.75	7	0.52;-0.017	0.34% ; -1.3%		0.67; 0.33	64%;17%
	GOME2-A	0.035	0.64	1.57	50			45		
	(20120615 - 20121225)	0.32	0.48	0.44	7	-0.86;-0.42	-28%;-8.1%		-0.99 ; -0.45	-32%;-28%
Kasuga	OMI	0.41	0.30	2.03	196			84		
8	(20131214 - 20170708)	0.46	0.28	1.98	41	-4;-4.2	-43% ; -52%		-3.7;-3.3	-42% ; -44%
	GOME2-A	0.3	0.16	2.94	126			108		
	(20131207 - 20170719)	0.16	0.11	3.48	39	-5.8 ; -5.3	-53%;-57%		-5.9 ; -5.3	-52%;-55%
Mainz	OMI	0.48	0.27	3	144			46		
	(20130701 - 20180408)	0.54	0.31	2.6	45	-4.8;-4.4	-37% ; -44%	-	-4 ; -3	-25% ; -30%
	GOME2-A	0.44	0.22	3.1	275			207		
	(20130617 - 20180816)	0.32	0.19	3.8	60	-6.4; -6.7	-46% ; -52%		-5.9; -5.7	-42% ; -49%
Nairobi	OMI	-0.07	-0.01	0.84	153			3		
	(20050603 - 20141126)	-0.23	-0.03	1	51	-5.4; -4.3	-80% ; -86%		-7.2 ; -2.3	-85% ; -88%
	GOME2-A	0.056	0.012	0.59	227			88		
	(20071128 - 20141128)	-0.31	-0.05	0.95	47	-5.1; -4.6	-78%;-85%		-5.2; -3.1	-70% ; -78%
OHP	OMI	0.33	0.31	1.38	983			673		
om	(20050211 - 20161212)	0.53	0.37	1.16	129	-0.6;-0.49	-12% ; -19%		-0.33 ; -0.25	-2.1%;-12%
	GOME2-A	0.48	0.69	-0.34	1049	,	,	974		
	(20070309 - 20161218)	0.59	0.56	-0.01	106	-1.2;-1.1	-44% ; -42%		-1.1;1	-40% ; -41%
Reunion	OMI	0.034	0.32	0.92	61	,	,	11	,	,
Redition	(20160501 - 20171126)	-0.073	-0.067	0.94	14	0.09; 0.07	36%;14%		0.1; -0.012	21%;5%
	GOME2-A	0.096	0.06	0.21	145			65		,
	(20160429 - 20180102)	0.2	0.77	0.16	21	-1.4 ; -1.4	-81%;-79%	00	-1.4 ; -1.4	-92% ; -76%
Thessaloniki	OMI	0.41	0.17	1.7	284	,	,	207	,	,
messalomia	(20110415 - 20180815)	0.7	0.27	1	63	-5.5; -4.8	-58% ; -61%		-4.8; -3.2	-39% ; -53%
	GOME2-A	0.27	0.07	1.6	565	,	,	506	,	
	(20110204 - 20180819)	0.45	0.13	1.3	73	-8.1: -7.2	-72% : -75%	200	-7.9 : -6.5	-70% : -75%
Tsukuba	OMI	0.68	0.78	1.63	175	,		120	<i>,</i>	,
I Suruou	(20100602 - 20140408)	0.65	0.60	2.82	41	-0.079; 0.13	3.9% ; 3%	120	-0.17 ; -0.37	3.8% ; -6%
	GOME2-A	0.53	0.45	2.86	359		,	337	. ,	,
	JOINIL2-A	0.55	0.40	2.00	557			551		

	(20070126 - 20140410)	0.54	0.44	2.99	47	-2.2 ; -2.4	-22% ; -27%		-2.3 ; -2.3	-23% ; -26%
Uccle	OMI	0.76	0.51	2.56	148			91		
	(20110430 - 20160228)	0.77	0.40	3.57	45	-3.8;-2.3	-20% ; -28%		-3.3 ; -2.2	-13% ; -16%
	GOME2-A	0.49	0.33	3.37	285			255		
	(20110429 - 20160228)	0.56	0.53	0.96	53	-4.4;-3.6	-37% ; -33%		-4.5;-3.9	-36% ; -34%
Xianghe	OMI	0.86	0.75	4.13	395			222		
	(20100316 - 20170707)	0.9	0.78	3.69	83	-0.26; 0.13	5.5%; 0.68%		-0.94 ; -0.75	3.1% ; -3.9%
	GOME2-A	0.85	0.68	5.7	677			644		
	(20100309 - 20170707)	0.88	0.71	4.15	84	-2.9 ; -2.3	-7.9% ; -8.7%		-3 ; -2.1	-7.2% ; -7.9%
Yokosuka	OMI	0.72	0.45	3.76	520			368		
	(20071021 - 20151226)	0.83	0.45	3.76	99	-7.5 ; -5.6	-29% ; -34%		-6.6 ; -5.2	-24% ; -33%
	GOME2-A	0.61	0.31	5.65	852			784		
	(20071020 - 20151229)	0.73	0.35	4.99	99	-11;-11	-43% ; -45%		-11;-10	-41% ; -44%
Zvenigorod	OMI	0.57	0.12	2.12	194			137		
	(20081009 - 20121225)	0.74	0.14	2.18	50	-8.7 ; -4.5	-40% ; -59%		-7.7 ; -2.4	-41% ; -55%
	GOME2-A	0.47	0.22	2.95	345			334		
	(20081016 - 20121027)	0.56	0.23	2.56	46	-5.5 ; -4.3	-39% ; -45%		-5.7 ; -4.3	-44% ; -46%



Figure S1. Visualization of the time coverage of the 23 ground-based MAX-DOAS dataset used in this study. The sites that also retrieved low tropospheric profiles are marked with an *.



Figure S2. Visualization of the time coverage of the 16 ground-based direct sun dataset used in this study.



Figure S3. Dilution factor slope at each station (both on mean and median values), see text in Sect. 6.1 for details.



Figure S4. Box and whisker plot of the daily OMI QA4ECV v1.1 biases for each station (a) for the original data, (b) and (c) when correcting for the dilution effect, in absolute and relative values. MAX-DOAS stations are presented in black, direct sun stations in dark red. The stations are ordered by increasing values of the ground-based VCDtropo, and corresponding values are given in the upper horizontal axis. The box and whisker plots are defined as in Fig 10. In panels (a) and (b), grey bars are the \pm comparison error, calculated adding in quadrature the satellite and ground-based VCDtropo errors.



Figure S5. Box and whisker plot of the daily GOME-2A QA4ECV v1.1 biases for each station (a) for the original data, (b) and (c) when correcting for the dilution effect, in absolute and relative values. MAX-DOAS stations are presented in black, direct sun stations in dark red. The stations are ordered by increasing values of the ground-based VCDtropo, and corresponding values are given in the upper horizontal axis. The box and whisker plots are defined as in Fig 10. In panels (a) and (b), grey bars are the $\hat{A}\pm$ comparison error, calculated adding in quadrature the satellite and ground-based VCDtropo errors.

Athens, OMI QA4ECV grid 0.025°x0.025°



NO2 VCD tropo [x10¹⁵]

Figure S6. NO_2 maps used for the Dilution Correction for MAX-DOAS Athens station.



Beijing, OMI QA4ECV 2005 grid 0.025°x0.025° 39.980°,116.380°

Figure S7. As figure S6, but for MAX-DOAS and direct sun Beijing station.



Beijing-CMA, OMI QA4ECV 2005 grid 0.025°x0.025° 39.950°,116.320°

Figure S8. As figure S6, but for MAX-DOAS Beijing-CMA station.



Boulder, OMI QA4ECV grid 0.025°x0.025°

Figure S9. As figure S6, but for direct sun Boulder station.



Bremen, OMI QA4ECV 2005 grid 0.025°x0.025° 53.100°,8.800°

Figure S10. As figure S6, but for MAX-DOAS Bremen station.









Figure S12. As figure S6, but for MAX-DOAS Chiba station.



Figure S13. As figure S6, but for MAX-DOAS De Bilt station.



FMI, OMI QA4ECV grid 0.025°x0.025°

Figure S14. As figure S6, but for direct sun FMI-Helsinki station.



Figure S15. As figure S6, but for direct sun FourCorners (New Mexico) station.

NASAHQ, SERC, GSFC OMI QA4ECV grid 0.025°x0.025°



Figure S16. As figure S6, but for direct sun GSFC station.



Gwangju, OMI QA4ECV 2005 grid 0.025°x0.025° 35.200°,126.800°

Figure S17. As figure S6, but for MAX-DOAS Gwangju station.



Figure S18. As figure S6, but for direct sun Harvard station.



Figure S19. As figure S6, but for direct sun Izana (IZO) station.

132[°] E 136[°] E 140[°] E 144[°] E 128[°] E 40[°] N 15 10 uba 36[°] N ba okosuka Kasug Fukue 5 32[°] N 0 NO2 VCD tropo [x10¹⁵]

Japan, OMI QA4ECV grid 0.025°x0.025°





Figure S21. As figure S6, but for direct sun Langley station.



Figure S22. As figure S6, but for MAX-DOAS Reunion Island LePort station.



Figure S23. As figure S6, but for MAX-DOAS Mainz station.

MaunaLoa, OMI QA4ECV 2005 grid 0.025°x0.025° 19.500°,-155.600°



Figure S24. As figure S6, but for direct sun MaunaLoa (Hawaii) station.

NASAHQ, SERC, GSFC OMI QA4ECV grid 0.025°x0.025°



Figure S25. As figure S6, but for direct sun NASA HQ (Head Quarter) station, and indication of SERC, GSFC and Langley stations.



Seoul, OMI QA4ECV 2005 grid 0.025°x0.025° 37.600°,126.900°

Figure S26. As figure S6, but for direct sun Seoul station.

Thessaloniki, OMI QA4ECV grid 0.025°x0.025°



Figure S27. As figure S6, but for MAX-DOAS and direct sun Thessaloniki station.



Figure S28. As figure S6, but for MAX-DOAS Uccle station.

UHMT, OMI QA4ECV grid 0.025°x0.025°



Figure S29. As figure S6, but for direct sun UHMT station.



Figure S30. As figure S6, but for MAX-DOAS Yokosuka station.