Supplementary Materials for the manuscript:

New approach to evaluate satellite derived XCO_2 over oceans by integrating ship and aircraft observations

Astrid Müller[1], Hiroshi Tanimoto[1], Takafumi Sugita[1], Toshinobu Machida[1], Shin-ichiro Nakaoka[1], Prabir K. Patra[2], Joshua Laughner[3], David Crisp[4]

1 National Institute for Environmental Studies, Tsukuba, Japan
2 Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan
3 California Institute of Technology, Pasadena, CA, USA
4 Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA, USA

Correspondence and request for material should be addressed to:
Hiroshi Tanimoto (tanimoto@nies.go.jp), Astrid Müller (mueller.astrid@nies.go.jp)

Table S1. The monthly averaged (Avg.) values and the standard deviation (Std.) of the ship and aircraft CO_2 retrievals for the latitude range 20° N–30° N, 2014–2017.

Date (MM/YY)	Avg. ship (ppm)	Std.	Avg. aircraft (ppm)	Std.
01/14	–	–	397.60	0.74
02/14	401.51	1.84	396.52	0.54
03/14	404.34	1.69	398.92	2.01
04/14	403.87	1.78	400.09	1.91
05/14	404.43	0.57	402.26	1.53
06/14	401.45	0.67	401.95	1.26
07/14	398.74	0.22	400.07	1.14
08/14	394.89	3.31	397.36	1.20
09/14	395.36	1.12	395.73	1.21
10/14	397.66	1.38	395.76	0.85
11/14	401.15	1.46	397.67	0.87
12/14	401.77	1.16	398.71	1.05
01/15	–	–	399.27	0.82
02/15	403.61	0.44	399.58	1.18
03/15	404.10	2.22	400.29	1.45
04/15	405.02	1.67	401.97	1.82
05/15	403.32	1.56	403.99	1.46
06/15	403.87	0.26	403.96	0.99
07/15	401.60	0.38	401.43	0.87
08/15	399.53	0.62	399.61	1.08
09/15	397.57	0.55	398.22	0.92
10/15	401.24	1.34	398.89	1.16
11/15	400.74	0.57	400.02	0.96
12/15	403.99	1.21	401.92	1.06
01/16	406.56	1.77	402.42	0.80
02/16	405.30	0.30	403.36	0.62
03/16	407.33	1.57	404.02	2.33
04/16	408.63	1.78	407.07	1.97
05/16	409.46	1.93	408.62	1.70
06/16	407.51	0.70	406.32	1.34
07/16	405.74	0.38	404.35	1.57
08/16	401.81	0.76	402.30	1.04
09/16	400.82	0.07	401.31	1.04
10/16	402.13	1.00	401.84	1.01
11/16	405.40	2.01	403.34	0.93
12/16	409.49	3.26	404.96	0.90

Table S2. The monthly averaged (Avg.) values and the standard deviation (Std.) of the ship and aircraft CO_2 retrievals for the latitude range 0° N–10° N, 2014–2017.

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Date (MM/YY)	Avg. ship (ppm)	Std.	Avg. aircraft (ppm)	Std.
01/14	–	–	397.60	0.53
02/14	398.44	0.55	–	–
03/14	398.78	0.80	398.48	0.55
04/14	399.16	0.76	399.12	0.82
05/14	400.66	0.62	399.67	1.16
06/14	399.01	0.98	400.54	0.93
07/14	397.81	0.39	399.17	0.85
08/14	397.34	0.25	397.72	0.24
09/14	396.85	0.24	396.20	0.35
10/14	396.73	0.33	396.85	0.36
11/14	397.44	0.37	397.09	0.46
12/14	397.97	0.21	397.53	0.22
01/15	–	–	–	–
02/15	401.53	0.69	399.79	0.48
03/15	401.15	0.75	399.95	0.21
04/15	401.91	0.90	399.49	0.79
05/15	402.42	1.45	401.34	1.20
06/15	401.36	0.93	401.78	0.80
07/15	399.16	1.08	–	–
08/15	398.58	0.26	399.36	0.22
09/15	–	–	398.88	0.41
10/15	399.10	0.41	398.89	0.31
11/15	399.49	0.26	–	–
12/15	401.68	0.62	400.97	0.35
01/16	402.47	0.10	402.31	0.42
02/16	403.85	0.23	402.92	0.23
03/16	404.39	0.39	404.50	0.61
04/16	406.39	0.39	405.13	0.62
05/16	405.50	0.84	405.44	0.80
06/16	405.38	0.40	–	–
07/16	404.24	0.45	–	–
08/16	403.55	0.31	402.94	0.30
09/16	402.73	0.32	402.75	0.32
10/16	402.12	0.20	401.98	0.30
11/16	403.22	0.51	402.64	0.33
12/16	404.53	0.32	404.46	0.40

Table S3. The monthly averaged (Avg.) values and the standard deviation (Std.) of the ship and aircraft CO_2 retrievals for the latitude range 20° S–10° S, 2014–2017.

Date (MM/YY)	Avg. ship (ppm)	Std.	Avg. aircraft (ppm)	Std.
01/14	396.52	1.21	396.00	0.48
02/14	395.30	0.34	–	–
03/14	394.42	0.27	396.28	0.83
04/14	395.63	1.30	396.66	0.86
05/14	394.49	0.32	397.18	0.82
06/14	395.07	0.65	398.64	0.74
07/14	395.11	0.30	398.77	0.57
08/14	395.66	0.31	397.39	0.42
09/14	395.71	0.44	396.53	0.33
10/14	396.29	0.08	397.21	0.54
11/14	396.61	0.38	398.36	0.82
12/14	398.76	1.19	398.52	0.59
01/15	–	–	–	–
02/15	396.63	0.38	397.65	0.54
03/15	396.61	0.13	397.88	0.67
04/15	397.76	0.67	398.50	0.32
05/15	397.68	0.66	399.62	0.80
06/15	397.19	0.24	400.19	0.88
07/15	397.88	0.28	–	–
08/15	398.03	0.30	399.35	0.29
09/15	–	–	399.25	0.39
10/15	398.67	0.40	399.00	0.40
11/15	399.42	0.10	–	–
12/15	400.36	1.16	402.19	0.61
01/16	400.30	0.26	400.95	0.43
02/16	400.95	1.14	401.23	0.48
03/16	401.17	1.12	402.94	0.64
04/16	400.47	0.55	403.22	0.89
05/16	401.01	0.50	402.18	0.51
06/16	401.18	0.16	–	–
07/16	402.09	0.54	–	–
08/16	401.91	0.49	402.92	0.26
09/16	401.96	0.63	402.90	0.42
10/16	402.02	0.38	402.04	0.41
11/16	402.47	0.31	402.76	0.55
12/16	402.08	0.21	403.91	0.48

Table S4. The monthly averaged (Avg.) values and the standard deviation (Std.) of the satellite XCO_2 retrievals of GOSAT (NIES, ACOS) and OCO-2 for the latitude range 20° N–30° N, 2014–2017.

Date (MM/YY)	Avg. NIES (ppm)	Std.	Avg. ACOS (ppm)	Std.	Avg. OCO-2 (ppm)	Std.
01/14	–	–	397.90	0.00	–	–
02/14	–	–	394.84	3.69	–	–
03/14	398.36	0.57	397.41	1.01	–	–
04/14	400.10	1.26	398.70	1.02	–	–
05/14	401.24	1.49	399.74	1.18	–	–
06/14	401.49	1.64	399.78	1.24	–	–
07/14	399.57	0.70	397.93	1.12	–	–
08/14	396.54	1.69	395.78	1.09	–	–
09/14	396.05	1.43	394.79	1.07	394.73	0.63
10/14	395.30	1.10	395.21	0.82	395.48	0.62
11/14	–	–	396.57	1.12	396.01	0.87
12/14	–	–	397.16	1.02	398.15	1.14
01/15	–	–	397.87	1.04	398.90	0.65
02/15	399.26	1.37	398.33	0.94	400.06	0.68
03/15	399.86	1.11	399.43	1.09	400.46	0.85
04/15	401.54	1.30	400.90	1.12	401.05	0.90
05/15	402.89	0.99	401.81	1.05	401.82	0.56
06/15	402.67	0.71	401.34	1.20	401.35	0.69
07/15	401.06	1.39	399.45	1.20	399.78	0.97
08/15	398.33	1.62	397.32	1.27	397.69	0.96
09/15	398.07	1.43	396.43	0.95	396.31	0.64
10/15	398.00	2.05	397.20	0.76	397.49	0.66
11/15	400.00	0.00	398.38	1.12	398.93	0.72
12/15	–	–	399.27	2.03	400.22	0.79
01/16	401.79	0.52	400.04	1.63	401.81	0.81
02/16	401.54	0.95	400.89	1.03	402.44	0.71
03/16	403.91	1.29	402.73	1.16	404.12	1.15
04/16	405.35	1.25	404.30	1.03	404.69	0.75
05/16	406.37	0.87	405.27	1.21	405.50	0.80
06/16	405.49	0.96	–	–	404.10	0.69
07/16	401.85	3.74	–	–	402.91	1.28
08/16	400.94	0.97	–	–	400.32	1.28
09/16	398.41	1.29	–	–	399.38	0.70
10/16	399.76	1.43	–	–	400.22	0.83
11/16	–	–	–	–	401.62	1.05
12/16	–	–	–	–	402.79	0.95

Table S5. The monthly averaged (Avg.) values and the standard deviation (Std.) of the satellite XCO_2 retrievals of GOSAT (NIES, ACOS) and OCO-2 for the latitude range 0° N–10° N, 2014–2017.

Date (MM/YY)	Avg. NIES (ppm)	Std.	Avg. ACOS (ppm)	Std.	Avg. OCO-2 (ppm)	Std.
01/14	–	–	395.36	0.81	–	–
02/14	–	–	395.94	0.95	–	–
03/14	396.16	1.52	396.80	0.93	–	–
04/14	399.73	0.78	397.85	1.15	–	–
05/14	399.22	1.23	398.56	1.12	–	–
06/14	–	–	398.10	1.31	–	–
07/14	–	–	396.89	1.02	–	–
08/14	398.25	0.97	396.99	1.04	–	–
09/14	–	–	395.94	1.03	395.90	0.64
10/14	–	–	395.15	0.71	395.21	0.71
11/14	–	–	395.71	0.93	395.39	0.62
12/14	396.87	0.82	396.73	0.62	396.68	0.80
01/15	–	–	398.31	0.09	398.64	0.81
02/15	398.39	0.00	397.97	0.97	398.19	0.84
03/15	399.36	1.09	398.81	1.03	399.02	0.59
04/15	399.68	0.94	399.59	1.04	399.59	0.72
05/15	–	–	400.62	1.26	399.92	0.87
06/15	–	–	400.29	1.23	399.94	0.72
07/15	402.48	2.94	399.40	0.97	399.22	0.64
08/15	398.56	1.54	398.96	1.10	398.60	0.64
09/15	400.19	1.58	397.80	1.07	398.40	0.53
10/15	398.13	1.61	397.77	0.84	398.27	0.58
11/15	–	–	398.35	0.80	398.34	0.64
12/15	400.04	0.00	399.17	0.68	399.29	0.69
01/16	400.83	1.05	399.96	0.74	400.46	0.61
02/16	401.26	1.37	400.58	1.00	401.00	0.69
03/16	401.96	1.69	401.55	0.96	401.70	0.78
04/16	404.15	1.26	402.59	1.04	403.03	0.74
05/16	405.57	0.00	403.37	1.37	403.40	0.89
06/16	–	–	–	–	403.60	0.76
07/16	402.50	1.11	–	–	402.66	0.59
08/16	401.54	0.51	–	–	401.64	0.55
09/16	–	–	–	–	400.87	0.60
10/16	400.16	0.33	–	–	400.23	0.63
11/16	–	–	–	–	400.58	0.64
12/16	402.76	1.29	–	–	401.60	0.69

Table S6. The monthly averaged (Avg.) values and the standard deviation (Std.) of the satellite XCO_2 retrievals of GOSAT (NIES, ACOS) and OCO-2 for the latitude range 20° S–10° S, 2014–2017.

Date (MM/YY)	Avg. NIES (ppm)	Std.	Avg. ACOS (ppm)	Std.	Avg. OCO-2 (ppm)	Std.
01/14	395.45	0.94	394.66	0.71	–	–
02/14	395.35	0.75	395.03	0.83	–	–
03/14	394.58	0.25	395.21	0.79	–	–
04/14	–	–	395.94	1.08	–	–
05/14	396.49	0.00	395.50	0.00	–	–
06/14	–	–	–	–	–	–
07/14	–	–	–	–	–	–
08/14	396.08	1.40	396.71	0.94	–	–
09/14	396.79	0.72	396.43	1.02	396.91	0.50
10/14	396.71	1.39	396.66	0.87	396.88	0.52
11/14	397.67	0.73	396.82	0.95	396.89	0.54
12/14	397.20	0.51	396.61	0.89	396.82	0.58
01/15	–	–	–	–	396.78	0.53
02/15	395.68	0.00	396.62	1.27	396.71	0.66
03/15	396.44	1.33	397.04	1.01	397.25	0.52
04/15	399.76	0.51	397.51	1.29	397.47	0.46
05/15	398.41	1.57	397.34	1.12	398.17	0.49
06/15	397.55	0.70	397.77	0.88	398.32	0.49
07/15	398.84	1.10	398.00	1.13	398.87	0.50
08/15	398.16	0.79	398.49	1.00	398.85	0.50
09/15	398.29	0.81	398.70	1.18	398.78	0.54
10/15	399.46	1.12	398.71	0.96	399.08	0.56
11/15	399.71	1.07	399.30	1.05	399.32	0.56
12/15	400.30	0.68	398.98	0.92	399.35	0.60
01/16	399.59	1.05	399.55	0.97	399.68	0.57
02/16	399.47	0.48	399.63	0.93	399.67	0.51
03/16	399.77	0.13	400.12	1.07	399.99	0.58
04/16	400.10	0.00	400.45	0.88	400.57	0.55
05/16	400.60	1.09	400.18	1.21	401.10	0.68
06/16	402.52	1.69	–	–	401.55	0.60
07/16	402.60	1.28	–	–	401.85	0.67
08/16	401.62	1.27	–	–	401.62	0.55
09/16	401.09	0.74	–	–	401.30	0.47
10/16	401.82	0.97	–	–	401.34	0.57
11/16	401.90	0.81	–	–	401.40	0.54
12/16	402.20	0.58	–	–	401.68	0.57

Table S7. Monthly in situ based XCO_2 values (in situ XCO_2) and its uncertainty interval derived from ±2 ppm variability in the in situ CO_2 profile at ~850 hPa (see text) for the latitude range 20° N–30° N, 2014–2017.

Date (MM/YY)	In situ XCO_2 (ppm)	+2 ppm uncertainty	-2 ppm uncertainty
01/14	–	–	–
02/14	–	–	–
03/14	400.24	400.87	399.61
04/14	400.71	401.33	400.08
05/14	401.99	402.62	401.36
06/14	400.70	401.33	400.08
07/14	398.80	399.42	398.17
08/14	396.07	396.69	395.44
09/14	395.54	396.16	394.92
10/14	396.38	397.00	395.76
11/14	398.38	398.99	397.77
12/14	398.78	399.36	398.19
01/15	–	–	–
02/15	400.38	401.00	399.75
03/15	401.02	401.65	400.40
04/15	402.31	402.94	401.68
05/15	402.58	403.21	401.96
06/15	402.87	403.50	402.24
07/15	400.82	401.44	400.19
08/15	399.22	399.84	398.60
09/15	397.80	398.43	397.17
10/15	399.43	400.05	398.80
11/15	399.52	400.12	398.92
12/15	401.55	402.14	400.96
01/16	–	–	–
02/16	403.02	403.64	402.40
03/16	404.31	404.94	403.69
04/16	406.37	407.00	405.74
05/16	407.29	407.91	406.67
06/16	405.62	406.25	404.38
07/16	404.06	404.69	402.80
08/16	401.52	402.14	400.89
09/16	400.59	401.22	399.97
10/16	401.30	401.92	400.67
11/16	–	–	–
12/16	–	–	–

Table S8. Monthly in situ based XCO_2 values (in situ XCO_2) and its uncertainty interval derived from ±2 ppm variability in the in situ CO_2 profile at ~850 hPa (see text) for the latitude range 0° N–10° N, 2014–2017.

Date (MM/YY)	In situ XCO_2 (ppm)	+2 ppm uncertainty	-2 ppm uncertainty
01/14	–	–	–
02/14	–	–	–
03/14	397.95	398.57	397.33
04/14	398.44	399.06	397.81
05/14	399.31	399.94	398.69
06/14	399.04	399.67	398.42
07/14	397.97	398.59	397.35
08/14	397.17	397.79	396.54
09/14	396.31	396.94	395.69
10/14	396.59	397.22	395.97
11/14	397.00	397.62	396.38
12/14	397.43	398.05	396.81
01/15	–	–	–
02/15	399.90	400.53	399.28
03/15	399.87	400.49	399.24
04/15	400.01	400.63	399.38
05/15	401.08	401.70	400.45
06/15	400.86	401.48	400.24
07/15	–	–	–
08/15	398.71	399.33	398.08
09/15	–	–	–
10/15	398.74	399.37	398.12
11/15	–	–	–
12/15	400.68	401.29	400.06
01/16	–	–	–
02/16	402.46	403.08	401.83
03/16	403.49	404.11	402.87
04/16	404.61	405.23	403.99
05/16	404.43	405.06	403.81
06/16	–	–	–
07/16	–	–	–
08/16	402.52	403.15	401.89
09/16	–	–	–
10/16	401.58	402.21	400.95
11/16	–	–	–
12/16	403.61	404.23	402.99

Table S9. Monthly in situ based XCO_2 values (in situ XCO_2) and its uncertainty interval derived from ±2 ppm variability in the in situ CO_2 profile at ~850 hPa (see text) for the latitude range 20° S–10° S, 2014–2017.

Date (MM/YY)	In situ XCO_2 (ppm)	+2 ppm uncertainty	-2 ppm uncertainty
01/14	–	–	–
02/14	–	–	–
03/14	–	–	–
04/14	395.87	396.50	395.25
05/14	395.64	396.26	395.01
06/14	–	–	–
07/14	–	–	–
08/14	396.26	396.88	395.64
09/14	395.96	396.58	395.34
10/14	396.54	397.16	395.91
11/14	397.26	397.88	396.63
12/14	398.24	398.86	397.61
01/15	–	–	–
02/15	396.99	397.62	396.37
03/15	397.09	397.71	396.47
04/15	397.85	398.47	397.24
05/15	398.26	398.88	397.64
06/15	398.26	398.88	397.65
07/15	–	–	–
08/15	398.40	399.02	397.78
09/15	–	–	–
10/15	398.62	399.25	398.00
11/15	–	–	–
12/15	400.79	401.40	400.18
01/16	400.87	399.62	400.24
02/16	400.58	401.21	399.96
03/16	401.46	402.08	400.84
04/16	401.29	401.92	400.67
05/16	401.03	401.65	400.41
06/16	–	–	–
07/16	–	–	–
08/16	401.58	402.18	400.98
09/16	401.74	402.36	401.13
10/16	401.33	401.95	400.72
11/16	401.85	402.46	401.24
12/16	402.43	403.05	401.81