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The use of QBO, ENSO, and NAO perturbations in the evaluation of GOME-2 MetOp A total ozone measurements

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Table S1. Ground-based stations from WOUDC with accessible total ozone data in the period 1996-2011 analysed in this study: (a) 25 stations within 60°-90° N, (b) 105 stations within 30°-60° N, (c) 26 stations within 0°-30° N, (d) 13 stations within 0°-30° S, (e) 12 stations within 30°-60° S, and (f) 12 stations within 60°-90° S. Stations are listed from the northern to the southern latitudes.

(a)	**60°-90° N (25 stations)**	**Latitude (deg.)**	**Longitude (deg.)**	**Instruments analysed**
1	STN 018 Alert / Alert Gaw Lab	82.5	-62.34	Brewer MKII, MKV
2	STN 315 Eureka / Eureka Lab	80.05	-86.42	Brewer MKV
3	STN 089 Ny Alesund (Norway)	78.92	11.92	Dobson Beck, Brewer MKIV
4	STN 273 Kotelnyj Island (Russian Federation)	76	137.9	Filter M-124
5	STN 024 Resolute (Canada)	74.72	-94.98	Brewer MKII
6	STN 186 Tiksi (Russian Federation)	71.59	128.9	Filter M-124
7	STN 199 Barrow (United States)	71.32	-156.6	Dobson Beck
8	STN 406 Scoresbysund (Greenland)	70.48	-21.95	SAOZ CP200_NMOS512, CP200_NMOS1024
9	STN 476 Andoya (Norway)	69.28	16.01	Brewer MKIII
10	STN 117 Murmansk (Russian Federation)	68.97	33.05	Filter M-124
11	STN 142 Igarka (Russian Federation)	67.47	86.57	Filter M-124
12	STN 262 Sodankyla (Finland)	67.36	26.63	Brewer MKII
13	STN 267 Sondrestrom (Greenland)	66.99	-50.95	Brewer MKII
14	STN 407 Zhigansk (Russian Federation)	66.79	123.4	SAOZ CP200_NMOS1024
15	STN 129 Pechora (Russian Federation)	65.2	57.17	Filter M-124
16	STN 105 Fairbanks (College) (United States)	64.82	-147.9	Dobson Beck
17	STN 144 Markovo (Russian Federation)	64.68	170.4	Filter M-124
18	STN 271 Arhangelsk (Russian Federation)	64.58	40.5	Filter M-124
19	STN 284 Vindeln (Sweden)	64.23	19.77	Brewer MKII
20	STN 276 Tura (Russian Federation)	64.17	100.1	Filter M-124
21	STN 051 Reykjavik (Iceland)	64.13	-21.9	Dobson Beck
22	STN 123 Yakutsk (Russian Federation)	62.08	129.8	Brewer MKII, Filter M-124
23	STN 150 Hanty Mansijsk (Russian Federation)	60.97	69.07	Filter M-124
24	STN 404 Jokioinen (Finland)	60.82	23.5	Brewer MKIII
25	STN 043 Lerwick (United Kingdom)	60.13	-1.18	Dobson Beck
(b)	**30°-60° N (105 stations)**	**Latitude (deg.)**	**Longitude (deg.)**	**Instruments analysed**
26	STN 042 St. Petersburg (Russian Federation)	59.97	30.3	Filter M-124
27	STN 165 Oslo (Norway)	59.9	10.73	Brewer MKIV, MKV
28	STN 118 Nagaevo (Russian Federation)	59.58	150.8	Filter M-124
29	STN 148 Vitim (Russian Federation)	59.45	112.6	Filter M-124
30	STN 077 Churchill (Canada)	58.75	-94.07	Brewer MKII
31	STN 279 Norrkoeping (Sweden)	58.58	16.15	Brewer MKIII
32	STN 350 Tahkuse (Estonia)	58.52	24.92	Filter M-83
33	STN 121 Riga (Latvia)	57.19	24.25	Filter M-124
34	STN 122 Ekaterinburg (Russian Federation)	56.8	60.63	Filter M-124
35	STN 143 Krasnoyarsk (Russian Federation)	56	92.88	Filter M-124
36	STN 116 Moscow (Russian Federation)	55.75	37.37	Filter M-124, Dobson Beck
37	STN 307 Obninsk (Russian Federation)	55.1	36.61	Brewer MKII
38	STN 120 Omsk (Russian Federation)	54.93	73.4	Filter M-124
39	STN 312 Kaunas (Lithuania)	54.88	23.84	Filter M-124
40	STN 354 Minsk (Belarus)	53.83	27.47	Pion 1

41	STN 021 Edmonton / Stony Plain (Canada)	53.55	-114.1	Brewer MKII
42	STN 352 Manchester (United Kingdom)	53.47	-2.23	Brewer MKIII
43	STN 076 Goose Bay (Canada)	53.29	-60.39	Brewer MKII
44	STN 115 Samara (Kuibyshev) (Russian Federation)	53.25	50.45	Filter M-124
45	STN 274 Nikolaevsk-Na-Amure (Russian Federation)	53.15	140.7	Filter M-124
46	STN 130 Petropavlovsk / Kamchatskii (Russian Federation)	52.97	158.8	Filter M-124
47	STN 050 Potsdam (Germany)	52.35	13.07	Brewer MKII
48	STN 085 Irkutsk (Russian Federation)	52.26	104.3	Filter M-124
49	STN 174 Lindenberg (Germany)	52.22	14.12	Brewer MKIV, MKII
50	STN 241 Saskatoon (Canada)	52.12	-106.7	Brewer MKII
51	STN 316 De Bilt	52.1	5.18	Brewer MKIII
52	STN 318 Valentia Observatory	51.94	-10.25	Brewer MKIV
53	STN 153 Voronez (Russian Federation)	51.9	39.6	Filter M-124
54	STN 068 Belsk (Poland)	51.84	20.79	Dobson Beck
55	STN 353 Reading (United Kingdom)	51.44	-0.94	Brewer MKIV, MKII
56	STN 053 Uccle (Belgium)	50.8	4.36	Brewer MKII, MKIII
57	STN 147 Semipalatinsk (Kazakhstan)	50.25	80.18	Filter M-124
58	STN 087 Kiev (Ukraine)	50.24	30.58	Filter M-124
59	STN 036 Camborne (United Kingdom)	50.22	-5.32	Dobson Beck
60	STN 338 Bratts Lake (Regina) (Canada)	50.2	-104.7	Brewer MKIV
61	STN 096 Hradec Kralove (Czech Republic)	50.18	15.83	Dobson Beck
62	STN 320 Winnipeg (Canada)	49.9	-97.23	Brewer MKIV
63	STN 412 Diekirch (Luxembourg)	49.87	6.17	Microtops II
64	STN 184 Lwow (Ukraine)	49.5	24.03	Filter M-124
65	STN 128 Karaganda (Kazakhstan)	49.48	73.09	Filter M-124
66	STN 331 Poprad-Ganovce (Slovakia)	49.03	20.32	Brewer MKIV
67	STN 290 Saturna Island (Canada)	48.78	-123.1	Brewer MKII
68	STN 099 Hohenpeissenberg (Germany)	47.8	11.01	Dobson Beck
69	STN 277 Cimljansk (Russian Federation)	47.73	42.25	Filter M-124
70	STN 100 Budapest-Lorinc (Hungary)	47.43	19.18	Dobson Beck, Brewer MKII
71	STN 183 Atiray (Gurev) (Kazakhstan)	47.03	51.85	Filter M-124
72	STN 455 Kishinev (Republic of Moldova)	47	28.82	Microtops II
73	STN 112 Bolshaya Elan (Russian Federation)	46.92	142.7	Filter M-124
74	STN 020 Caribou (United States)	46.87	-68.01	Dobson Beck
75	STN 035 Arosa (Switzarland)	46.78	9.67	Dobson Beck
76	STN 019 Bismarck (United States)	46.77	-100.8	Dobson Beck
77	STN 119 Odessa (Ukraine)	46.26	30.46	Filter M-124
78	STN 301 J.R.C. Ispra (Varese) (Italy)	45.8	8.63	Brewer MKIV
79	STN 479 Aosta (Italy)	45.74	7.36	Brewer MKIV
80	STN 319 Montreal (Dorval) (Canada)	45.48	-73.6	Brewer MKIV
81	STN 452 Sainshand (Mongolia)	45	110	Filter M-124
82	STN 419 Bordeaux (France)	44.84	-0.53	Dobson Beck
83	STN 321 Halifax (Bedford) (Canada)	44.73	-63.2	Brewer MKIV
84	STN 326 Longfengshan (China)	44.73	127.6	Brewer MKII
85	STN 086 Feodosija (Ukraine)	44.55	35.12	Filter M-124
86	STN 226 Bucharest (Romania)	44.48	26.13	Dobson Beck
87	STN 201 Sestola (Italy)	44.22	10.77	Dobson Beck
88	STN 474 Lannemezan (France)	44.13	0.49	Dobson Beck
89	STN 040 Haute Provence (France)	43.92	5.75	SAOZ CP200_NMOS1024, Dobson Beck
90	STN 065 Toronto (Canada)	43.78	-79.49	Brewer MKII

91	STN 282 Kislovodsk (Russian Federation)	43.73	42.66	Brewer MKII
92	STN 405 La Coruña (Spain)	43.33	-8.47	Brewer MKIV
93	STN 003 Alma-Ata (Kazakhstan)	43.14	76.56	Filter M-124
94	STN 016 Vladivostok (Russian Federation)	43.12	131.9	Filter M-124
95	STN 012 Sapporo (Japan)	43.06	141.3	Dobson Beck
96	STN 132 Sofia (Bulgaria)	42.82	23.38	Filter M-124
97	STN 347 Issyk-Kul (Kyrgyzstan)	42.62	76.98	SpecialO3
98	STN 055 Vigna Di Valle (Italy)	42.08	12.52	Dobson Beck, Brewer MKII
99	STN 305 Rome University (Italy)	41.9	12.52	Brewer MKIV
100	STN 411 Zaragoza (Spain)	41.63	-0.91	Brewer MKIV
101	STN 261 Thessaloniki (Greece)	40.63	22.96	Brewer MKII
102	STN 308 Madrid / Barajas (Spain)	40.45	-3.72	Brewer MKIV, MKIII
103	STN 410 Amberd (Armenia)	40.38	44.25	Dobson Beck
104	STN 067 Boulder (United States)	39.99	-105.3	Dobson Beck
105	STN 208 Xianghe (China)	39.98	116.4	Dobson Beck
106	STN 348 Ankara (Turkey)	39.95	32.88	Brewer MKIII
107	STN 447 Goddard (United States)	38.99	-76.83	Brewer MKIII
108	STN 082 Lisbon (Portugal)	38.77	-9.13	Dobson Beck, Brewer MKII
109	STN 113 Dushanbe (Tajikistan)	38.57	67.77	Filter M-124
110	STN 346 Murcia (Spain)	38	-1.17	Brewer MKIV
111	STN 293 Athens (Greece) (*)	37.98	23.73	Dobson Beck
112	STN 107 Wallops Island (United States)	37.94	-75.46	Dobson Beck
113	STN 252 Seoul (Republic of Korea)	37.57	126.9	Dobson Beck, Brewer MKIV
114	STN 213 El Arenosillo (Spain)	37.1	-6.73	Dobson Beck
115	STN 341 Hanford (United States)	36.32	-119.6	Dobson Beck
116	STN 295 Mt. Waliguan (China)	36.29	100.9	Brewer MKII
117	STN 106 Nashville (United States)	36.25	-86.57	Dobson Beck
118	STN 298 Aleppo (Syrian Arab Republic)	36.14	37.1	Filter M-124
119	STN 014 Tateno / Tsukuba (Japan)	36.05	140.1	Dobson Beck
120	STN 332 Pohang (Republic of Korea)	36.03	129.4	Brewer MKII, MKIV
121	STN 464 Univ. of Tehran (Islamic Republic of Iran)	35.44	51.23	Dobson Beck
122	STN 158 Casablanca (Morocco)	33.57	-7.2	Brewer MKII, MKIII
123	STN 287 Funchal (Portugal)	32.65	-16.88	Brewer MKII
124	STN 336 Isfahan (Islamic Republic of Iran)	32.48	51.43	Dobson Beck, Brewer MKIV
125	STN 007 Kagoshima (Japan)	31.55	130.6	Dobson Beck
126	STN 376 Mrsa Matrouh (Egypt)	31.33	27.22	Brewer MKII
127	STN 079 Tallahassen (United States)	30.43	-84.33	Dobson Beck
128	STN 011 Quetta (Pakistan)	30.19	66.95	Dobson Beck
129	STN 325 Linan (China)	30.18	119.4	Brewer MKII
130	STN 152 Cairo (Egypt)	30.08	31.28	Dobson Beck
(c)	**0^o-30^o N (26 stations)**	**Latitude (deg.)**	**Longitude (deg.)**	**Instruments analysed**
131	STN 349 Lhasa (China)	29.4	91.03	Brewer MKII, MKIV
132	STN 010 New Delhi / New Delhi Sonde (India)	28.63	77.18	Dobson Beck
133	STN 300 Izaña (Tenerife) (Spain)	28.31	-16.5	Brewer MKIII
134	STN 409 Hurghada (Egypt)	27.42	33.75	Dobson Beck
135	STN 190 Naha (Japan)	26.2	127.7	Dobson Beck
136	STN 074 Varanasi (Banaras) (India)	25.3	83.02	Dobson Beck
137	STN 209 Kunming (China)	25.03	102.68	Dobson Beck
138	STN 095 Taipei (Taiwan, Province of China)	25.02	121.5	Brewer MKIII
139	STN 030 Minamitorishima (Marcus Is.) (Japan)	24.29	154	Brewer MKII, MKIII

140	STN 245 Aswan (Egypt)	23.97	32.78	Dobson Beck
141	STN 311 Havana (Cuba)	23.15	-82.35	Filter M-124, Dobson Beck
142	STN 306 Chengkung (Taiwan, Province of China)	23.1	121.4	Brewer MKIV
143	STN 073 Ahmedabad (India)	23.02	72.65	Dobson Beck
144	STN 002 Tamanrasset (Algeria)	22.78	5.52	Dobson Beck
145	STN 468 Cape D'Aguilar (Hong Kong)	22.21	114.3	Brewer MKIV
146	STN 031 Mauna Loa (United States)	19.54	-155.6	Dobson Beck
147	STN 192 Mexico City (Also Tecamec) (Mexico)	19.32	-99.17	Dobson Beck
148	STN 187 Pune (India)	18.53	73.85	Dobson Beck, Brewer MKIV
149	STN 218 Manila (Philippines)	14.65	121.1	Dobson Beck
150	STN 216 Bangkok (Thailand)	13.67	100.6	Dobson Beck
151	STN 008 Kodaikanal (India)	10	77.47	Brewer MKIV, Dobson Beck
152	STN 345 Songkhla (Thailand)	7.18	100.6	Brewer MKIV
153	STN 435 Paramaribo (Suriname)	5.81	-55.21	Brewer MKIII
154	STN 322 Petaling Jaya (Malaysia)	3.1	101.7	Brewer MKII
155	STN 497 Tarawa (Kiribati)	1.4	172.9	SAOZ UFS200_NMOS512
156	STN 214 Singapore (Singapore)	1.32	103.9	Dobson Beck
(d)	**0^o-30^o S (13 stations)**	**Latitude (deg.)**	**Longitude (deg.)**	**Instruments analysed**
157	STN 175 Nairobi (Kenya)	-1.3	36.75	Dobson Beck
158	STN 207 Mahe (Seychelles) (Seychelles)	-4.67	55.17	Dobson Beck
159	STN 219 Natal (Brazil)	-6	-35.2	Dobson Beck
160	STN 429 Marcapomacocha (Peru)	-11.4	-76.33	Dobson Beck
161	STN 084 Darwin (Australia)	-12.42	130.9	Dobson Beck
162	STN 191 Samoa (American Samoa)	-14.25	-170.6	Dobson Beck
163	STN 467 Maun (Botswana)	-19.98	23.43	Dobson Beck
164	STN 436 La Reunion Island (Réunion)	-21.08	55.45	SAOZ CP200_NMOS512, CP200_NMOS1024
165	STN 446 Bauru (Brazil)	-22.35	-49.03	SAOZ UFS200_NMOS512, CP200_NMOS1024
166	STN 200 Cachoeira Paulista (Brazil)	-23.5	-46.2	Dobson Beck
167	STN 265 Irene (South Africa)	-25.91	28.22	Dobson Beck
168	STN 027 Brisbane (Australia)	-27.42	153.1	Dobson Beck
169	STN 340 Springbok (South Africa)	-29.667	17.9	Dobson Beck
(e)	**30^o-60^o S (12 stations)**	**Latitude (deg.)**	**Longitude (deg.)**	**Instruments analysed**
170	STN 343 Salto (Uruguay)	-31.38	-57.95	Dobson Beck
171	STN 442 Pilar (Argentina)	-31.4	-57.95	Filter Afo
172	STN 091 Buenos Aires (Argentina)	-34.59	-58.48	Dobson Beck
173	STN 159 Perth (Australia)	-34.72	138.6	Dobson Beck
174	STN 253 Melbourne / Airport (Australia)	-37.8	144.967	Dobson Beck
175	STN 256 Lauder (New Zealand)	-45.04	169.7	Dobson Beck
176	STN 342 Comodoro Rivadavia (Argentina)	-45.78	-67.5	Dobson Beck
177	STN 062 Port Aux Francais / Kerguelen (France)	-49.35	70.28	SAOZ CP200_NMOS512, CP200_NMOS1024
178	STN 493 Rio Gallegos (Argentina)	-51.6	-69.32	SAOZ CP200_NMOS1024
179	STN 473 Punta Arenas (Chile)	-53.14	-70.88	Brewer MKIII

180	STN 029 Macquarie Island (Australia)	-54.5	158.9	Dobson Beck
181	STN 339 Ushuaia (Argentina)	-54.85	-68.31	Dobson Beck
(f)	**60^o-90^o S (12 stations)**	**Latitude (deg.)**	**Longitude (deg.)**	**Instruments analysed**
182	STN 351 King George Island (Uruguay)	-62.18	-58.9	Brewer MKII
183	STN 233 Marambio (Antarctica)	-64.24	-56.62	Dobson Beck
184	STN 232 Faraday / Vernadsky	-65.25	-64.26	Dobson Beck
185	STN 028 Dumont D'Urville (Antarctica)	-66.66	140	SAOZ CP200_NMOS1024
186	STN 454 San Martin (Antarctica)	-68.13	-67.1	Brewer MKIV
187	STN 101 Syowa (Japan)	-69	39.58	Dobson Beck
188	STN 478 Zhongshan (Antarctica)	-69.37	76.37	Brewer, MKIV
189	STN 400 Maitri (Antarctica)	-70.46	11.45	Brewer MKIV
190	STN 492 Concordia (Antarctica)	-75.1	123.3	SAOZ CP200_NMOS1024
191	STN 057 Halley (Antarctica)	-75.36	25.13	Dobson Beck
192	STN 268 Arrival Heights / Mcmurdo (Antarctica)	-77.83	166.7	Dobson Beck
193	STN 314 Belgrano II (Antarctica)	-77.88	-34.63	Brewer MKIV

(*) For the period 2004-2016 we use data from a Brewer MKIV instrument installed at the Academy of Athens (37.99^o N, 23.78^o E).

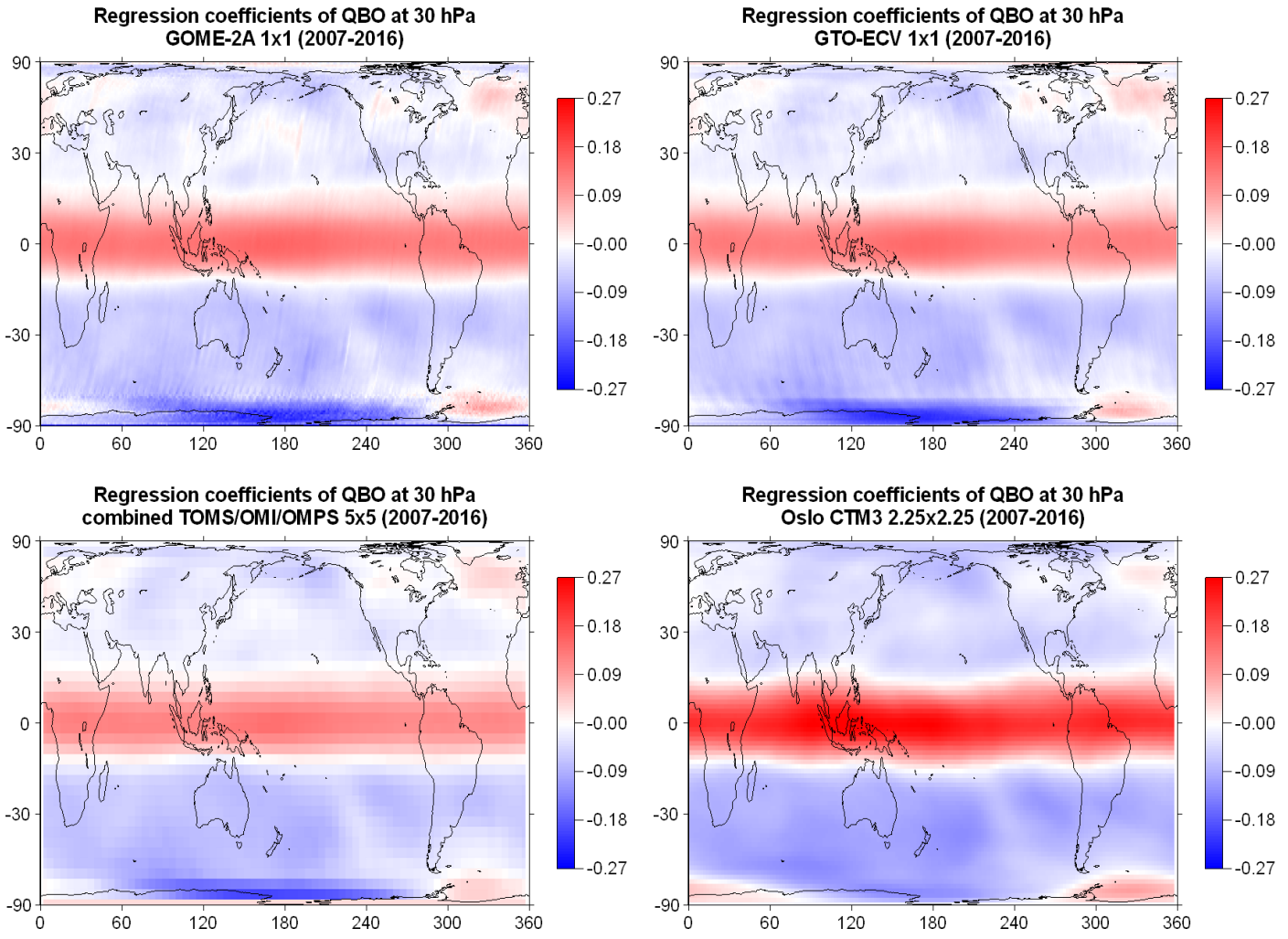

Figure S1. Regression coefficients of total ozone with the QBO at 30 hPa for zero month lag after removing variability related to the seasonal cycle. Upper left: GOME-2A, upper right: GTO-ECV, lower left: combined TOMS/OMI/OMPS, lower right: Oslo CTM3. The coefficients are in % per unit change of the explanatory variable.

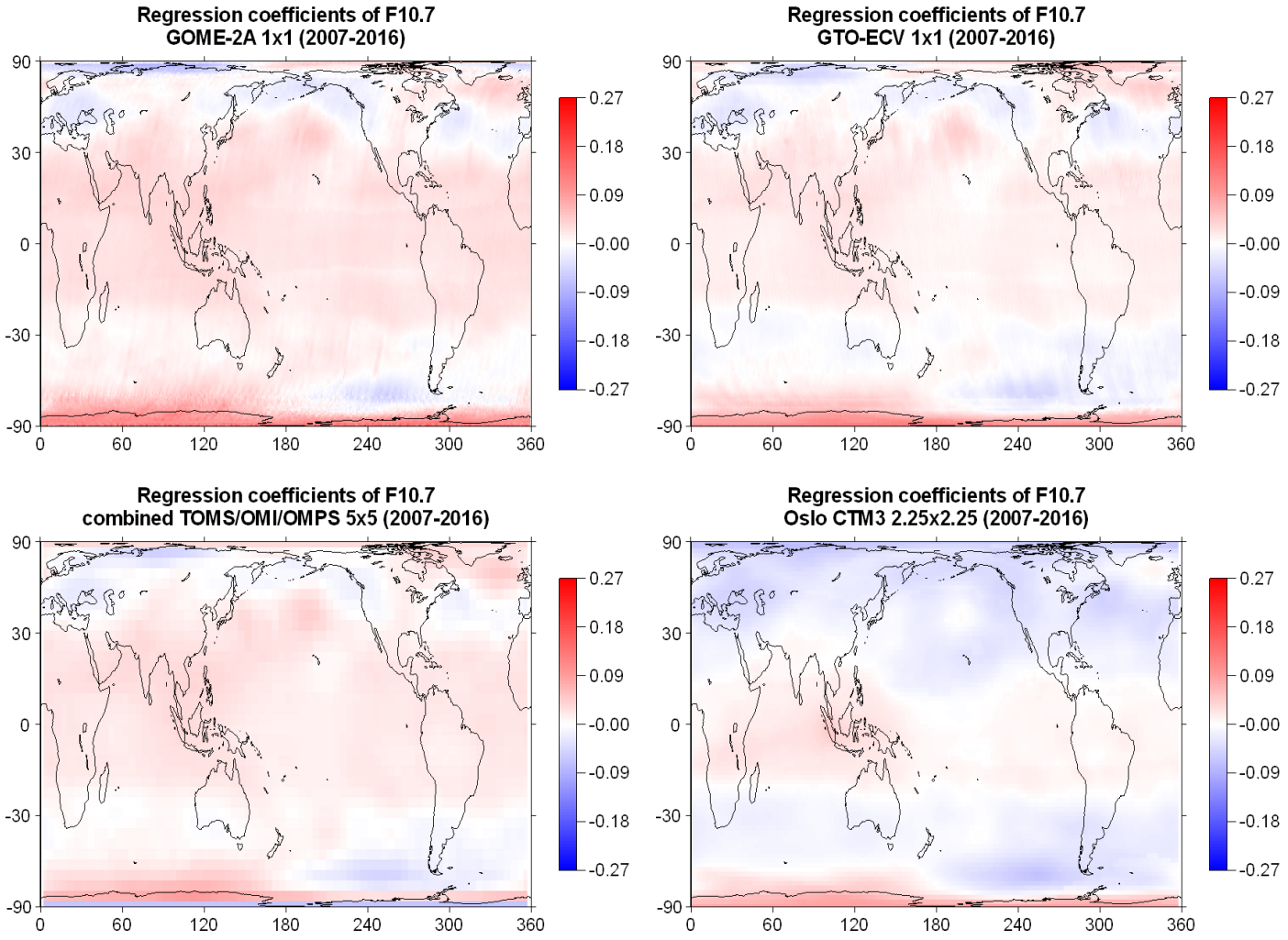

Figure S2. Regression coefficients of total ozone with the solar cycle (F10.7) for zero month lag after removing variability related to the seasonal cycle and the QBO. Upper left: GOME-2A, upper right: GTO-ECV, lower left: combined TOMS/OMI/OMPS, lower right: Oslo CTM3. The coefficients are in % per unit change of the explanatory variable.

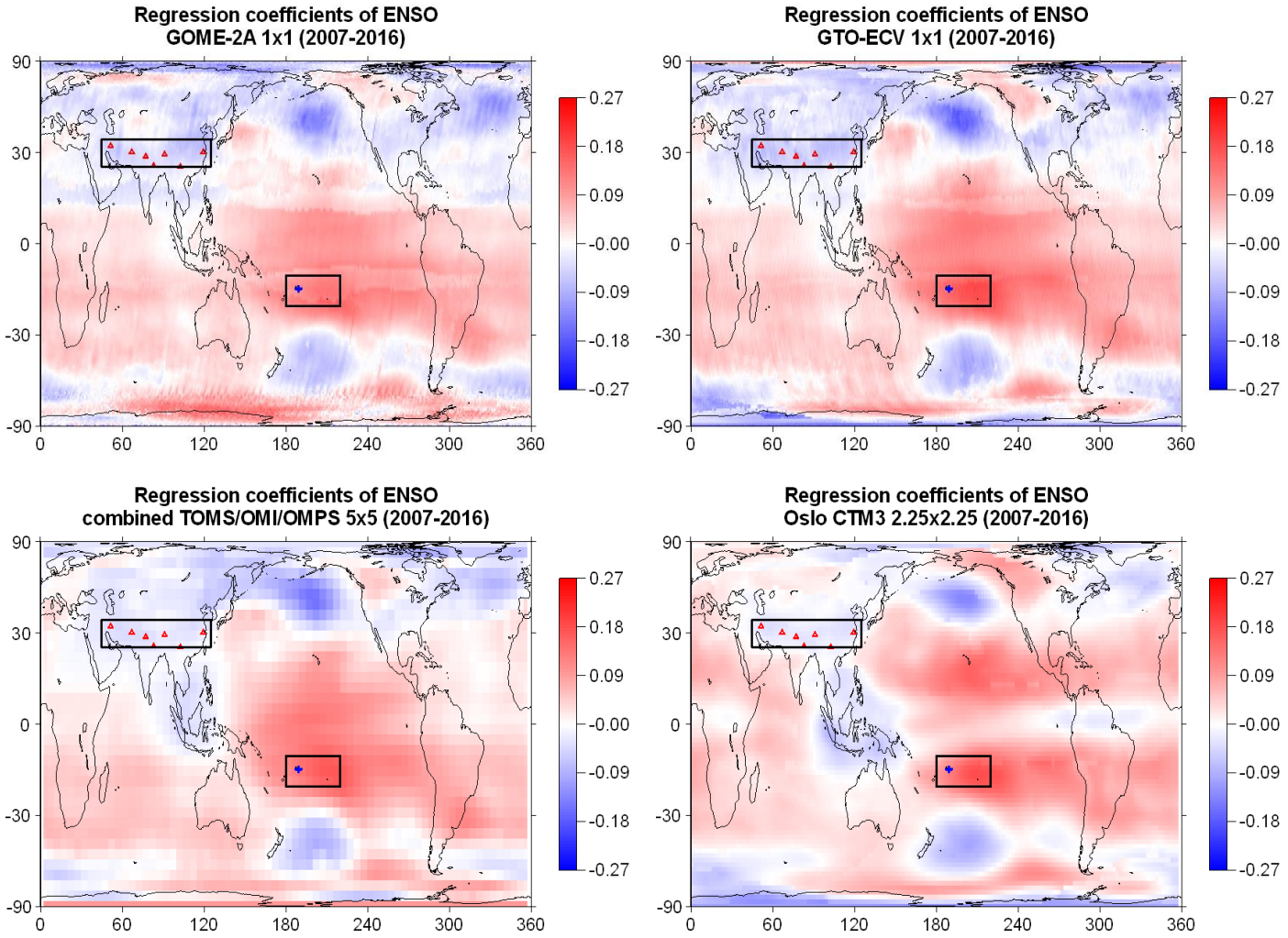

Figure S3. Regression coefficients of total ozone with ENSO (SOI) for zero month lag after removing variability related to the seasonal cycle, QBO and the solar cycle. Upper left: GOME-2A, upper right: GTO-ECV, lower left: combined TOMS/OMI/OMPS, lower right: Oslo CTM3. The coefficients are in % per unit change of the explanatory variable. Rectangles correspond to the South Pacific region (10-20 ^{o}S, 180-220 ^{o}E) and South Asia region (35-45 ^{o}N, 45-125 ^{o}E), blue cross to the station Samoa (14.25 ^{o}S, 189.4 ^{o}E) and red triangles to stations in South Asia, in which total ozone has been studied as for the impact of ENSO.

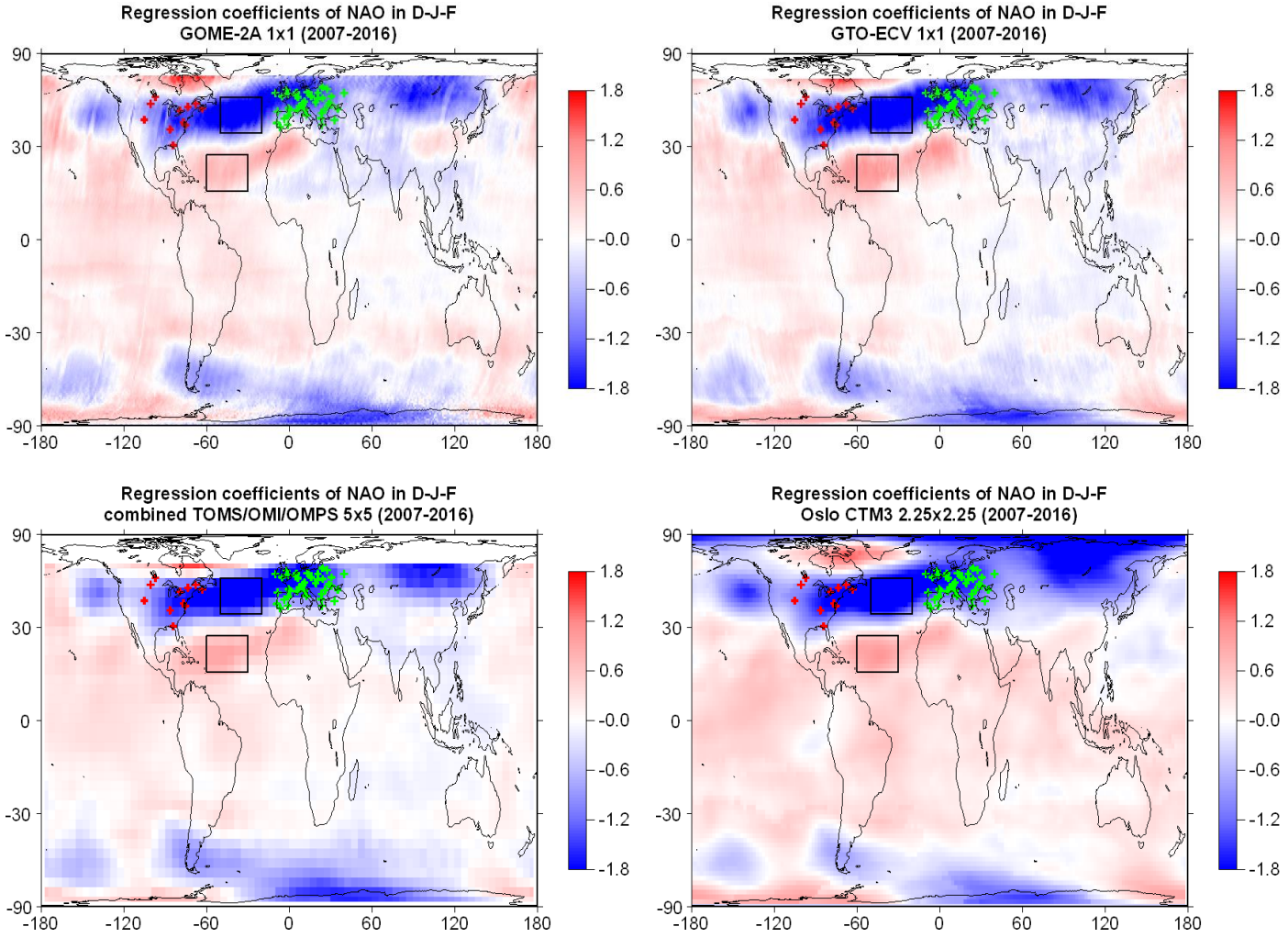

Figure S4. Regression coefficients of total ozone with the NAO index during wintertime (December, January, February; D-J-F) for zero month lag after removing variability related to the seasonal cycle, QBO, solar cycle and ENSO. Upper left: GOME-2A, upper right: GTO-ECV, lower left: combined TOMS/OMI/OMPS, lower right: Oslo CTM3. The coefficients are in % per unit change of the explanatory variable. Rectangles correspond to regions in the North Atlantic (35°-50° N, 20°-50° W; 15°-27° N, 30°-60° W), and red and green crosses to stations in Canada/USA and Europe, in which total ozone has been studied as for the impact of NAO.