Supplement of Biogeosciences, 12, 193–208, 2015
http://www.biogeosciences.net/12/193/2015/
doi:10.5194/bg-12-193-2015-supplement

Biogeosciences
Open Access

Supplement of

Evaluating the ocean biogeochemical components of Earth system models using atmospheric potential oxygen and ocean color data

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Supplemental Material

This section presents an evaluation of the 9 ATMs participating in both the T3L2 and APO Transcom experiments. The seasonal cycle in atmospheric potential oxygen (APO) at a variety of northern and southern monitoring sites is estimated using the pulse-response code (PRC) described in the main text and from APO Transcom forward simulations (FS) described below. All simulations are forced by monthly mean air-sea O_2 and N_2 fluxes from the climatology of *Garcia and Keeling* [2001].

In contrast to the matrix-based PRC simulations, which used uniform regional distributions of O_2 and N_2, the archived APO Transcom forward simulations were forced by fine-scale (0.5 x 0.5 degree) monthly mean air-sea flux distributions (interpolated by APO Transcom from the original 1.125 degree resolution of *Garcia and Keeling* [2001]). The simulations were run by each participating model group with the fluxes turned on for the first year and turned off for the last two years. The resulting ATM atmospheric O_2 and N_2 fields in ppm were sampled in each of the 36 months of the simulations at 253 monitoring sites. The steady-state response, i.e., the mean seasonal cycle, was computed by summing all Januaries, Februaries, etc., for the three years. Conceptually, this calculation assumes that the ATM behaves linearly and that the steady-state response can be represented as the sum of the response to the fluxes from the present year, the past year, and two years previously, which correspond to the first, second, and third years of the simulations, respectively.

In using the archived APO Transcom results, it was necessary to account for several irregularities. First, the JMA O_2 and N_2 results were multiplied by 10^6 to convert to ppm units. Second, TM3 ran all 36 months with pulses on, so instead of summing all 3 sets of Januaries, Februaries, etc., the mean annual cycle was calculated based on the third year of the simulation alone. Finally, GISS UCI in principle was a 10^{th} model that participated in both T3L2 and APO Transcom, but in practice it could not be used because only the first (pulse-on) year of GISS UCI output was submitted to APO Transcom.

Table S1. Mean values of the correlation coefficient R and the ratio of standard deviations: σ_{prc}/σ_{fs},, representing the PRC vs. FS correlation in the shape and phase and the amplitude ratio, respectively, of the seasonal cycle in APO among 6 extratropical monitoring sites in the Southern Hemisphere (SPO, SYO, PSA, MQA, CGO, AMS) and 6 extratropical sites in the Northern Hemisphere (LJO, RYO, SBL, CBA, BRW, ALT) – see also Figure S1. For σ_{prc}/σ_{fs},, the standard deviation among ratios at invidual stations (in parentheses) is given.

ATM	Correlation Coefficient R^2		σ_{prc}/σ_{fs}	
	>25°N	< -25°S	>25°N	< -25°S
GCTM	0.95	0.98	0.86 (0.21)	0.91 (0.10)
GISS:UCB	0.98	1.00	0.87 (0.16)	0.91 (0.05)
JMA	0.95	1.00	0.99 (0.12)	1.00 (0.07)
MATCH:NCEP	0.93	0.97	1.01 (0.17)	1.11 (0.17)
MATCH:MACCM	0.97	0.99	0.79 (0.16)	0.86 (0.05)
NIES	0.97	1.00	0.79 (0.12)	0.86 (0.07)
NIRE	0.98	1.00	0.65 (0.07)	0.73 (0.09)
TM2	0.95	0.99	0.85 (0.11)	0.86 (0.08)
TM3	0.92	1.00	0.76 (0.19)	0.91 (0.06)
Model Mean	0.98	1.00	0.83 (0.13)	0.91 (0.08)

Table S2. Correlation coefficient R and ratio of standard deviations: σ_{prc}/σ_{fs},, representing the pulse-response code (PRC) vs. forward simulation (FS) correlation in the shape and phase and the amplitude ratio, respectively, of the seasonal cycle in APO at 13 selected monitoring sites. The mean and standard deviation (for σ_{prc}/σ_{fs}, in parentheses) among the 9 ATMs participating in the APO Transcom experiment are given.

Station	Code	Lat.°N	Long. °E	Elev. (m)	Obs Years	R^2	σ_{prc}/σ_{fs}
Alert	ALT	82.5	-62.5	210	1991-2013 SIO	0.99	0.95 (0.12)
Barrow Alaska	BRW	71.3	-156.6	11	1993-2008 PU	0.97	0.96 (0.10)
Cold Bay Alaska	CBA	55.2	-162.7	25	N/A	0.96	0.66 (0.11)
Sable Island Nova Scot.	SBL	43.9	-60.0	5	N/A	0.95	0.77 (0.11)
Ryori, Japan	RYO	39.0	141.8	260	N/A	0.93	0.77 (0.14)
La Jolla CA	LJO	32.9	-117.3	16	N/A	0.96	0.93 (0.19)
Kumukahi HI	KUM	19.5	-154.8	3	N/A	0.95	1.20 (0.17)
Mauna Loa HI	MLO	19.5	-155.6	3397	N/A	0.97	1.22 (0.20)
Samoa	SMO	-14.3	-170.6	42	N/A	0.95	0.78 (0.07)
Amsterdam Island	AMS	-38.0	77.5	150	N/A	1.00	0.88 (0.10)
Cape Grim Tasmania	CGO	-40.7	144.7	5500	N/A	1.00	0.86 (0.14)
Cape Grim Tasmania	CGO	-40.7	144.7	94	N/A	0.99	0.82 (0.08)
Macquarie Island	MQA	-54.5	159.0	12	1997-2007 PU	1.00	0.89 (0.09)
Palmer Antarctica	PSA	-64.9	-64.0	10	1996-2013 SIO	0.97	1.04 (0.14)
Syowa Antarctica	SYO	-69.0	39.6	11	N/A	0.99	0.93 (0.11)

South Pole	SPO	-90.0	-24.8	2830	1993-2013 SIO	1.00	0.88 (0.11)

At most extratropical stations, the σ_{prc}/σ_{fs} ratios are < 1 in Table S2, suggesting that the Pulse Response Code tends to underestimate the true APO amplitude from the forward simulations. This may be due to the uniform flux distributions assumed across Transcom regions, which could smooth out hotspots for O_2 air-sea flux that may lead to more intense peaks in true APO. Although the PRC vs. FS comparison is purely model based, the timespan used to compute the observed mean APO seasonal cycle at the 5 selected stations shown in the main text is also listed in Table S2.

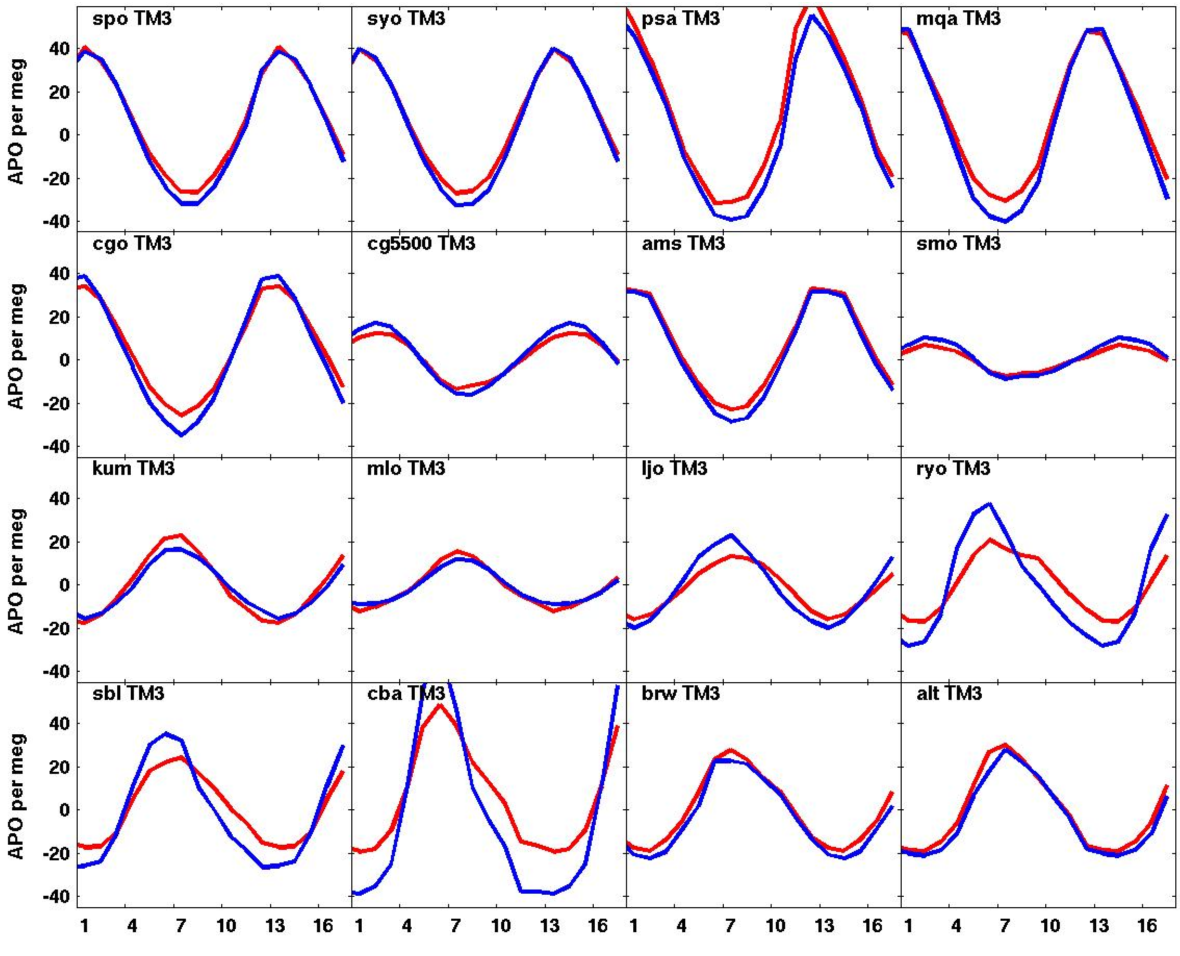

Figure S1. Mean seasonal cycle in atmospheric APO produced by forcing the TM3 atmospheric transport model with monthly mean O_2 and N_2 fluxes from the monthly flux climatology of *Garcia and Keeling* [2001]. Archived results from T3L2 TM3 forward simulations from the APO Transcom experiment (blue) are compared to estimates using the TM3 variant of the pulse-response code (red) at 16 stations: SPO (South Pole), SYO (Syowa), PSA (Palmer Station), MQA (Macquarie), CGO (Cape Grim surface), CGO5500 (Cape Grim/Bass Strait 5500m), AMS (Amsterdam Island), SMO (Samoa), MLO (Mauna Loa), LJO (La Jolla, California), RYO (Ryori), SBL (Sable Island, Canada), CBA (Cold Bay, Alaska), BRW (Barrow, Alaska), ALT (Alert, Greenland).

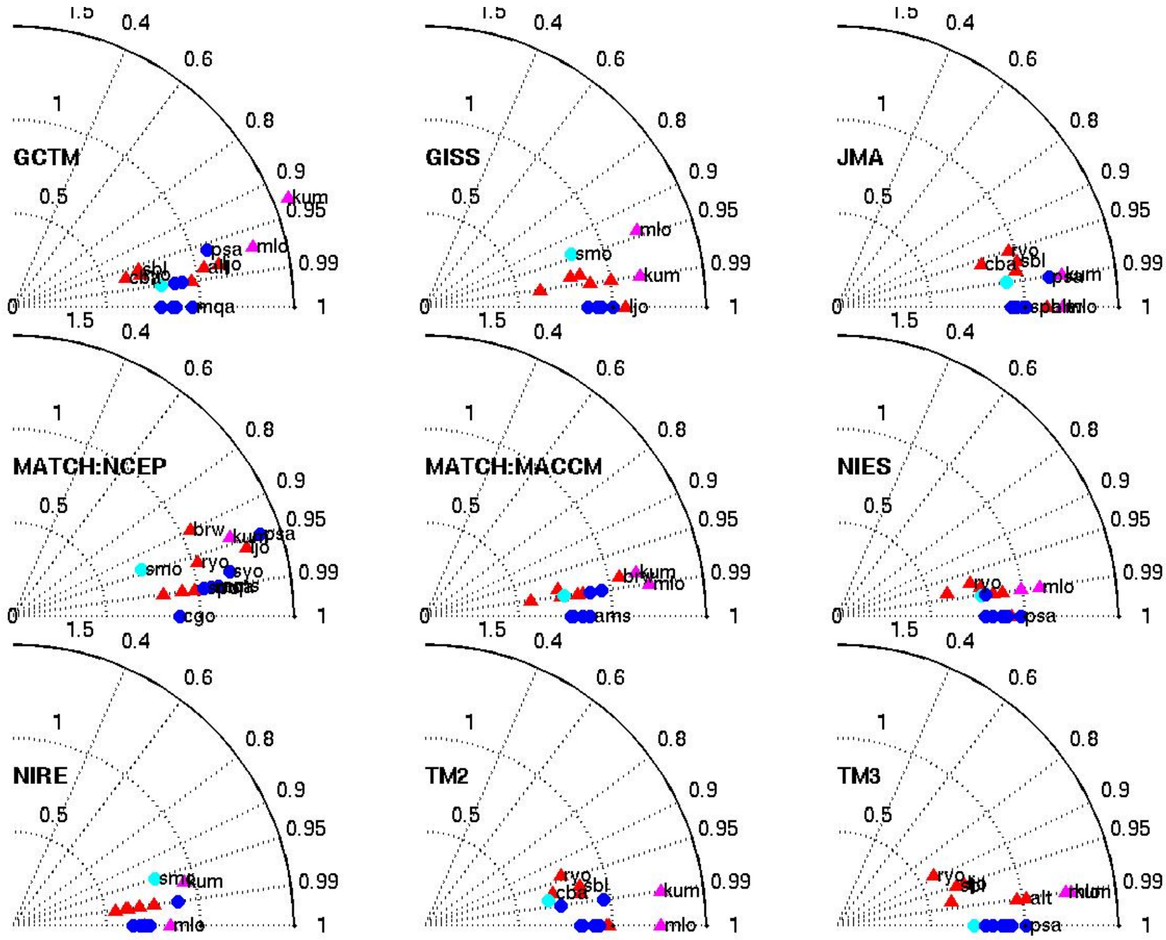

Figure S2. Taylor diagrams [*Taylor*, 2001] illustrating the correlation in in phase, shape and amplitude between the pulse-response code and the archived T3L2 forward simulations for the 9 ATMs participating in APO Transcom, forced by monthly mean O_2 and N_2 fluxes from the monthly flux climatology of *Garcia and Keeling* [2001]. The reference point at a radius (amplitude ratio) of 1 and correlation coefficient (angle) of 1.0 represents perfect agreement with the forward simulation. Each symbol on the Taylor diagram represents one of 16 sampling sites, color coded by latitude (blue = <-25S, cyan=southern tropical, magenta = northern tropical, red = >25N), which are labeled by 3-letter station code where legibility permits.

Reference:

Taylor, K. E., 2001, Summarizing multiple aspects of model performance in a single diagram, J. Geophys. Res., 106(D7), 7183–7192.