Supplement A: Surface area normalization of sea-air fluxes for OBGCMs

Here the effect of normalizing the ocean surface areas of the OBGCMs and pCO_2 climatology is investigated. This is accomplished by determining the flux density in each the 23 surface regions of the ocean inversion project (IOP) (Fig. A1) (Mikaloff Fletcher et al., 2006, 2007) and then using the area of each of the regions as provided in RECCAP to calculate the total flux. Area and ocean volume are integral parts of model dynamics such that interpretation of the adjusted values should be done with caution. The adjusted values are closer to other approaches discussed and agreement between OBGCM is better, as expressed in their standard deviation, when normalized to a common surface area. Table A1 provides the original sea-air anthropogenic CO_2 fluxes along with the adjusted value for each OGCM.
The impact of areal normalization on the T09 global sea-air anthropogenic CO_2 flux for each of the ocean regions is provided in Table A2 with the global uptake provided in Table 2 (main text).

Table A1. Twenty-year mean sea-air anthropogenic CO_2 fluxes from the OGCM and the adjusted flux normalizing for area (Pg C yr^{-1}).

Abbreviation	OGCM	Area (10^{13} m^2)[b]	Provided flux	Adjusted flux[c]
UEA_{NCEP}	NEMO-PlankTOM5$_{NCEP}$	35.0	-2.08	-2.03
UEA_{ECMWF}	NEMO-PlankTOM5$_{ECMWF}$	35.0	-2.48	-2.46
UEA_{CCMP}	NEMO-PlankTOM5$_{CCMP}$	35.0	-2.16	-2.12
LSC	NEMO-PISCES	31.9	-1.93	-2.03
CSI	CSIRO-BOGCM	34.3	-1.93	-2.00
BER	MICOM-HAMOCCv1	36.1	-2.58	-2.54
BEC	CCSM-BEC	30.6	-1.39	-1.71
ETH_{k15}	CCSM-ETH_{k15}[a]	33.0	-1.49	-1.67
ETH_{k19}	CCSM-ETH_{k19}[a]	33.0	-1.53	-1.73
Median (6-model runs)[d]			-1.93	-2.01
Average			-1.90	-1.99
St. dev. (6-model runs)[d]			0.43	0.31

[a]For the period of 1990-2007
[b]The areas used in the models. They differ slightly from those described in the model documentation due to the transposition of the original grid area to 1° × 1° grid area
[c]Using the areas as provided in the OIP with a total surface area of 34.00 × 10^{13} m^2 (35.87 total-1.87 (ice cover) × 10^{13} m^2) (see Table A2)
[d]Using UEA_{NCEP}, LSC,CSI, BER, BEC, and ETH_{k15}

Table A2. Fluxes using ΔpCO_2 fields from T-09 and CCMP winds, and adjusted fluxes based on areas ocean inversion project (OIP) regions

Region Name	Region #	Area[a] ($10^{13} m^2$)	T-09 Flux (Pg C yr^{-1})	Flux dens. (mol C m^{-2} yr^{-1})	Areas OIP[b] ($10^{13} m^2$)	Adj. Flux (Pg C yr^{-1})
Arctic	1	.368	-0.04	-0.81	.308	-0.07
High Lat. N. Atlantic	2	.761	-0.23	-2.49	.898	-0.29
Mid-Lat. N. Atlantic	3	.668	-0.13	-1.67	1.03	-0.21
Subtropical N. Atlantic	4	1.40	-0.05	-0.32	1.51	-0.06
Tropical N. Atlantic	5	1.10	0.03	0.22	1.26	0.03
Tropical S. Atlantic	6	1.01	0.08	0.65	1.06	0.08
Subtropical S. Atlantic	7	.823	0.02	0.23	.896	0.02
Mid-Lat. S. Atlantic	8	.925	-0.12	-1.12	.972	-0.13
Subpolar S. Atlantic	9	.928	-0.10	-0.86	.877	-0.09
Southern Ocean	10	2.38	0.05	0.17	1.57	0.06
High Lat. N.W. Pacific	11	.301	0.01	0.25	.381	0.01
Mid-High Lat. N.E. Pacific	12	.688	-0.11	-1.27	.733	-0.11
W. Subtropical N. Pacific	13	1.99	-0.29	-1.22	2.22	-0.32
E. Subtropical N. Pacific	14	1.01	-0.05	-0.41	1.07	-0.05
W. Tropical N. Pacific	15	1.85	0.03	0.13	1.95	0.03
E. Tropical N. Pacific	16	1.60	0.12	0.61	1.67	0.12
W. Tropical S. Pacific	17	1.16	0.02	0.15	1.20	0.02
E. Tropical S. Pacific	18	1.80	0.33	1.53	1.83	0.34
W. S. Pacific	19	2.32	-0.31	-1.10	2.50	-0.33
E. S. Pacific	20	1.33	0.02	0.15	1.38	0.03
Subpolar S. Pac. and S. Ind.	21	2.92	-0.22	-0.64	2.84	-0.22
Tropical Indian	22	2.55	0.11	0.36	3.24	0.14
S. Indian	23	2.42	-0.34	-1.17	2.65	-0.37
Total		32.3	-1.17	-0.30	34.0	-1.36

[a] Total area is not adjusted for ice coverage

[b] Open ocean, adjusted for ice cover

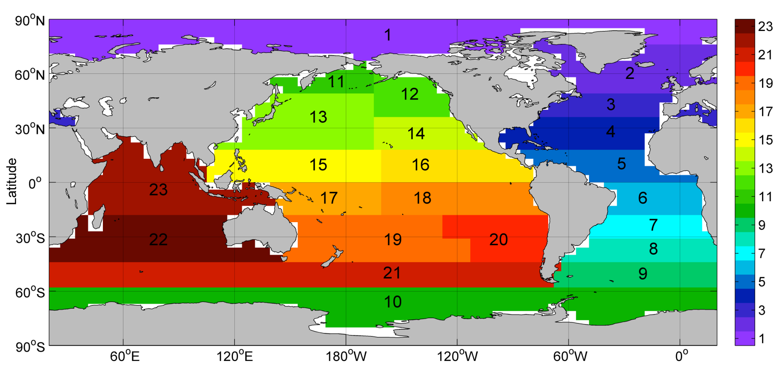

Figure A1. Map of regions used in ocean inverse and used to normalize fluxes (the numbers reference the regions in Table A2).

Supplement B. Global maps of interannual and subannual variability

Fig. B1a provides a map of the fluxes using the ΔpCO_2 climatology of Takahashi et al. (2009) (T-09) on a 4˚ by 5˚ grid and procedures outline in the text. Fig. B1b shows the standard deviation of the monthly flux values that are an indication of subannual variability (SAV).

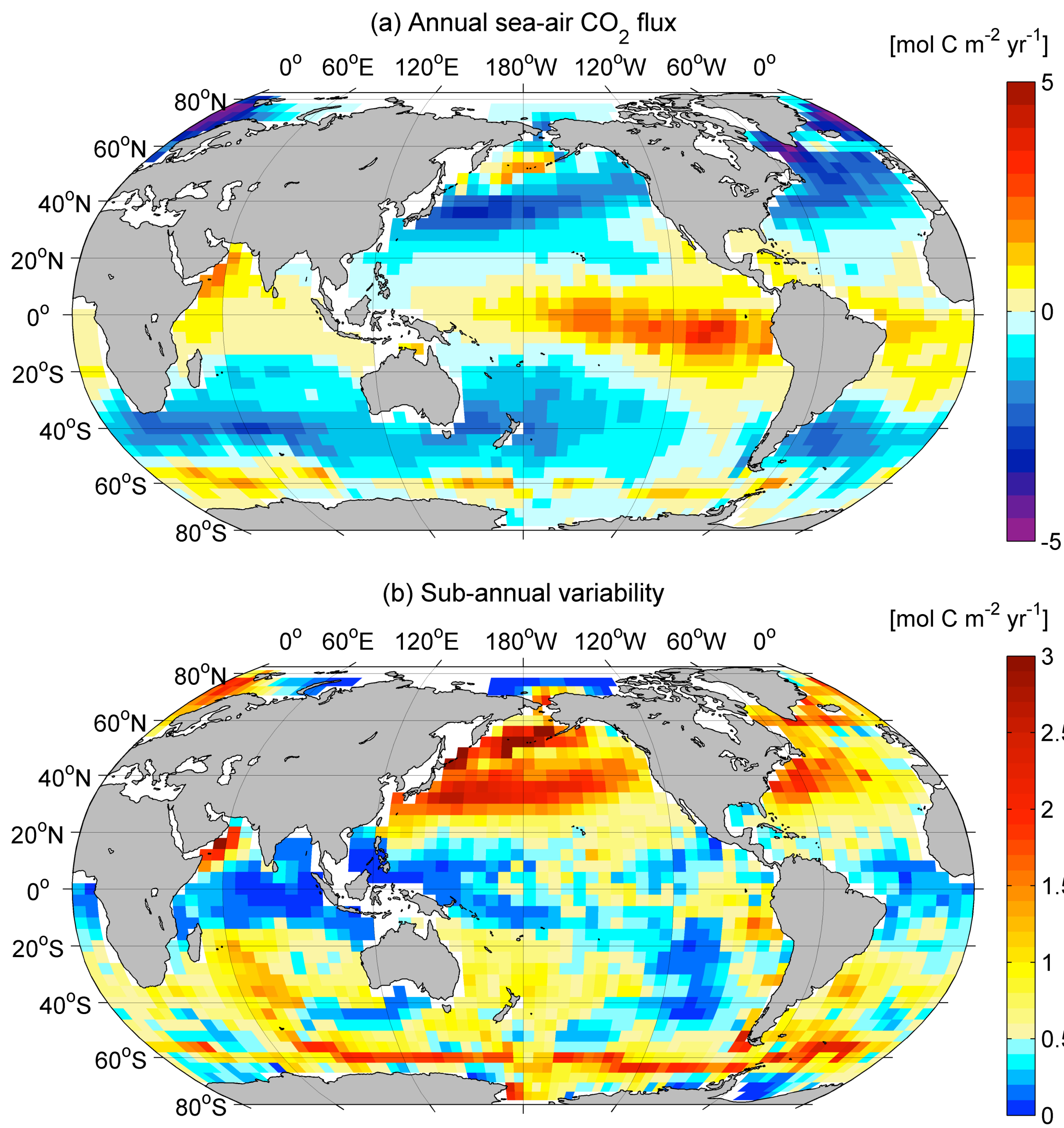

Figure B1. (a) Annual average flux for climatological year 2000 using the T-09 monthly ΔpCO_2 climatology and monthly <U^2> from the CCMP wind product, positive values indicate that the region is sources of CO_2 to the atmosphere; (b) standard deviation of the fluxes at 4˚ by 5˚ as an indicator of sub-annual variability, (See main text for details).

Fig. B2a shows the mean annual flux for 1990-2009 according to the method of Park et al., 2010a (P10) and Fig. B2b shows the standard deviation of the 20-year average as an indicator of interannual variability (IAV). Regions with a high standard deviation are those with large year-to-year differences and correspond to regions impacted by large-scale climate reorganizations such as the ENSO, the North Atlantic Oscillation (NAO), and Southern Annual Mode (SAM).

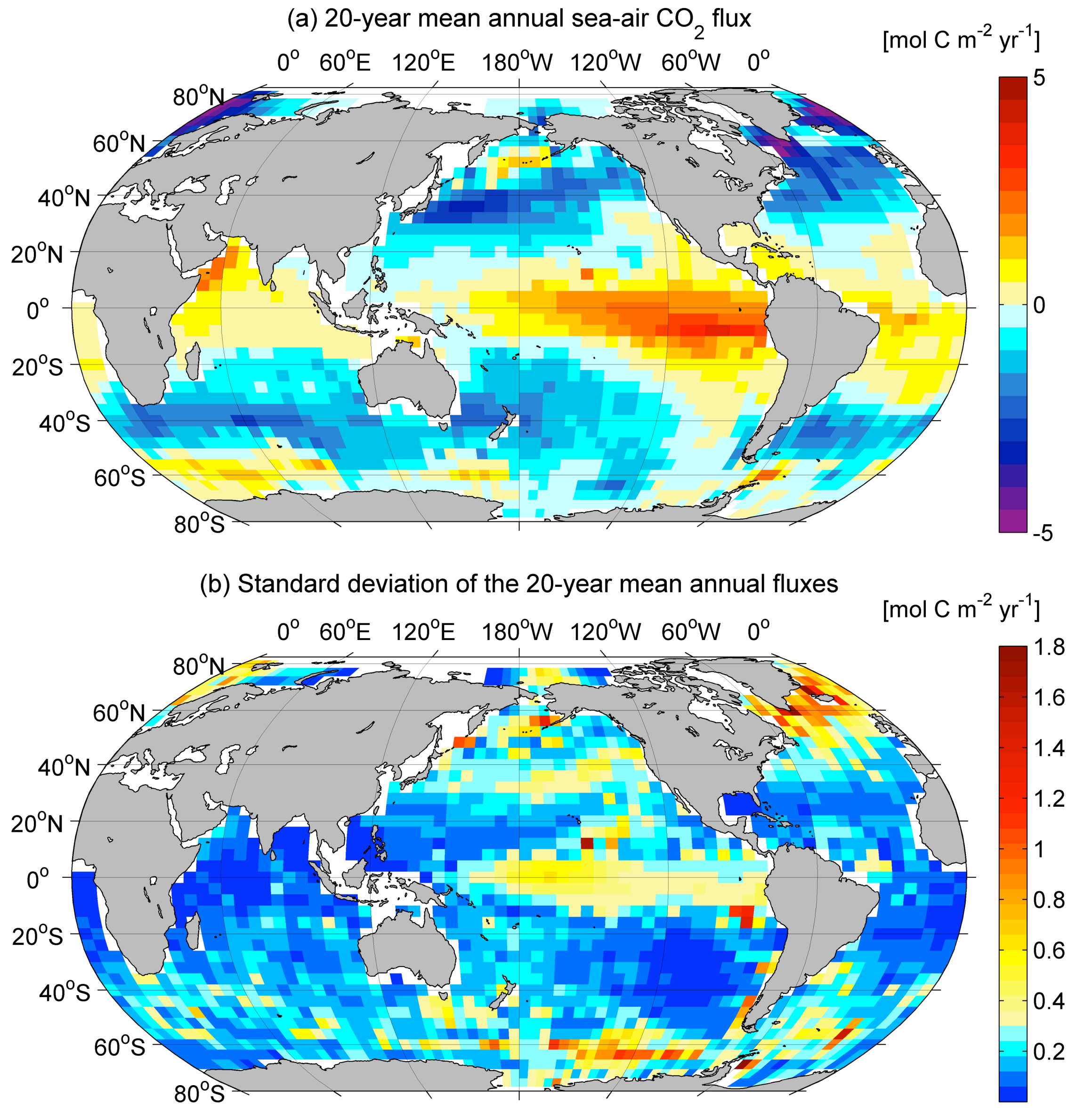

Figure B2. (a) Mean Annual Flux for 20 years (1990-2009); (b) Standard deviation of the 20-year annual means as an indicator of interannual variability. Fig. B2a shows the multi-annual mean rather than a climatological one shown in B1a. Fig. B1b is the subannual variability (SAV) while B2b shows the interannual variability (IAV).

Figure B3 provides the ratio of interannual to subannual variability (IAV/SAV).

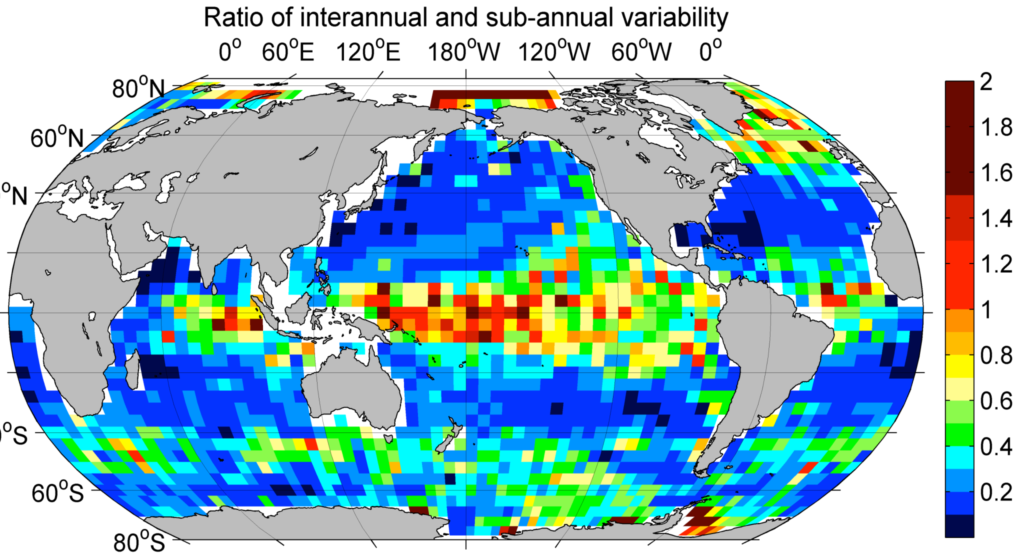

Figure B3. Ratio of interannual variability, IAV (Fig. B2b) and subannual variability, SAV (Fig. B1b) in sea-air CO_2 fluxes.