Supporting Information for "Improved constraints on northern extratropical CO_2 fluxes obtained by combining surface-based and space-based atmospheric CO_2 measurements"

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Figure S1. Locations of aircraft observations used in this study for (a) East Asia, (b) North America, and (c) Alaska/Arctic.

Table S1. Mean and standard deviation (std) of data–model mismatch between each flux inversion and aircraft-based CO_2 observations over East Asia, North America, and Alaska/Arctic. Posterior-simulated-CO_2 was calculated at $4° \times 5°$ spatial resolution.

Region		East Asia		North America		Alaska/Arctic	
data set	prior NEE	mean (ppm)	std (ppm)	mean (ppm)	std (ppm)	mean (ppm)	std (ppm)
prior	SiB3	-0.06	0.85	0.08	0.97	-0.84	1.61
	CASA	-0.01	0.76	0.26	0.56	-0.59	1.36
	FLUXCOM	1.18	0.70	1.54	0.57	1.24	1.00
	Mean NEE	0.37	0.57	0.63	0.54	-0.06	1.16
TCCON	SiB3	0.16	0.46	0.33	0.43	-0.10	0.86
	CASA	0.33	0.74	0.65	0.57	-0.02	1.30
	FLUXCOM	0.42	0.45	0.42	0.45	-0.02	1.18
	Mean NEE	0.30	0.42	0.43	0.47	-0.05	1.05
surface-only	SiB3	0.01	0.44	0.34	0.35	-0.06	0.80
	CASA	0.13	0.71	0.48	0.50	-0.14	1.22
	FLUXCOM	0.22	0.60	0.46	0.33	-0.01	0.88
	Mean NEE	0.12	0.43	0.43	0.31	-0.07	0.93
GOSAT-only	SiB3	0.25	0.41	0.49	0.37	-0.06	0.76
	CASA	0.14	0.36	0.43	0.36	-0.17	0.81
	FLUXCOM	0.23	0.44	0.50	0.33	0.03	0.89
	Mean NEE	0.21	0.33	0.47	0.32	-0.06	0.79
GOSAT	SiB3	0.18	0.35	0.34	0.31	-0.7	0.75
+surface	CASA	0.15	0.39	0.42	0.36	-0.03	0.89
+TCCON	FLUXCOM	0.16	0.38	0.39	0.32	0.00	0.93
	Mean NEE	0.16	0.31	0.38	0.32	-0.03	0.84

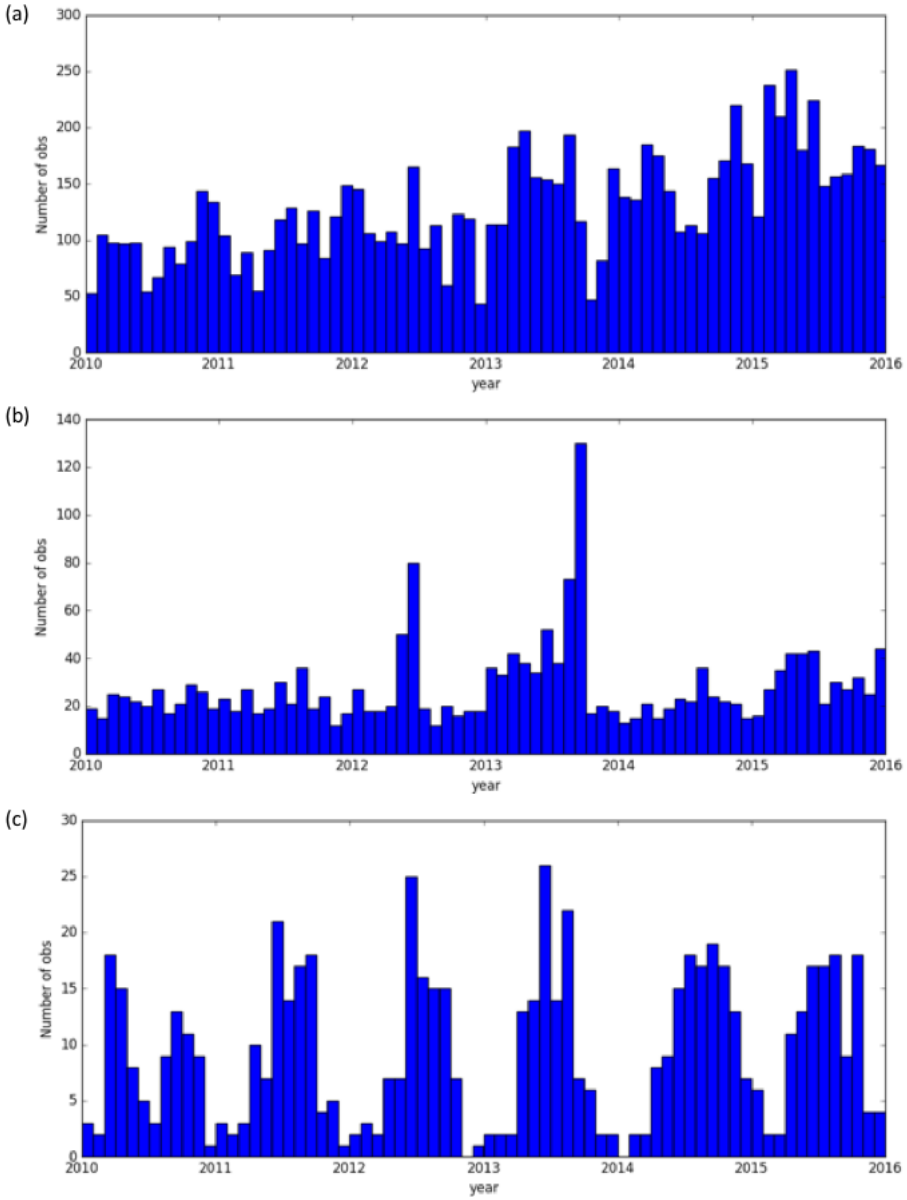

Figure S2. Number of hourly-mean aircraft measurements between 3–8 km altitude above sea level per month for (a) East Asia, (b) North America, and (c) Alaska/Arctic.

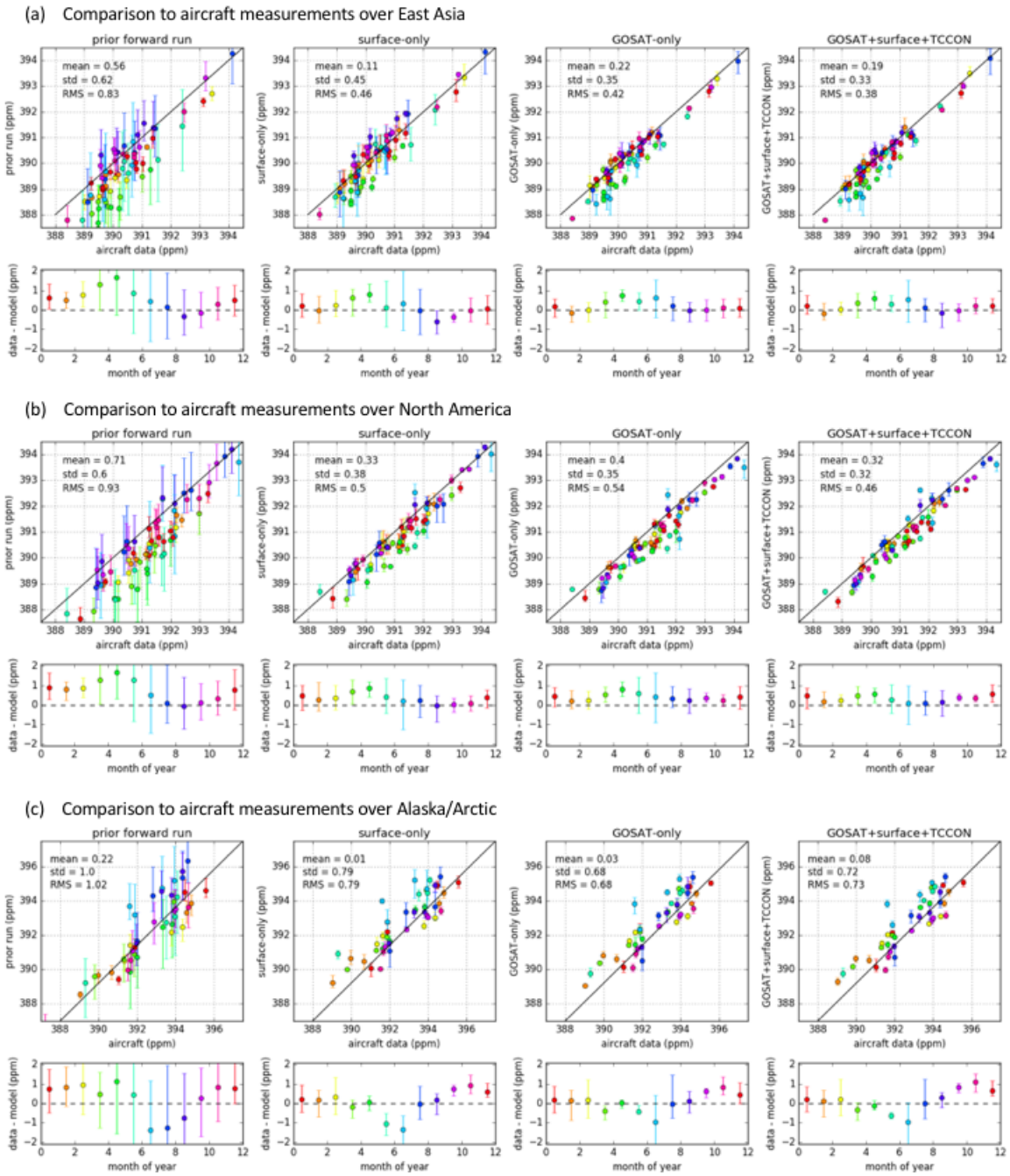

Figure S3. Same as Fig. 3 but at $2° \times 2.5°$ spatial resolution (except for TCCON). Comparison of monthly mean measured and simulated aircraft-based CO_2 for (a) East Asia, (b) North America, and (c) Alaska/Arctic. For each region, the mismatch for (left to right) prior, surface-only, GOSAT-only, and GOSAT+surface+TCCON simulated CO_2 are shown. The top panel shows a scatter plot of the simulated aircraft-based CO_2 against the measured aircraft-based CO_2, and the error bars indicate the spread in posterior NEE. The lower panel shows the mean data–model mismatch for each month, with error bars showing the range of monthly mean mismatched over the six-years and inversion set-ups. Colors correspond to the month of year.

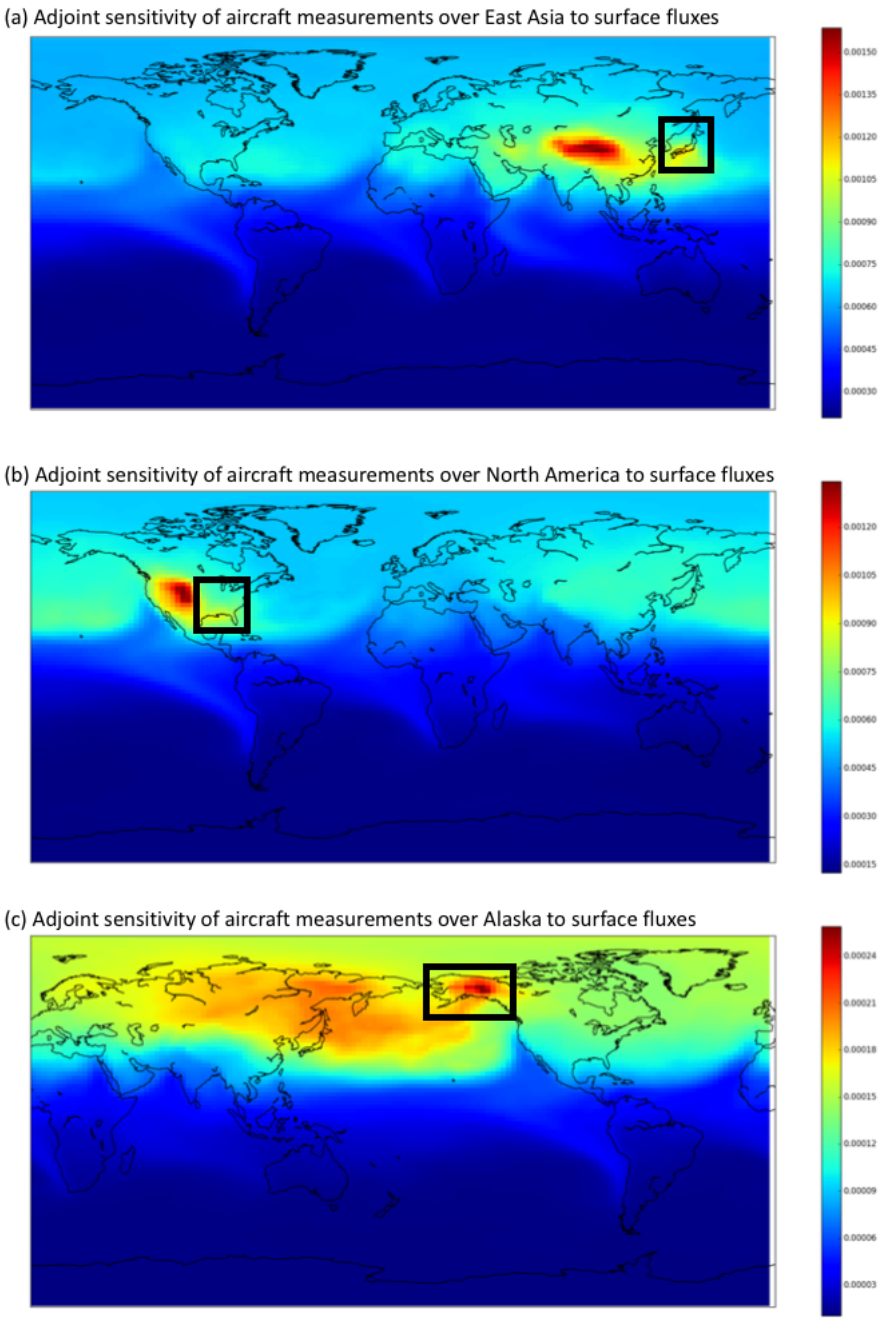

Figure S4. Adjoint sensitivity of aircraft-based CO_2 measurements to surface fluxes for measurements over (a) East Asia, (b) North America, and (c) Alaska/Arctic. Black boxes show the location of aircraft-based CO_2 measurements.

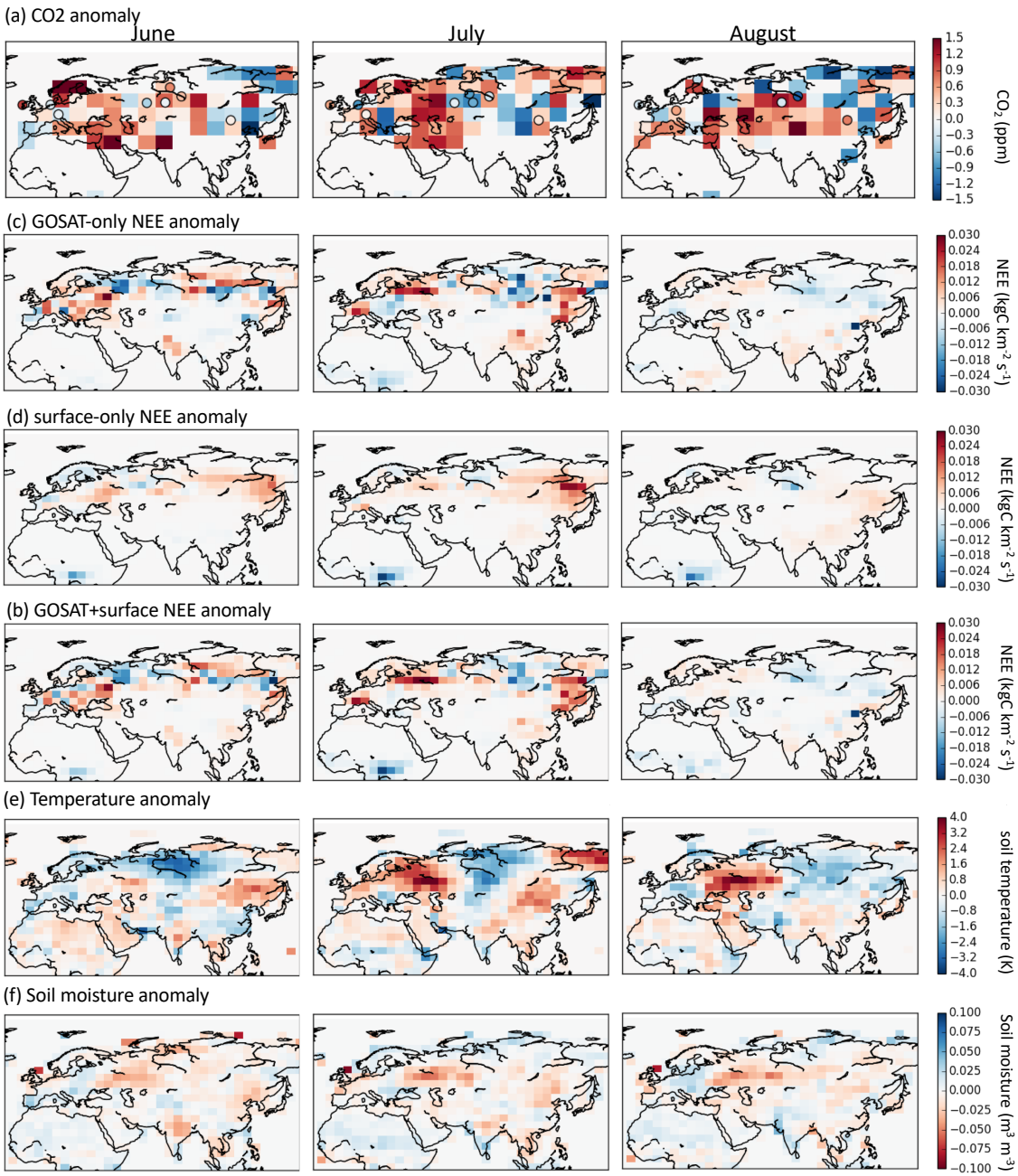

Figure S5. Same as Fig. 8 but for Eurasia during (left-to-right) May, June, July and August of 2010. Monthly anomalies in (a) GOSAT X_{CO_2} (ppm, $4° \times 5°$ grid cells) and surface site CO_2 (ppm divided by four, circles), (b) GOSAT-only posterior NEE, (c) surface-only posterior NEE, (d) GOSAT+surface posterior NEE, (e) MERRA-2 soil temperature anomalies (K), and (f) ESA CCI soil moisture.

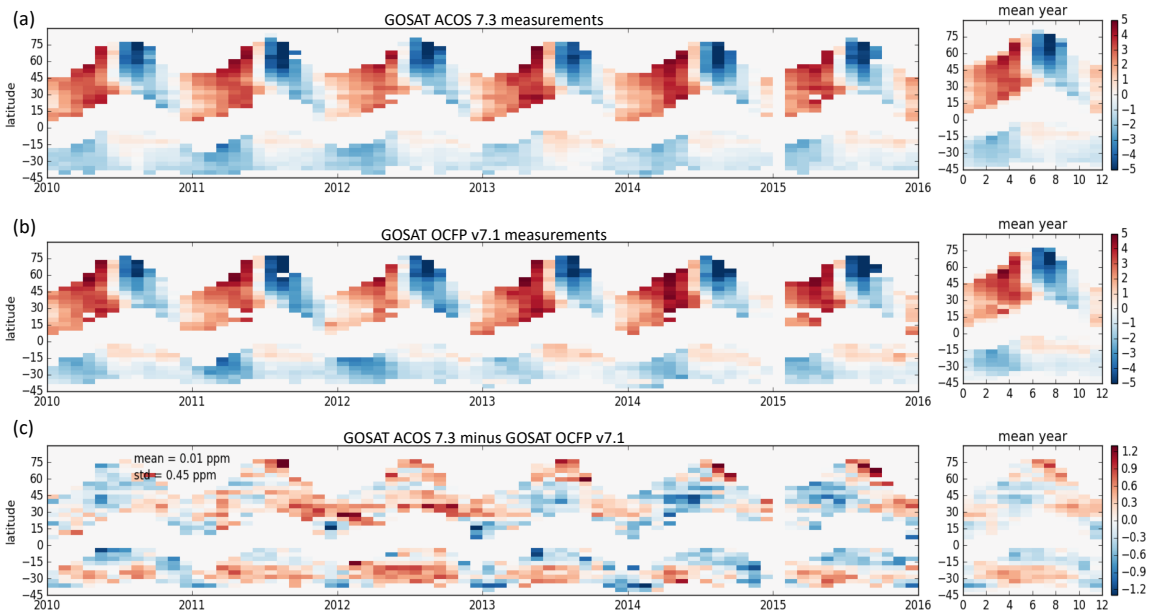

Figure S6. Detrended zonal-monthly mean high-gain nadir GOSAT X_{CO_2} retrieved by (a) ACOS 7.3 and (b) OCFP v7.1. (c) Difference in X_{CO_2} between the two retrieval algorithms.

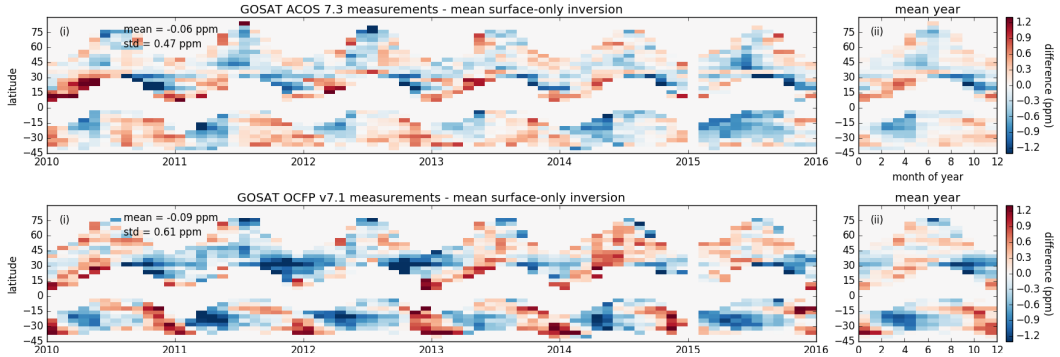

Figure S7. Data–model mismatch of the (a) ACOS 7.3 and (b) OCFP v7.1 GOSAT high-gain nadir X_{CO_2} measurements as a function of latitude and time for the surface-only flux inversion.

Table S2. Mean and standard deviation (std) of data–model mismatch between each flux inversion and aircraft-based CO_2 observations over East Asia, North America, and Alaska/Arctic. Posterior-simulated-CO_2 was calculated at $2° \times 2.5°$ spatial resolution.

Region		East Asia		North America		Alaska/Arctic	
data set	prior NEE	mean (ppm)	std (ppm)	mean (ppm)	std (ppm)	mean (ppm)	std (ppm)
4prior	SiB3	0.57	0.94	0.56	1.03	0.01	1.56
	CASA	-0.05	0.73	0.18	0.57	-0.54	1.20
	FLUXCOM	1.16	0.75	1.39	0.62	1.19	0.90
	Mean NEE	0.56	0.62	0.71	0.60	0.22	1.00
surface-only	SiB3	0.01	0.44	0.26	0.40	0.03	0.73
	CASA	0.11	0.69	0.38	0.57	-0.06	1.04
	FLUXCOM	0.22	0.62	0.35	0.39	0.06	0.79
	Mean NEE	0.11	0.45	0.33	0.38	0.01	0.79
GOSAT-only	SiB3	0.25	0.38	0.42	0.38	0.03	0.65
	CASA	0.18	0.39	0.37	0.39	-0.07	0.72
	FLUXCOM	0.24	0.46	0.42	0.36	0.14	0.75
	Mean NEE	0.22	0.35	0.40	0.35	0.03	0.68
GOSAT	SiB3	0.20	0.37	0.28	0.33	0.06	0.66
+surface	CASA	0.15	0.40	0.33	0.39	0.04	0.78
+TCCON	FLUXCOM	0.22	0.38	0.36	0.32	0.15	0.78
	Mean NEE	0.19	0.33	0.32	0.32	0.08	0.72