Table S1: Marine Boundary Layer (MBL) stations within the NOAA Earth System Research Laboratory CO_2 sampling network (ESRL). These sites were selected for obtaining at least 50% data coverage over the analysis period of 1982 to 2010.

Region	Station	Acronym	Lat	Lon
60°–90°N	Alert, AK	ALT	82.5	-62.5
	Ny-Ålesund, Svalbard	ZEP	78.9	11.9
	Barrow, AK	BRW	71.3	-156.6
	Stórhöfði, Iceland	ICE	63.4	-20.0
23°–60°N	Mace Head, Ireland	MHD	53.3	-9.9
	Shemya, AK	SHM	52.7	174.1
	Terceira Island, Azores	AZR	38.8	-27.4
	Tudor Hill, Bermuda	BMW	32.3	-64.9
	Sand Island, Midway	MID	28.2	-177.4
	Key Biscayne, FL	KEY	25.7	-80.2
	Pacific Ocean, 25°N	POCN25	25.0	-135.0
0°–23°N	Pacific Ocean, 20°N	POCN20	20.0	-139.0
	Cape Kumukahi, HI	KUM	19.5	-154.8
	Pacific Ocean, 15°N	POCN15	15.0	-143.0
	Mariana Islands, Guam	GMI	13.4	144.8
	Ragged Point, Barbados	RPB	13.2	-59.4
	Pacific Ocean, 10°N	POCN10	10.0	-147.0
	Pacific Ocean, 5°N	POCN05	5.0	-151.0
	Christmas Island	CHR	1.7	-157.2
0°–23°S	Seychelles	SEY	-4.7	55.2
	Pacific Ocean 5°S	POCS05	-5.0	-159.0
	Ascension Island	ASC	-8.0	-14.4
	Pacific Ocean 10°S	POCS10	-10.0	-163.0
	Tutuila American Samoa	SMO	-14.2	-170.6
	Pacific Ocean 15°S	POCS15	-15.0	-167.0
	Pacific Ocean 20°S	POCS20	-20.0	-171.0
23°–60°S	Pacific Ocean 25°S	POCS25	-25.0	-174.0
	Pacific Ocean 30°S	POCS30	-30.0	-177.0
	Cape Grim, Australia	CGO	-40.7	144.7
	Crozet Island	CRZ	-46.5	51.9
60°–90°S	Palmer Station, Antarctica	PSA	-64.0	-64.0
	Syowa Antarctica	SYO	-69.0	39.6
	Halley Bay, Antarctica	HBA	-75.6	-26.5
	South Pole	SPO	-90.0	-24.8

Table S2: Coefficient of variation for flux variables by latitude zone. All variables have been detrended using a third-order polynomial fit. For NEP, a negative sign represents flux into land and a positive sign represents a flux to the atmosphere from land.

Region	Model Flux	Mean Flux [Pg C yr^{-1}]	Flux Standard Deviation (STD) [Pg C yr^{-1}]	STD : Flux [%]
NHL 61°-90°N	CASA HR	3.94	0.08	2
	CORPSE HR	4.52	0.23	5
	MIMICS HR	3.96	0.09	2
	CASA NPP	4.07	0.09	2
	CASA NEP	-0.13	0.05	40
	CORPSE NEP	0.45	0.16	35
	MIMICS NEP	-0.11	0.08	76
				0
NML 24°-60°N	CASA HR	22.73	0.24	1
	CORPSE HR	23.06	0.31	1
	MIMICS HR	22.88	0.48	2
	CASA NPP	23.15	0.28	1
	CASA NEP	-0.42	0.40	96
	CORPSE NEP	-0.09	0.46	505
	MIMICS NEP	-0.27	0.66	245
				0
NT 1°-23°N	CASA HR	10.63	0.08	1
	CORPSE HR	10.63	0.10	1
	MIMICS HR	10.57	0.22	2
	CASA NPP	10.66	0.44	4
	CASA NEP	-0.03	0.48	1428
	CORPSE NEP	-0.03	0.47	1571
	MIMICS NEP	-0.09	0.62	732
				0
ST 0°-23°S	CASA HR	14.26	0.10	1
	CORPSE HR	14.30	0.12	1
	MIMICS HR	14.24	0.29	2
	CASA NPP	14.52	0.57	4
	CASA NEP	-0.27	0.61	232
	CORPSE NEP	-0.22	0.58	262
	MIMICS NEP	-0.28	0.84	296
				0
SE 24°-90°N	CASA HR	3.72	0.05	1
	CORPSE HR	3.74	0.07	2
	MIMICS HR	3.74	0.08	2

CASA NPP	3.77	0.26	7
CASA NEP	-0.05	0.26	518
CORPSE NEP	-0.03	0.24	810
MIMICS NEP	-0.03	0.33	1135

Table S3: Multiple linear regression coefficients (γ) and R^2 are used to model interannual variability in heterotrophic respiration as a function of interannual variability in temperature, NPP, or preceding year NPP. All variables have been detrended and deseasonalized. We list statistically significant predictors of HR IAV, as determined by p-values from ANOVA.

Region	Model IAV	HR IAV Regression γ* , R^2		
		CASA-CNP Temperature IAV [Pg C y^{-1} K^{-1}]	CASA-CNP NPP Current year IAV [--]	CASA-CNP NPP Preceding year IAV [--]
NHL 61°-90°N	CASA HR	**0.16** , 0.64	**0.74** , 0.67	-0.14, 0.02
	CORPSE HR	**0.42**, 0.54	**2.22**, 0.77	-0.23, 0.01
	MIMICS HR	**0.13**, 0.32	**0.63**, 0.40	0.06, 0.00
	CASA-CNP NPP	**0.15**, 0.43		
NML 24°-60°N	CASA HR	**0.78**, 0.58	0.2, 0.05	0.33, 0.15
	CORPSE HR	**1.00**, 0.57	-0.28, 0.06	0.32, 0.08
	MIMICS HR	**1.74**, 0.70	**-0.90**, 0.27	0.05, 0.00
	CASA-CNP NPP	-0.38, 0.10		
NT 1°-23°N	CASA HR	0.17, 0.14	**-0.10**, 0.26	**0.12**, 0.45
	CORPSE HR	0.00, 0.00	-0.06, 0.07	**0.17**, 0.61
	MIMICS HR	**1.03**, 0.68	**-0.40**, 0.60	-0.03, 0.00
	CASA-CNP NPP	**-1.57**, 0.42		
ST 0°-23°S	CASA HR	**0.24**, 0.17	**-0.07**, 0.17	**0.12**, 0.41
	CORPSE HR	-0.01, 0.00	-0.01, 0.00	**0.17**, 0.61
	MIMICS HR	**1.50**, 0.87	**-0.46**, 0.79	0.03, 0.00
	CASA-CNP NPP	**-2.65**, 0.72		
SE 24°-90°N	CASA	0.00, 0.00	0.03, 0.03	**0.12**, 0.32
	CORPSE	-0.07, 0.04	0.09, 0.13	**0.17**, 0.36
	MIMICS	**0.32**, 0.42	**-0.26**, 0.65	-0.08, 0.04
	CASA-CNP NPP	**-1.11**, 0.52		

*bolded values are statistically significant ($p < 0.05$)

Supplemental Figure 1

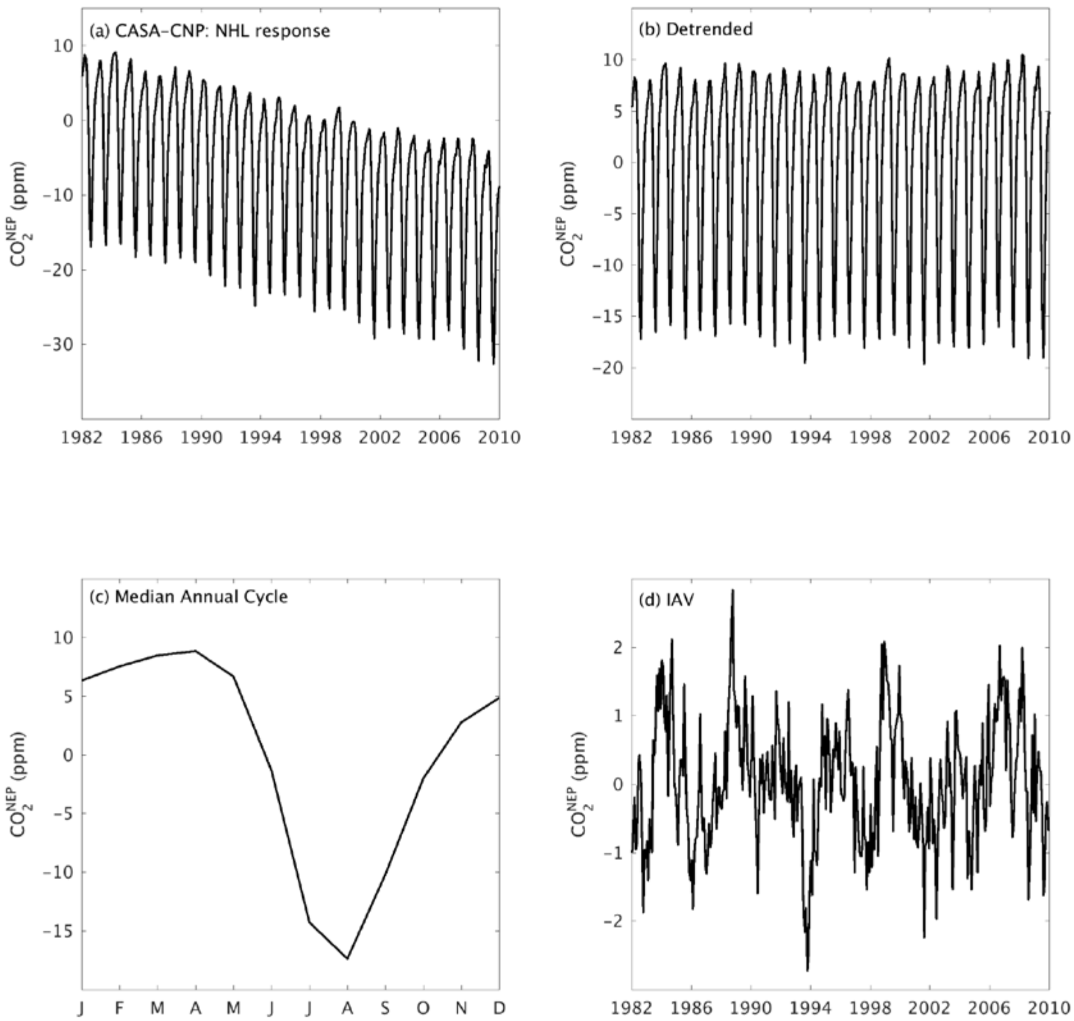

Figure 1: Depiction of interannual variability (IAV) calculation. (a) Multi-site mean CASA-CNP CO_2^{NEP} in the Northern Hemisphere high latitudes (NHL) region for 1982 to 2010 (CO_2^{NEP} = CO_2^{HR} + CO_2^{NPP}). (b) Detrended CASA-CNP CO_2^{NEP} timeseries after removing a third-order polynomit fit. (c) Climatological annual cycle calculated using the median of monthly values over the analysis period. (d) CASA-CNP CO_2^{NEP} interannual variability calculated from removing the climatological annual cycle from each year in the detrended timeseries.