

Supplementary information

S1: GASLAB quadratic fits

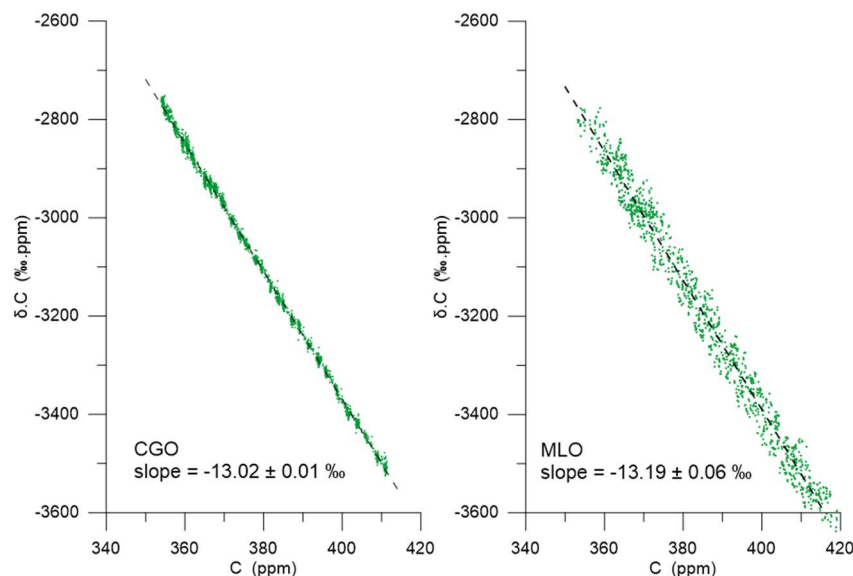
The GASLAB baseline Cape Grim (CGO) and Mauna LOA (MLO) quadratics are taken from Francey et al. (2023):

$$C \text{ and } \delta.C = a.y^2 + b.y + c \text{ (ppm), } \delta = b.y + c \quad \text{where } y \text{ is in (years-1990):}$$

(1b)		a	b	c	r ²
CGO	C	0.0156	1.4829	349.76	0.9988
	δ		-0.0255	-7.746	0.9833
	$\delta.C$	-0.1909	-19.688	-2713.5	0.9963
MLO	C	0.01482	1.5707	351.62	0.9777
	δ		-0.0275	-7.796	0.7566
	$\delta.C$	-0.1426	-22.876	-2734.2	0.9135

S2: The GASLAB baseline ¹³C variation

The remarkably small inter-annual variation in individual flask stable carbon isotope data, particularly at CGO, is shown in this Figure of $\delta.C$ versus C reproduced from Francey et al. (2023). At CGO regular seasonality is evident as small vertical excursions. The only evidence for interannual variation corresponds to flattening of the δ decline between 1999 and 2002. At MLO, the opposing influences of large seasonal δ and C excursions in the $\delta.C$ product result in more scatter around the similar mean slope.



S3: NOAA sites identification

An early comparison between data from GASLAB SIS data (and surrounding NOAA Northern Hemisphere sites) was published in 1998 (Francey et al. ,1998), relative to an average trend in the NOAA data. Comparison is made here of the three decade mean of residuals from the GASLAB MLO and CGO baseline quadratics (quad).

	Latitude		ppm from CGO quad	ppm from MLO quad
SPO	89.98°S	South Pole (US)	0.25	-2.73
CGO	40.68°S	Cape Grim (Aus)	0.12	-2.85
RPB	13.17°N	Ragged Pt (Barbados)	3.05	0.10
GMI	13.39°N	Guam (US)	3.23	0.40
KUM	19.52°N	Kumakahi (US)	3.66	0.69
MLO	19.54°N	Mauna Loa (US)	3.29	0.33
DSI	20.70°N	Dongsha (Taiwan)	6.28	2.69
LLN	23.47°N	Lulin (Taiwan)	3.61	0.10
MID	28.21°N	Midway (US)	3.79	0.82
IZO	28.30°N	Izana (Spain)	3.06	0.00
BMW	32.28°N	Bermuda (UK)	3.87	0.94
TAP	36.73°N	Tae-ahn (Korea)	8.58	5.58
AZR	38.77°N	Serretta (Portugal)	3.37	0.39
THD	41.05°N	Trinidad Hd (UK)	6.57	3.26
SHM	52.71°N	Shemya Is (Alaska)	4.43	1.58
MHD	53.33°N	Mace Hd (Ireland)	3.40	0.36
CBA	55.20°N	Cold Bay (US)	4.79	1.84
ICE	63.40°N	Storhofa (Iceland)	3.51	0.64
BRW	71.32°N	Barrow (Alaska)	4.68	1.71
SUM	72.58°N	Summit (Denmark)	3.89	0.51
ZEP	78.91°N	Zeppelin (Norway)	4.33	1.20
ALT	82.50°N	Alert (Canada)	4.30	1.34

Constructed using Supplementary Information S1 with annually averaged monthly data from https://gml.noaa.gov/aftp/data/greenhouse_gases/co2/flask/surface/txt/. Dr Xin Lan of NOAA provided valuable discussion on our use of these data.

S4: Definition of IH exchange indices

Obtained using NCEP reanalysis data, Kalnay et al. (1996)

Eddy exchange index: u_{duct} :

- 300mb Pressure Level u_{duct} wind (m/s),
- Latitude Range used: 5°N to 5°S,
- Longitude Range used 140°E to 170°W

Mean or Hadley Cell exchange indices: ω_{300} , v_{200} :

- 300mb Pressure Level ω_{300} (Pa/s),
- Latitude Range used: 15°N to 10°S,
- Longitude Range used: 120°E to 240°E
- 200mb Pressure Level v_{200} wind (m/s),
- Latitude Range used: 10°N to 5°S,
- Longitude Range used: 120°E to 240°E

S5: Isotopic signatures of annually averaged global data

Isotopic signatures of the interannual variation in the residuals are summarised in the Table below. Annual averages of $\delta_{\text{res.C}_{\text{res}}}$ versus C_{res} are plotted (suppressing the seasonal cycle), and the slope used to indicate the δ source of the annual variation. This is done with and without the 2010-2014 anomaly data.

At all sites the annual variation source δ is more negative than that describing the 3-decade δC versus C (which is in the range -12.9‰ to -13.3‰) but less negative than -22 to -29‰ values (Francey et al., 2023), indicating net exchange involving terrestrial carbon that has had insufficient time for full isotopic equilibration. Without the 2010-2014 data the slopes indicate marginally more negative δ values. This is interpreted as the 2010-2014 period having more equilibrated C_3 photosynthate isotope values of Fossil emissions in the NH and gross exchange, mainly with oceans, before inter-hemispheric exchange.

Isotopic characterisation of the annual variation in residuals.

		Annual residuals (‰)		without 2010-2014 (‰)	
Site	Latitude	Slope δC v C (‰)	Std. Err.	Slope δC v C (‰)	Std. Err.
SPO	90.0°S	-16.2	1.7	-16.5	2.5
MQA	54.5°S	-17.7	1.9	-19.1	2.9
CGO	40.7°S	-17.3	1.5	-20.0	2.2
CFA	19.3°S	-18.0	1.5	-19.2	2.0
MLO	19.5°N	-19.7	2.0	-20.3	2.3
ALT	82.5°N	-22.6	2.2	-23.2	2.8

Supplementary Information References:

Francey, R.J., R. L. Langenfelds, E-A. Guerrette, A. Williams, S. Chambers, L. P. Steele, C. E. Allison, P. B. Krummel Z. Loh and J. S Frederiksen. Comparison of three-decade baseline CO_2 data from Cape Grim and Mauna Loa, Baseline Atmospheric Program (Australia), (in press).

Francey, R. J., L. P. Steele, R. L. Langenfelds, C. E. Allison, L. N. Cooper, B. L. Dunse, B. G. Bell, T. D. Murray, H. S. Tait, L. Thompson and K. A. Masarie, Atmospheric carbon dioxide and its stable isotope ratios, methane, carbon monoxide, nitrous oxide and hydrogen from Shetland Isles, *Atmos. Environ.*, 32, 3331-3338, 1998.

Kalnay, E., Kanamitsu, M., Kistler, R., Collins, W., Deaven, D., Gandin, L., Iredell, M., Saha, S., White, G., Woollen, J., Zhu, Y., Leetmaa, A., Reynolds, R., Chelliah, M., Ebisuzaki, W., Higgins, W., Janowiak, J., Mo, K. C., Ropelewski, C., Wang, J., Jenne, R., and Joseph, D.: The NCEP/NCAR Reanalysis 40-year Project, *B. Am. Meteorol. Soc.*, 77, 437–471, 1996.

(data available at: <http://www.esrl.noaa.gov/psd/>, last access: 3 March 2023).