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Mismatch of glacier extent and summer insolation in Southern Hemisphere mid-latitudes

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CONSTRUCTION OF COMPOSITE CO_2 RECORD

The CO_2 record presented in Figure 3 (see text) was constructed from a composite of multiple published records from different Antarctic ice cores. Specifically, plotted are the CO_2 concentrations measured from gas bubbles trapped in the Byrd ice core from West Antarctica (Ahn and Brook, 2008; Ahn et al., 2012) and the EPICA Dome C ice core in East Antarctica (Monnin et al., 2001). For the EPICA Dome C record, we employed the most recently published gas age timescale of Parrenin et al., (2013).

SUPPLEMENTAL FIGURES AND TABLES

Supplemental diagram Fig. DR1 presents plots of individual age determination statistics for the moraine belts in the study area. Table DR1 provides sample details and ^{10}Be measurements, while Table DR2 presents ^{10}Be data for the procedural blanks. Table DR2 lists the individual age determinations.

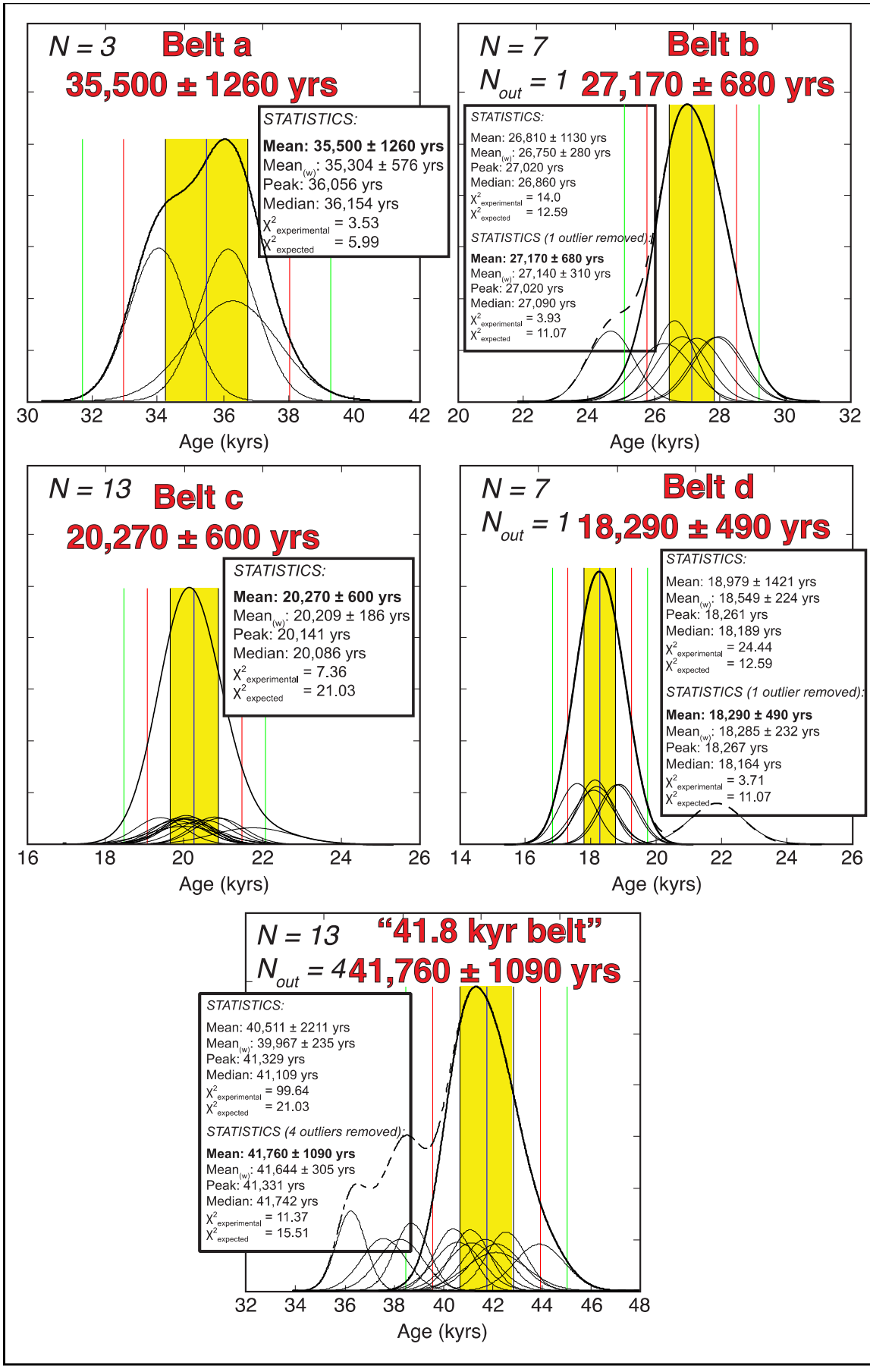
N = 3
Belt a
35,500 ± 1260 yrs
STATISTICS:
Mean: 35,500 ± 1260 yrs
Mean(w): 35,304 ± 576 yrs
Peak: 36,056 yrs
Median: 36,154 yrs
χ2 experimental = 3.53
χ2 expected = 5.99
30 32 34 36 38 40 42
Age (kyrs)
N = 7
Belt b
Nout = 1
27,170 ± 680 yrs
STATISTICS:
Mean: 26,810 ± 1130 yrs
Mean(w): 26,750 ± 280 yrs
Peak: 27,020 yrs
Median: 26,860 yrs
χ2 experimental = 14.0
χ2 expected = 12.59
STATISTICS (1 outlier removed):
Mean: 27,170 ± 680 yrs
Mean(w): 27,140 ± 310 yrs
Peak: 27,020 yrs
Median: 27,090 yrs
χ2 experimental = 3.93
χ2 expected = 11.07
20 22 24 26 28 30 32
Age (kyrs)
N = 13
Belt c
20,270 ± 600 yrs
STATISTICS:
Mean: 20,270 ± 600 yrs
Mean(w): 20,209 ± 186 yrs
Peak: 20,141 yrs
Median: 20,086 yrs
χ2 experimental = 7.36
χ2 expected = 21.03
16 18 20 22 24 26
Age (kyrs)
N = 7
Belt d
Nout = 1
18,290 ± 490 yrs
STATISTICS:
Mean: 18,979 ± 1421 yrs
Mean(w): 18,549 ± 224 yrs
Peak: 18,261 yrs
Median: 18,189 yrs
χ2 experimental = 24.44
χ2 expected = 12.59
STATISTICS (1 outlier removed):
Mean: 18,290 ± 490 yrs
Mean(w): 18,285 ± 232 yrs
Peak: 18,267 yrs
Median: 18,164 yrs
χ2 experimental = 3.71
χ2 expected = 11.07
14 16 18 20 22 24 26
Age (kyrs)
N = 13
"41.8 kyr belt"
Nout = 4
41,760 ± 1090 yrs
STATISTICS:
Mean: 40,511 ± 2211 yrs
Mean(w): 39,967 ± 235 yrs
Peak: 41,329 yrs
Median: 41,109 yrs
χ2 experimental = 99.64
χ2 expected = 21.03
STATISTICS (4 outliers removed):
Mean: 41,760 ± 1090 yrs
Mean(w): 41,644 ± 305 yrs
Peak: 41,331 yrs
Median: 41,742 yrs
χ2 experimental = 11.37
χ2 expected = 15.51
32 34 36 38 40 42 44 46 48
Age (kyrs)

Fig. DR1 (previous page) Normal kernel density functions ('camel plots') for the four moraine belts of the study area, plus another moraine (41.8 kyr belt) farther north along the Pukaki left-lateral moraines (Kelley et al., 2014). Lines depict Gaussian curves for individual samples (thin black) and the summed probabilities of all samples (dashed thick black), and with outliers excluded (the reduced data set; thick solid black). Vertical blue line is the arithmetic mean, with paired black, red, and green vertical lines denoting 1σ, 2σ, and 3σ bounds, for the reduced data set. Yellow region highlights the 1σ uncertainty range. Measurements are presented in Tables DR1 and DR2, and ages for individual samples are listed in Table DR3. Only two samples were excluded as outliers (see text).

Table DR1. Moraine surface-exposure sample details and ^{10}Be data.

CAMS laboratory no.	Sample ID	Latitude (DD)	Longitude (DD)	Elevation (m a.s.l.)	Boulder dimensions Length (cm)	Width (cm)	Height[1] (cm)	Sample Thickness (cm)	Shielding Correction	Quartz weight (g)	Carrier Added (g)[a]	^{10}Be/^{9}Be ± 1s (10^{-14})[b]	[^{10}Be] ± 1s (10^{4} atoms g^{-1})[c]	AMS Std[d]
Moraine belt a														
BE24117	MB-07-25	-44.077897	170.285198	647	160	90	58	2.07	1.000	5.0232	0.1971	9.05 ± 0.23	23.46 ± 0.61	07KNSTD$_{B4}$
BE24118	MB-07-26	-44.080554	170.280364	649	170	140	63	1.76	1.000	5.012	0.2009	9.45 ± 0.23	25.03 ± 0.62	07KNSTD$_{B4}$
BE29522	PL-09-78	-44.096400	170.289674	615	240	190	69	1.09	1.000	2.5589	0.1804	5.30 ± 0.14	24.72 ± 0.65	07KNSTD$_{B5}$
Moraine belt b														
BE21323	Kiwi-509	-44.082932	170.276422	665	350	nd	200	2.70	1.000	6.0564	0.2464	7.36 ± 0.17	20.11 ± 0.47	KNSTD
BE24110	MB-07-17	-44.080764	170.278303	665	170	145	54	1.92	1.000	3.0898	0.2030	4.24 ± 0.14	18.49 ± 0.60	07KNSTD$_{B3}$
BE24111	MB-07-19	-44.084399	170.275689	666	200	105	56	1.13	1.000	5.0247	0.2020	7.12 ± 0.20	19.00 ± 0.54	07KNSTD$_{B3}$
BE24112	MB-07-20*	-44.088766	170.276473	647	220	80	68	1.81	1.000	5.0118	0.2034	6.34 ± 0.18	17.08 ± 0.49	07KNSTD$_{B3}$
BE24107	MC-07-04	-44.068440	170.273736	689	200	180	118	3.05	1.000	5.0685	0.2022	7.52 ± 0.20	19.92 ± 0.54	07KNSTD$_{B3}$
BE24108	MC-07-05	-44.068261	170.274118	689	240	230	116	1.28	1.000	4.4393	0.2024	6.50 ± 0.18	19.66 ± 0.56	07KNSTD$_{B3}$
BE24109	MC-07-10	-44.055932	170.273471	690	500	240	245	1.65	0.998	5.0202	0.2028	7.46 ± 0.21	20.02 ± 0.55	07KNSTD$_{B3}$
Moraine belt c														
BE21324	Kiwi-513	-44.086356	170.266198	659	310	nd	230	4.90	1.000	0.8696	0.1510	1.39 ± 0.06	16.15 ± 0.74	KNSTD
BE21788	Kiwi-514	-44.086356	170.266198	659	350	nd	240	4.00	1.000	3.0492	0.1993	3.43 ± 0.11	14.98 ± 0.48	KNSTD
BE23797	Kiwi-520	-44.053600	170.257542	706	420	360	330	2.28	1.000	4.0784	0.1974	4.39 ± 0.15	14.20 ± 0.50	07KNSTD
BE24105	MB-07-23	-44.091994	170.266176	671	210	70	84	1.28	1.000	5.0224	0.2011	5.35 ± 0.17	14.01 ± 0.44	07KNSTD$_{B2}$
BE24113	MB-07-24	-44.090885	170.266651	670	240	160	110	1.95	0.999	5.0123	0.2033	5.35 ± 0.17	14.38 ± 0.47	07KNSTD$_{B3}$
BE24211	MB-07-28	-44.094322	170.253197	696	250	180	76	1.91	0.987	4.0683	0.2037	4.33 ± 0.14	14.15 ± 0.46	07KNSTD$_{B1}$
BE24212	MB-07-29	-44.092265	170.255901	696	210	190	89	1.82	0.996	5.0203	0.2036	5.22 ± 0.16	13.85 ± 0.44	07KNSTD$_{B1}$
BE24205	MB-07-34	-44.140829	170.238048	641	110	65	153	1.63	0.998	5.2388	0.2019	5.38 ± 0.15	13.75 ± 0.39	07KNSTD$_{B2}$
BE24119	MB-07-35	-44.139325	170.238420	642	280	200	170	0.88	1.000	5.0062	0.2008	5.28 ± 0.20	13.93 ± 0.53	07KNSTD$_{B4}$
BE24120	MB-07-37	-44.128343	170.240007	659	320	160	95	1.79	1.000	2.7719	0.2055	2.89 ± 0.13	13.92 ± 0.64	07KNSTD$_{B4}$
BE24099	MC-07-09	-44.048889	170.262582	737	250	240	93	1.40	0.989	5.07	0.2022	5.68 ± 0.17	14.84 ± 0.44	07KNSTD$_{B2}$
BE24100	MC-07-12	-44.063038	170.270150	702	200	170	88	1.23	0.999	4.5619	0.2016	5.20 ± 0.15	15.04 ± 0.43	07KNSTD$_{B2}$
BE24101	MC-07-15	-44.060274	170.269464	703	600	260	183	1.14	1.000	5.0316	0.2018	5.77 ± 0.17	15.17 ± 0.46	07KNSTD$_{B2}$
Moraine belt d														
BE24210	MB-07-27	-44.100514	170.246009	709	160	90	63	1.37	1.000	5.0115	0.2027	4.98 ± 0.14	13.17 ± 0.38	07KNSTD$_{B1}$
BE24121	MB-07-40	-44.137021	170.223387	648	160	100	60	1.99	1.000	5.0171	0.2027	4.69 ± 0.16	12.44 ± 0.43	07KNSTD$_{B4}$
BE24122	MB-07-41*	-44.133723	170.224243	654	330	270	184	1.95	1.000	5.0221	0.2030	5.71 ± 0.21	15.17 ± 0.57	07KNSTD$_{B4}$
BE24123	MB-07-42	-44.131335	170.225243	666	270	120	86	1.75	1.000	4.4161	0.2016	4.25 ± 0.13	12.71 ± 0.41	07KNSTD$_{B4}$
BE24102	MC-07-18	-44.074376	170.259044	692	140	130	99	2.07	0.996	5.0351	0.2023	5.08 ± 0.15	13.35 ± 0.40	07KNSTD$_{B2}$
BE24103	MC-07-19	-44.072628	170.258158	691	350	310	159	1.11	1.000	5.1651	0.2014	5.31 ± 0.16	13.54 ± 0.40	07KNSTD$_{B2}$
BE24104	MC-07-20	-44.071967	170.257979	691	280	210	86	2.82	1.000	4.7366	0.2010	4.50 ± 0.14	12.45 ± 0.39	07KNSTD$_{B2}$

Table DR1 - Notes

[a] – Carrier ^{9}Be concentration is 999 ppm for Kiwi-500-series samples, 996 ppm for MB-07 and MC-07 samples, 1024 ppm for PL-09-78.

[b] – Boron-corrected ^{10}Be/^{9}Be. Ratios are not corrected for background ^{10}Be detected in procedural blanks.

[c] – Reported [^{10}Be] values have been corrected for background ^{10}Be detected in procedural blanks.

[d] – AMS standard against which respective ratios and concentrations are measured. Reported ^{10}Be/^{9}Be ratios for 07KNSTD and KNSTD are 2.85×10^{-12} and 3.15×10^{-12}, respectively. Respective blanks are indicated in subscript and refer to the blanks given in Table DR2.

[1] – Average of four measurements from ground to sample surface at the north, south, east, and west quadrants of the boulder.

nd - no data available.

Table DR2. Procedural blank ^{10}Be data.

Blank No.	CAMS laboratory no.	Sample ID	Carrier Added (g)[a]	^{10}Be/^{9}Be ± 1s (10^{-16})[b]	N_{10Be} ± 1s (10^{3} atoms)[c]	AMS Std[d]
1	BE24213	Blank_2 7-Aug-10	0.2032	8.55 ± 3.41	11.56 ± 4.61	07KNSTD
2	BE24106	Blank_1 7-Jun-14	0.2015	9.17 ± 2.13	12.29 ± 2.86	07KNSTD
3	BE24114	Blank_1 7-Jun-28	0.2023	1.84 ± 2.25	2.48 ± 3.03	07KNSTD
4	BE24124	Blank_1 7-Jul-13	0.1995	6.93 ± 2.39	9.21 ± 3.17	07KNSTD
5	BE29513	Blank_1 10-Apr-29	0.1822	17.33 ± 2.35	21.61 ± 2.93	07KNSTD

[a] – Carrier ^{9}Be concentration is 996 ppm for all blanks except for Blank No. 5, for which carrier ^{9}Be concentration is 1024 ppm.

[b] – Boron-corrected ^{10}Be/^{9}Be.

[c] – Total ^{10}Be (in atoms) in each procedural blank.

[d] – AMS standard against which respective ratios and concentrations are measured. Reported ^{10}Be/^{9}Be ratio is 2.85×10^{-12}.

Table DR3. ^{10}Be surface-exposure ages for moraines southeast of Lake Pukaki. Scaling schemes St and Lm follow Balco et al. (2008).

Moraine belt	Sample ID	St Age (yrs) ± 1σ	Lm Age (yrs) ± 1σ
a	MB-07-25	34,540 ± 910	34,040 ± 900
a	MB-07-26	36,720 ± 920	36,150 ± 900
a	PL-09-78	36,840 ± 1390	36,300 ± 1370
	Arithmetic Mean Age (± 1σ):	**36,030 ± 1300**	**35,500 ± 1260**
b	Kiwi-509	26,970 ± 630	26,630 ± 620
b	MB-07-17	26,720 ± 870	26,310 ± 860
b	MB-07-19	27,280 ± 790	26,860 ± 770
b	MB-07-20*	25,010 ± 720	24,680 ± 710
b	MC-07-04	28,450 ± 780	27,980 ± 770
b	MC-07-05	27,750 ± 800	27,310 ± 790
b	MC-07-10	28,360 ± 790	27,900 ± 780
	Arithmetic Mean Age - all samples (± 1σ):	27,220 ± 1180	26,810 ± 1130
	Arithmetic Mean Age - outlier excluded (± 1σ):	**27,590 ± 720**	**27,170 ± 680**
c	Kiwi-513	21,940 ± 1010	21,750 ± 1000
c	Kiwi-514	20,210 ± 650	20,090 ± 650
c	Kiwi-520	19,940 ± 710	19,810 ± 700
c	MB-07-23	20,010 ± 640	19,880 ± 630
c	MB-07-24	20,670 ± 680	20,510 ± 680
c	MB-07-28	20,130 ± 650	19,990 ± 650
c	MB-07-29	19,520 ± 620	19,410 ± 620
c	MB-07-34	20,190 ± 580	20,060 ± 570
c	MB-07-35	20,310 ± 780	20,170 ± 770
c	MB-07-37	20,130 ± 930	20,000 ± 920
c	MC-07-09	20,310 ± 610	20,150 ± 610
c	MC-07-12	20,960 ± 610	20,780 ± 610
c	MC-07-15	21,090 ± 640	20,910 ± 640
	Arithmetic Mean Age (± 1σ):	**20,420 ± 620**	**20,270 ± 600**
d	MB-07-27	18,220 ± 530	18,140 ± 530
d	MB-07-40	18,170 ± 630	18,100 ± 630
d	MB-07-41*	22,070 ± 830	21,860 ± 820
d	MB-07-42	18,260 ± 590	18,190 ± 590
d	MC-07-18	18,910 ± 570	18,810 ± 570
d	MC-07-19	18,990 ± 570	18,890 ± 570
d	MC-07-20	17,660 ± 560	17,590 ± 560
	Arithmetic Mean Age - all samples (± 1σ):	18,900 ± 1470	18,800 ± 1420
	Arithmetic Mean Age - outlier excluded (± 1σ):	**18,370 ± 500**	**18,290 ± 490**

* - Outlier. Outliers are defined as ages that are morphostratigraphically discordant.

Note: All ages are calculated using the P_{NZ2} production rates of Putnam et al. (2010), and are referenced to the year AD1950 by subtracting 52, 57, and 59 yrs from samples collected in AD2002, AD2007, and AD2009, respectively. Reported errors reflect 1s analytical uncertainties only.

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