



Supplement of

Chronostratigraphy of the Larsen blue-ice area in northern Victoria Land, East Antarctica, and its implications for paleoclimate

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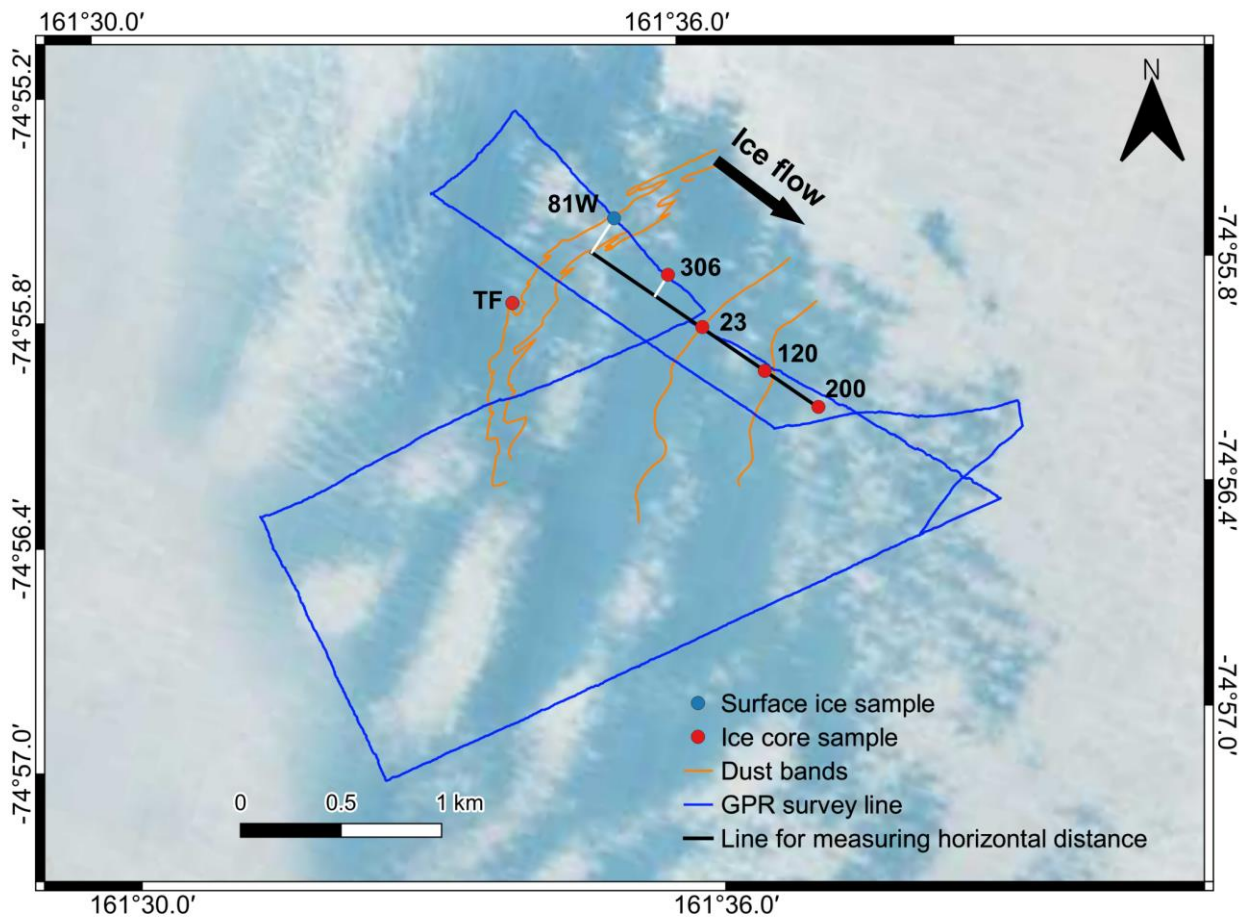


Figure S1. Map of Larsen BIA. Locations of representative ice samples (red and blue dots), GPR survey line (blue line), and dust bands (orange line) are shown on the map. The horizontal distance between the ice samples was measured by drawing a perpendicular line (white line) to an imaginary line (black line), which is parallel to the ice flow direction. Satellite photo of Antarctica is from the QGIS Quantarctica package (Bindschadler et al., 2008).

Sect. S1

1 Age uncertainty

1.1 Gas age uncertainty

There are two types of uncertainty to consider: (1) the relative Larsen gas age uncertainties to the WAIS Divide (WD) gas age, and (2) the absolute WD gas age uncertainty itself. To assess the relative Larsen gas age uncertainty to WD gas age, we applied a Monte Carlo simulation running the model 10,000 times. The model is described in detail in the following paragraph.

First, to assign relative Larsen gas age uncertainties of the points that were pin-pointed to WD (pink and purple dots in Fig. 7a, b), analytical uncertainty should be defined. The analytical uncertainty of $\delta^{18}\text{O}_{\text{atm}}$ from Larsen is assumed to be $\pm 0.05\%$, as discussed in Sect. 3.3.2. The analytical uncertainty of $\delta^{18}\text{O}_{\text{atm}}$ from WD was $\pm 0.006\%$ (Severinghaus et al., 2015). Because the analytical uncertainty of $\delta^{18}\text{O}_{\text{atm}}$ from WD is about one order of magnitude lower than Larsen's uncertainty, we assume the total analytical uncertainty to be $\pm 0.05\%$. Then, the gas age for the pink dots (Fig. 7a, b) was assigned 10,000 times using a Monte Carlo simulation considering the analytical uncertainty. The standard deviation of the assigned ages were used for the relative gas age uncertainty.

The relative Larsen gas age uncertainty estimation process for the older tie-points (purple dots in Fig. 7a, b) is more complicated. We repeatedly produced the spline curve 10000 times using the Monte Carlo approach and found the location (horizontal distance) of the local maximum and local minima. The simulation results were rejected when there was no or only one local minimum. This Monte Carlo result and its uncertainties were used to detect outliers ($> 2\sigma$). The process was iterated until no outliers were detected. Using the location (horizontal distance) uncertainty of the local maximum and local minima, we then estimated the relative Larsen gas age uncertainty to WD gas age by assigning the age 10,000 times using a Monte Carlo simulation.

The absolute WD gas age uncertainty itself should also be considered (Sigl et al., 2019). Because the relative Larsen gas age uncertainty to WD gas age and the absolute WD gas age uncertainty are independent, the total Larsen gas age uncertainty can be calculated using Eq. (S1):

$$\sigma_{\text{total}} = \sqrt{\sigma_{\text{abs.}}^2 + \sigma_{\text{rel.}}^2} \quad (\text{S1})$$

The uncertainties (1σ) are presented in Table S1. The gas age uncertainty between the tie-points was determined by linear interpolation, and the uncertainty located outside the last tie-point was linearly extrapolated using the uncertainty/age relationship of 18–22 ka BP.

Table S1. Result of gas age uncertainties. $\sigma_{\text{rel.}}$, $\sigma_{\text{abs.}}$, and σ_{total} represent relative Larsen gas age uncertainty to WD gas age, absolute WD gas age uncertainty, and total uncertainty of Larsen gas age, respectively.

Gas age (ka)	$\sigma_{\text{rel.}}$ (ka)	$\sigma_{\text{abs.}}$ (ka)	σ_{total} (ka)
--------------	-----------------------------	-----------------------------	------------------------------

9.24	0.324	0.055	0.329
10.74	0.130	0.062	0.144
13.02	0.274	0.117	0.298
15.17	0.084	0.158	0.179
18.05	0.194	0.214	0.289
22.04	0.254	0.257	0.361

35 1.2 Ice age uncertainty

Similar to the Larsen gas age uncertainty, the Larsen ice age uncertainty consists of (1) the relative Larsen ice age uncertainty to TALDICE ice age, and (2) the absolute TALDICE ice age uncertainty itself. The total analytical uncertainty of $\delta^{18}\text{O}_{\text{ice}}$ is assumed to be $\pm 0.6\%$, the same as the $\delta^{18}\text{O}_{\text{ice}}$ uncertainty of Larsen ice (Sect. 3.2) because the analytical uncertainty of $\delta^{18}\text{O}_{\text{ice}}$ for TALDICE ($\pm 0.07\%$) is negligible (Stenni et al., 2011). The method to constrain the relative Larsen ice age uncertainty to the TALDICE ice age is similar to the case of estimating the gas age uncertainty of the older tie-points (purple dots in Fig. 7a, b). In contrast, in this case, we found the location (horizontal distance) of the inflection points, not the local maxima or minima. The relative uncertainty can also be derived from when choosing the tie-points in TALDICE. In addition, the ice age uncertainty for a depth of 1.95 m should be larger than the uncertainty we provide because it was estimated using the average dip of the ice layer. Therefore, the relative Larsen ice age uncertainty provided here is a lower limit.

45 The absolute TALDICE ice age uncertainty itself should also be considered, where the uncertainty is calculated by quadratically combining the absolute WD ice age uncertainty and the volcanic synchronization uncertainty (relative TALDICE ice age uncertainty to the WD ice age). Then, quadratically combining the absolute TALDICE ice age uncertainty and the relative Larsen ice age uncertainty to the TALDICE ice age (Eq. (S1)) provides the total Larsen ice age uncertainty (1σ) (Table S2). The ice age uncertainty between the tie-points was determined by linear interpolation, and the uncertainty located outside 50 the last tie-point was linearly extrapolated using the uncertainty/age relationship of 18–23.8 ka BP.

Table S2. Result of ice age uncertainties. $\sigma_{\text{rel.}}$, $\sigma_{\text{abs.}}$, and σ_{total} represent relative Larsen ice age uncertainty to TALDICE ice age, absolute TALDICE ice age uncertainty, and total uncertainty of Larsen ice age, respectively.

Ice age (ka)	$\sigma_{\text{rel.}}$ (ka)	$\sigma_{\text{abs.}}$ (ka)	σ_{total} (ka)
6.73	0.023	0.030	0.038
8.51	0.014	0.040	0.043
12.12	0.044	0.084	0.095
14.12	0.023	0.135	0.137
14.67	0.041	0.147	0.152
21.14	0.053	0.211	0.218

1.3 Δ age uncertainty

To estimate the Larsen Δ age uncertainty, the relative Larsen gas age uncertainty and relative Larsen ice age uncertainty should be on the same ice core. Here, we used the relative Larsen gas age and ice age uncertainties to the WD gas age and ice age, respectively. We assumed that the Larsen Δ age uncertainty consists of (1) the relative Larsen gas age uncertainty to WD gas age (see Sect. 1.1), (2) the relative Larsen ice age uncertainty to WD ice age, and (3) the Δ age uncertainty of WD (Sigl et al., 2019). Quadratically combining these three components provides the total Larsen Δ age uncertainty, similar to Eq. (S1). The relative Larsen ice age uncertainty to TALDICE ice age and the relative TALDICE ice age uncertainty to WD ice age were quadratically combined to estimate the relative Larsen ice age uncertainty to WD ice age (2). Volcanic synchronization uncertainty is used for the relative TALDICE ice age uncertainty to the WD ice age. The Larsen Δ age uncertainty (1σ) is presented in Table S3.

Table S3. Δ age and the uncertainty.

Core number	Horizontal distance (m)	Gas age (yr BP, WD2014)	Δ age (yr)	Δ age uncertainty (yr)
306	378.77	9237	274	326
305	411.00	9561	327	284
303	467.16	10125	419	213
302	495.81	10412	467	177
300	557.12	11174	421	163
9	573.62	11425	451	178
98	614.57	12048	526	217
23	663.09	12785	615	261
100	695.43	13294	861	252
101	715.00	13551	910	230
103	752.92	13993	897	193
104	779.27	14414	1032	157
105	797.29	14697	1129	134
106	815.72	14986	1155	110
108	857.49	15563	1292	111
109	879.39	15850	1380	121
110	894.80	16052	1442	129
111	918.71	16365	1538	141
112	935.91	16590	1607	149
114	981.22	17184	1788	173

115	1002.67	17465	1874	184
116	1022.44	17724	1953	194
117	1042.56	17988	2000	205
119	1083.62	18670	1952	218
120	1102.39	18990	1951	223
121	1120.63	19301	1950	228
122	1141.29	19653	1946	232
124	1181.95	20346	1892	242
125	1200.40	20661	1867	247
207	1219.27	20982	1843	252
206	1240.66	21347	1814	258
205	1261.12	21696	1788	263
202	1323.25	22750	1725	278
200	1363.86	23439	1692	288

65 **Table S4. Gas isotope ratios and greenhouse gas concentrations at a depth of 1.95 m in the Larsen BIA.** $\delta^{18}\text{O}_{\text{atm}}$, $\delta\text{O}_2/\text{N}_2$ and $\delta\text{Ar}/\text{N}_2$ are gravity corrected. CH_4 , CO_2 and N_2O are not gravity corrected. NA = Not Available.

Core number	Horizontal distance (m)	Gas age (yr BP, AICC2012)	Gas age (yr BP, WD2014)	$\delta^{15}\text{N}-\text{N}_2$ (‰)	$\delta^{18}\text{O}_{\text{atm}}$ (‰)	$\delta\text{O}_2/\text{N}_2$ (‰)	$\delta\text{Ar}/\text{N}_2$ (‰)	CH_4 (ppb)	CO_2 (ppm)	N_2O (ppb)
306	378.77	9441	9237	0.194	-0.075	-2.793	-0.373	767.7	293.3	282.5
305	411.00	9569	9561	0.224	0.053	-10.880	-4.337	785.7	301.0	273.4
303	467.16	10239	10125	0.305	0.242	-6.356	-2.838	771.3	310.7	279.7
302	495.81	10580	10412	0.307	0.260	-3.557	-1.517	757.7	309.8	277.6
301	527.89	10988	10811	0.320	0.453	-31.774	-15.280	740.1	303.3	272.7
300	557.12	11359	11174	0.243	0.443	-6.380	-3.042	716.1	305.7	275.3
9	573.62	11535	11425	0.264	0.564	-16.668	-8.325	676.4	286.6	273.4
98	614.57	12185	12048	0.288	0.668	-13.158	-5.474	540.8	295.9	261.5
23	663.09	12850	12785	0.423	0.741	-6.268	-3.636	748.4	309.9	278.9
100	695.43	13576	13294	0.445	0.769	-5.752	-2.420	677.1	266.9	282.9
101	715.00	13714	13551	0.406	0.807	-8.249	-3.113	588.8	267.7	274.7
103	752.92	14214	13993	0.282	1.014	-15.452	-5.500	748.4	268.2	269.0
104	779.27	14533	14414	0.365	1.054	-6.370	-2.957	1185.2	314.9	278.0
105	797.29	14754	14697	0.316	0.988	-13.788	-4.587	778.3	274.0	239.9
106	815.72	15068	14986	0.370	1.126	-23.224	-11.120	669.0	273.6	225.5
108	857.49	15816	15563	0.403	1.051	-18.432	-8.732	584.3	279.0	221.2
109	879.39	15975	15850	0.364	1.004	-10.485	-3.366	730.6	290.5	226.2
110	894.8	16087	16052	0.410	1.052	-0.642	0.122	571.5	268.1	214.9
111	918.71	16433	16365	0.416	1.070	-6.541	-4.175	671.8	290.6	230.6
112	935.91	16861	16590	0.403	1.040	-4.301	-2.079	583.6	263.0	214.5
114	981.22	17326	17184	0.393	1.033	-3.888	-1.797	779.0	263.6	216.1
115	1002.67	17598	17465	0.353	0.965	-7.884	-3.071	798.9	283.1	235.9

116	1022.44	18190	17724	0.361	0.949	-13.753	-6.743	859.2	269.6	222.9
117	1042.56	18476	17988	0.409	0.954	-1.397	-1.158	797.2	250.3	219.7
119	1083.62	19294	18670	0.368	0.971	-6.792	-5.241	503.4	214.4	236.8
120	1102.39	19564	18990	0.315	1.005	-23.341	-10.666	534.7	217.1	243.1
121	1120.63	19809	19301	0.338	0.924	-9.681	-4.745	509.8	211.7	250.8
122	1141.29	20057	19653	0.286	0.944	-4.697	-2.821	522.3	213.0	277.0
124	1181.95	20790	20346	0.403	0.909	2.806	-0.153	538.2	NA	NA
125	1200.40	21337	20661	0.383	0.927	-14.874	-6.969	509.9	216.3	247.7
207	1219.27	21586	20982	0.391	0.942	-10.068	-5.146	495.2	217.9	246.3
206	1240.66	21793	21347	0.379	0.902	-8.148	-4.949	537.1	217.3	249.8
205	1261.12	22072	21696	0.362	0.858	-4.888	-2.992	472.6	213.5	241.3
202	1323.25	22895	22750	0.367	0.905	-7.014	-3.050	539.9	215.3	253.8
200	1363.86	23390	23439	0.379	0.877	-12.966	-9.195	487.2	248.5	231.1

Table S5. Gas isotope ratios and greenhouse gas concentrations for ice core #23 in Larsen BIA. $\delta^{18}\text{O}_{\text{atm}}$, $\delta\text{O}_2/\text{N}_2$ and $\delta\text{Ar}/\text{N}_2$ are gravity corrected. CH_4 , CO_2 and N_2O are not gravity corrected.

Depth (cm)	Gas age (yr BP, AICC2012)	Gas age (yr BP, WD2014)	$\delta^{15}\text{N}-\text{N}_2$ (‰)	$\delta^{18}\text{O}_{\text{atm}}$ (‰)	$\delta\text{O}_2/\text{N}_2$ (‰)	$\delta\text{Ar}/\text{N}_2$ (‰)	CH_4 (ppb, NIPR)	CH_4 (ppb, SNU)	CO_2 (ppm)	N_2O (ppb)
15	12565	12470						537.7		
25	12579	12487						631.4		
35	12595	12505						707.7		
45	12611	12522	0.327	0.609	-9.067	-3.545	801.9	940.1	339.0	282.3
55	12627	12540						719.8		
65	12643	12557						680.8		
75	12659	12575						691.1		
85	12674	12592						634.8		
95	12688	12610	0.39	0.721	-5.661	-1.575	672.2	707.6	354.2	277.8
105	12702	12627						645.2		
115	12717	12645						787.4		
125	12731	12662						679.8		
135	12748	12680						827.6		
145	12765	12697						875.0		
155	12783	12715	0.386	0.773	-16.407	-6.893	859.2	807.2	316.4	292.8
165	12799	12732						724.5		
175	12816	12750						714.0		
185	12832	12767						716.3		
195	12850	12785	0.423	0.741	-6.268	-3.636	748.4	708.1	309.9	278.9
205	12867	12802						763.4		
215	12884	12820						727.7		
225	12901	12837						719.4		
235	12919	12855	0.415	0.709	-7.73	-3.459	745.5	782.1	284.5	268.5
245	12938	12873						841.6		
255										

265	12978	12908							736.1		
275	12998	12925							778.8		
285	13018	12943							741.2		
295	13048	12960	0.433	0.792	-6.721	-2.463	690.9		720.2	272.7	267.7
305	13082	12978							694.7		
315	13115	12995							753.7		
325	13148	13013							735.3		
335	13178	13030							750.8		
345	13208	13046							706.6		
355	13238	13063							715.6		
365	13268	13080							698.1		
375	13298	13096							704.5		
385	13327	13113							753.7		
395	13357	13130	0.437	0.759	-2.119	0.065	687.5		694.0	267.4	267.5
405	13387	13146							676.9		
415	13413	13163							679.3		
425	13439	13179							773.5		
435	13466	13196							720.1		
445	13493	13213							692.6		
455	13520	13229							677.8		
465	13566	13278							656.2		
475	13576	13293							673.4		
485	13585	13308							673.9		
495	13594	13323							668.2		
505	13602	13338							661.3		
515	13611	13354							660.3		
525	13619	13369							663.6		
535	13627	13384							675.6		
545	13635	13399	0.476	0.778	-6.777	-2.612	644.5		657.4	249.4	271.5
555	13643	13414							658.0		
565	13651	13429							655.1		
575	13659	13444							654.7		
585	13667	13459							652.5		
595	13675	13474							643.4		
605	13682	13490							638.2		
615	13690	13505							639.6		
625	13698	13520							631.4		
635	13706	13535							626.8		
645	13713	13550							605.9		
655	13720	13562							621.2		
665	13727	13574							609.1		
675	13738	13586							627.9		
685	13748	13599							634.7		
695	13759	13611	0.36	0.838	-17.349	-7.488	624.7		633.7	248.4	263.5
705	13770	13623							621.6		

715	13781	13635							642.3		
725	13792	13647							661.0		
735	13803	13659							659.5		
745	13814	13671							669.2		
755	13827	13684							682.0		
765	13842	13696							676.0		
775	13858	13708							678.3		
785	13873	13720							671.4		
795	13888	13732							683.6		
805	13904	13744							679.1		
815	13919	13757							704.2		
825	13934	13769							669.1		
835	13951	13781							672.5		
845	13967	13793							658.6		
855	13983	13805							660.1		
865	14000	13817							656.6		
875	14016	13829							675.4		
885	14032	13842							666.4		
895	14048	13854	0.29	0.921	-5.297	-2.17	657.3	663.2	252.1	262.4	
905	14064	13866							672.6		
915	14081	13878							676.9		
925	14107	13897							650.7		
935	14132	13917							657.6		
945	14158	13936							642.6		
955	14185	13955							632.7		
965	14201	13975							615.0		
975	14214	13994							594.6		
985	14228	14013							604.3		
995	14241	14033	0.322	1.004	-5.658	-2.747	599.9	608.2	252.4	261.0	
1005	14251	14052							641.5		
1015	14251	14071							636.8		
1025	14251	14091							642.6		
1035	14251	14110							621.8		

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Table S6. CO₂ concentrations of ice core #23 analysed at SNU. The results are not gravity corrected.

Depth (cm)	CO ₂ (ppm, SNU)
17.5	344.6
27.5	325.5
37.5	332.7
47.5	340.1
57.5	314.2

67.5	346.2
77.5	341.2
87.5	342.9
97.5	327.0
107.5	300.8
117.5	305.9
127.5	316.7
137.5	323.9
147.5	342.1
157.5	297.7
167.5	293.5
177.5	295.2
187.5	292.0
197.5	299.0
207.5	300.8
217.5	284.5
227.5	287.1
237.5	272.4
247.5	287.9
267.5	278.2
277.5	282.3
287.5	282.7
297.5	273.7
307.5	267.2
317.5	261.0
327.5	263.6
337.5	268.4
347.5	260.7
357.5	271.2
367.5	268.4
377.5	265.5
387.5	261.7
397.5	260.2

407.5	266.0
417.5	258.3
427.5	256.8
437.5	258.8
447.5	254.7
457.5	250.1
467.5	249.8
477.5	253.3
487.5	246.8
497.5	245.9
507.5	248.5
517.5	249.3
527.5	246.9
537.5	254.4
547.5	251.3
556.5	250.1
567.5	246.1
577.5	247.8
587.5	249.8
597.5	248.7
607.5	251.3
617.5	259.0
627.5	250.3
637.5	247.9
647.5	248.1
657.5	245.0
667.5	247.7
677.5	250.6
687.5	245.2
697.5	244.6
707.5	244.5
717.5	248.1
727.5	259.9

737.5	257.4
747.5	250.8
757.5	246.1
767.5	241.0
777.5	250.8
787.5	246.5
797.5	262.9
807.5	252.3
817.5	250.3
827.5	254.3
837.5	253.9
847.5	249.2
857.5	249.4
867.5	256.6
877.5	256.3
887.5	254.3
897.5	251.7
907.5	253.6
917.5	250.4
927.5	259.1
937.5	257.2
947.5	256.3
957.5	254.8
967.5	252.6
977.5	252.9
987.5	252.5
997.5	256.6
1007.5	253.5
1017.5	245.7
1027.5	253.4
1037.5	257.5

Table S7. CO₂ results of horizontal measurement at SNU using a dry extraction method. The results are not gravity corrected. For the measurement, ice from the depth of 190–195 cm was used.

Core number	CO ₂ (ppm)
306	288.4
305	278.8
303	312.2
302	312.8
301	300.1
300	284.8
9	284.4
98	300.4
23	289.0
100	263.9
101	266.5
103	260.0
104	281.6
105	251.0
106	256.1
108	259.0
109	273.0
110	259.2
111	257.2
112	265.1
114	269.5
115	279.6
116	249.6
117	243.4
119	209.8
120	211.5
121	200.4
122	217.1
124	212.9
125	215.8
207	203.2
206	214.3
205	209.8

202	213.4
200	217.9

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Table S8. Stable water isotope results from ice near surface. Sample name with “W” is the surface ice samples, which are collected at depth of ~5–10 cm. Sample name without “W” is the sample from ice cores; ice from the depth of 20 cm is used.

Surface ice and core number	Horizontal distance (m)	Ice age (yr BP, AICC2012)	Ice age (yr BP, WD2014)	$\delta^{18}\text{O}_{\text{ice}}$ (‰)	$\delta^2\text{H}_{\text{ice}}$ (‰)	d-excess (‰)
81W	0.00	5631	5608	-31.25	-244.60	5.40
80W	7.30	5706	5682	-30.98	-239.40	8.44
79W	17.67	5819	5788	-34.72	-272.30	5.46
78W	28.74	5939	5900	-33.02	-259.10	5.06
77W	41.55	6055	6032	-33.68	-266.90	2.54
76W	51.60	6155	6134	-33.53	-264.40	3.84
75W	67.33	6307	6294	-34.41	-273.30	1.98
74W	93.74	6574	6564	-33.38	-262.90	4.14
73W	106.82	6705	6697	-35.75	-282.80	3.20
72W	122.31	6867	6855	-37.37	-295.66	3.30
71W	142.26	7038	7025	-35.02	-273.86	6.30
70W	166.07	7244	7228	-40.27	-319.93	2.23
69W	186.50	7420	7401	-35.09	-289.41	-8.69
68W	207.56	7594	7581	-39.09	-310.09	2.63
67W	230.11	7792	7773	-36.05	-286.58	1.82
66W	249.63	7966	7939	-36.66	-290.60	2.68
65W	268.46	8133	8099	-37.59	-299.15	1.57
64W	289.96	8316	8282	-36.99	-291.88	4.04
63W	306.76	8460	8425	-38.48	-304.43	3.41
62W	327.70	8668	8636	-33.91	-269.63	1.65
61W	346.18	8888	8852	-35.08	-277.94	2.70
60W	368.26	9154	9110	-34.61	-274.32	2.56
306	378.77	9284	9233	-37.37	-298.17	0.79
59W	387.15	9386	9331	-38.86	-307.72	3.16
58W	405.33	9605	9544	-36.55	-291.82	0.58
305	411.00	9672	9610	-37.66	-301.19	0.09

57W	425.54	9842	9780	-39.49	-313.81	2.11
304	437.65	9984	9921	-38.09	-304.52	0.20
56W	446.53	10087	10025	-37.08	-294.57	2.07
303	467.16	10337	10266	-36.10	-289.17	-0.37
55W	478.47	10471	10398	-39.14	-308.81	4.31
302	495.81	10667	10601	-39.68	-318.47	-1.03
54W	498.00	10694	10626	-38.82	-307.05	3.51
53W	518.03	10941	10860	-35.83	-283.80	2.84
301	527.89	11057	10976	-38.84	-310.82	-0.10
52W	538.29	11180	11097	-36.20	-287.00	2.60
51W	556.13	11400	11306	-35.16	-278.74	2.54
300	557.12	11412	11317	-35.09	-280.80	-0.08
1W	573.62	11621	11510	-37.13	-294.90	2.14
9W	584.70	11760	11640	-36.60	-291.65	1.15
20W	604.26	12006	11868	-37.62	-300.50	0.46
21W	624.47	12260	12104	-39.26	-312.55	1.53
99	633.80	12499	12321	-41.02	-328.30	-0.14
22W	644.54	12785	12595	-41.49	-328.49	3.43
23W	661.00	13210	13015	-44.45	-355.33	0.27
23	663.09	13264	13068	-42.75	-342.69	-0.69
24W	684.07	13824	13603	-41.70	-333.23	0.37
100	695.43	14124	13893	-43.08	-345.48	-0.84
25W	703.79	14354	14106	-40.43	-321.65	1.79
101	715.00	14478	14223	-38.86	-310.92	-0.04
26W	723.30	14562	14304	-37.14	-296.40	0.72
102	729.98	14629	14368	-38.87	-311.28	-0.32
27W	745.60	14792	14519	-36.13	-288.42	0.62
103	752.92	14866	14590	-40.29	-323.20	-0.88
28W	764.49	15019	14729	-40.35	-321.13	1.67
104	779.27	15298	14982	-38.80	-312.96	-2.56
29W	785.15	15411	15082	-40.81	-326.37	0.11
105	797.29	15625	15290	-40.41	-325.45	-2.17
30W	806.61	15786	15450	-40.25	-322.12	-0.12

106	815.72	15936	15605	-39.18	-315.25	-1.81
31W	825.10	16086	15766	-41.02	-328.15	0.01
107	836.67	16272	15964	-40.91	-329.30	-2.02
32W	846.48	16427	16132	-40.52	-323.73	0.43
108	857.49	16588	16320	-41.52	-334.00	-1.84
33W	866.76	16721	16478	-40.78	-325.74	0.50
109	879.39	16903	16695	-40.45	-325.53	-1.93
34W	888.00	17026	16842	-41.18	-329.09	0.35
110	894.80	17125	16958	-40.61	-327.29	-2.41
35W	909.18	17332	17204	-41.03	-328.87	-0.63
111	918.71	17469	17367	-40.75	-328.81	-2.81
36W	928.74	17614	17539	-41.63	-333.48	-0.44
112	935.91	17713	17661	-40.05	-322.77	-2.37
37W	948.00	17892	17868	-40.66	-325.47	-0.19
113	960.85	18082	18088	-42.43	-343.63	-4.19
38W	969.41	18209	18234	-42.40	-339.84	-0.64
114	981.22	18384	18436	-42.00	-339.84	-3.84
39W	990.17	18523	18590	-43.37	-347.85	-0.89
115	1002.67	18715	18803	-43.29	-350.42	-4.10
40W	1010.13	18827	18931	-43.02	-344.43	-0.27
116	1022.44	19007	19142	-43.39	-350.76	-3.64
41W	1029.57	19112	19263	-42.46	-341.39	-1.71
117	1042.56	19298	19486	-43.92	-355.62	-4.26
42W	1050.15	19405	19616	-45.28	-364.57	-2.33
118	1060.80	19550	19798	-44.57	-361.61	-5.05
43W	1071.24	19693	19976	-44.26	-355.93	-1.85
119	1083.62	19877	20188	-45.26	-366.55	-4.47
44W	1091.17	19995	20317	-43.32	-348.81	-2.25
120	1102.39	20169	20509	-43.93	-356.82	-5.38
45W	1111.95	20329	20673	-44.47	-357.51	-1.75
121	1120.63	20470	20821	-44.66	-361.97	-4.69
46W	1133.72	20696	21045	-44.30	-357.08	-2.68
122	1141.29	20826	21172	-45.49	-369.26	-5.34

47W	1153.30	21021	21360	-46.23	-371.87	-2.03
123	1162.13	21165	21499	-46.30	-374.83	-4.43
48W	1176.66	21418	21727	-46.63	-375.53	-2.49
124	1181.95	21513	21810	-45.37	-367.45	-4.49
49W	1195.69	21758	22025	-45.82	-367.80	-1.24
125	1200.40	21841	22099	-46.09	-372.64	-3.92
207	1219.27	22178	22395	-45.62	-367.52	-2.56
206	1240.66	22559	22731	-45.39	-367.65	-4.53
205	1261.12	22924	23052	-44.91	-363.52	-4.24
204	1281.89	23294	23378	-44.79	-362.54	-4.22
203	1302.52	23664	23701	-44.42	-358.95	-3.59
202	1323.25	24044	24037	-46.57	-374.88	-2.32
201	1343.56	24413	24367	-45.49	-366.71	-2.79
200	1363.86	24763	24696	-45.68	-369.33	-3.89

80 **Table S9. Stable water isotope results for ice core #23.**

Depth (cm)	Ice age (yr BP, AICC2012)	Ice age (yr BP, WD2014)	$\delta^{18}\text{O}_{\text{ice}}$ (‰)	$\delta^2\text{H}_{\text{ice}}$ (‰)	d-excess (‰)
20	13264	13068	-43.11	-343.35	1.53
40	13323	13127	-41.99	-333.65	2.27
60	13382	13185	-42.21	-335.07	2.61
80	13443	13243	-42.71	-340.45	1.23
100	13504	13302	-41.53	-330.80	1.44
120	13564	13360	-44.31	-353.13	1.35
140	13624	13418	-41.86	-333.05	1.83
160	13686	13477	-42.11	-334.98	1.90
180	13749	13535	-42.46	-337.40	2.28
200	13814	13594	-43.20	-343.65	1.95
220	13871	13652	-41.84	-332.76	1.96
240	13929	13710	-42.01	-334.70	1.38
260	13995	13769	-42.37	-338.12	0.84
280	14055	13827	-42.76	-340.90	1.18

300	14116	13886	-42.59	-339.16	1.56
320	14179	13944	-42.31	-336.71	1.77
340	14242	14002	-40.83	-325.98	0.66
360	14305	14061	-41.76	-331.42	2.66
380	14359	14112	-41.14	-327.94	1.18
400	14385	14135	-41.61	-331.05	1.83
420	14411	14159	-40.15	-319.31	1.89
440	14436	14183	-40.79	-324.81	1.51
460	14461	14207	-40.10	-319.61	1.19
480	14486	14231	-38.88	-309.62	1.42
500	14510	14253	-37.85	-301.67	1.13
520	14533	14275	-36.78	-293.20	1.04
540	14555	14297	-37.44	-298.78	0.74
560	14578	14319	-37.64	-300.60	0.52
580	14600	14341	-37.96	-302.78	0.90
600	14623	14363	-39.47	-314.93	0.83
620	14647	14386	-38.70	-308.72	0.88
640	14672	14408	-38.37	-306.84	0.12
660	14696	14430	-37.87	-302.48	0.48
680	14721	14452	-36.47	-291.05	0.71
700	14745	14474	-36.33	-290.77	-0.13
720	14768	14496	-37.57	-300.33	0.23
740	14791	14518	-39.10	-312.76	0.04
760	14814	14540	-39.16	-312.46	0.82
780	14837	14563	-39.66	-316.51	0.77
800	14861	14585	-40.64	-324.28	0.84
820	14889	14611	-40.43	-322.58	0.86
840	14920	14638	-41.65	-332.37	0.83
860	14950	14666	-40.08	-319.07	1.57
880	14980	14693	-40.62	-325.04	-0.08
900	15011	14721	-41.07	-328.47	0.09
920	15050	14757	-39.77	-317.57	0.59
940	15093	14796	-40.58	-324.67	-0.03

960	15136	14835	-40.80	-326.04	0.36
980	15179	14874	-39.95	-319.04	0.56
1000	15221	14913	-40.21	-321.83	-0.15
1020	15266	14953	-40.57	-325.75	-1.19
1035	15298	14982	-39.36	-315.88	-1.00

Table S10. Stable water isotope results of ice at a depth of 1.95 m.

Core number	Horizontal distance (m)	Ice age (yr BP, AICC2012)	Ice age (yr BP, WD2014)	$\delta^{18}\text{O}_{\text{ice}}$ (‰)	$\delta^2\text{H}_{\text{ice}}$ (‰)	d-excess (‰)
306	378.77	9571	9511	-36.96	-294.15	1.53
305	411.00	9951	9888	-37.91	-301.60	1.68
304	437.65	10265	10199	-39.11	-310.45	2.43
303	467.16	10612	10544	-38.22	-303.76	2.00
302	495.81	10960	10879	-39.64	-315.29	1.83
301	527.89	11345	11253	-37.92	-301.06	2.30
300	557.12	11713	11595	-36.51	-288.81	3.27
9	573.62	12014	11876	-36.54	-291.57	0.75
98	614.57	12764	12574	-42.87	-342.69	0.27
99	633.80	13089	12901	-43.53	-347.73	0.51
23	663.09	13605	13400	-43.58	-346.93	1.71
100	695.43	14406	14155	-37.31	-297.60	0.88
101	715.00	14731	14461	-38.66	-308.26	1.02
102	729.98	14898	14619	-39.64	-316.59	0.53
103	752.92	15196	14890	-39.67	-317.33	0.03
104	779.27	15783	15446	-41.49	-331.35	0.57
105	797.29	16143	15826	-40.97	-327.56	0.20
106	815.72	16436	16141	-41.24	-329.49	0.43
107	836.67	16738	16499	-40.81	-326.89	-0.41
108	857.49	17038	16855	-41.45	-332.03	-0.43
109	879.39	17354	17230	-41.70	-334.30	-0.70
110	894.80	17576	17494	-42.45	-340.13	-0.53
111	918.71	17922	17903	-43.13	-346.96	-1.92
112	935.91	18177	18197	-42.19	-338.87	-1.35
113	960.85	18554	18623	-43.89	-352.57	-1.45

114	981.22	18862	18972	-44.25	-355.34	-1.34
115	1002.67	19176	19339	-44.52	-358.66	-2.50
116	1022.44	19455	19677	-45.03	-361.80	-1.56
117	1042.56	19702	19988	-45.91	-368.69	-1.41
118	1060.80	19952	20270	-43.46	-351.40	-3.72
119	1083.62	20278	20622	-46.18	-371.69	-2.25
120	1102.39	20588	20941	-45.23	-365.15	-3.31
121	1120.63	20908	21251	-44.12	-355.70	-2.74
122	1141.29	21274	21599	-45.44	-369.04	-5.52
123	1162.13	21646	21927	-46.52	-375.28	-3.12
124	1181.95	21999	22238	-46.68	-375.32	-1.88
125	1200.40	22329	22528	-46.82	-376.75	-2.19
207	1219.27	22666	22825	-45.66	-368.20	-2.92
206	1240.66	23048	23161	-44.51	-358.81	-2.73
205	1261.12	23416	23484	-45.55	-367.31	-2.91
204	1281.89	23790	23812	-44.78	-360.72	-2.48
203	1302.52	24162	24139	-44.89	-360.77	-1.65
202	1323.25	24530	24475	-46.65	-375.73	-2.53
201	1343.56	24878	24804	-45.80	-368.64	-2.24
200	1363.86	25211	25131	-47.28	-379.52	-1.28

Table S11. Reconstructed surface temperature and accumulation rate.

Core number	Age (ka)	ΔT ($^{\circ}\text{C}$)	ΔT uncertainty ($^{\circ}\text{C}$)	Acc. rate (m ice yr $^{-1}$)	Acc. rate uncertainty (m ice yr $^{-1}$)
306	9.4	10.5	14.6	0.119	0.144
305	9.7	7.0	11.1	0.112	0.100
303	10.3	1.2	7.4	0.115	0.061
302	10.6	0.0	6.3	0.103	0.042
300	11.4	3.4	6.6	0.093	0.040
9	11.7	1.9	6.6	0.093	0.040
98	12.3	-0.6	6.6	0.086	0.038
23	13.1	-5.9	6.4	0.103	0.045
100	13.7	-9.7	5.4	0.076	0.024
101	14.0	-9.4	5.2	0.066	0.018

103	14.4	-5.9	5.2	0.048	0.013
104	14.9	-9.6	4.8	0.053	0.011
105	15.3	-9.2	4.8	0.042	0.008
106	15.6	-10.8	4.6	0.047	0.008
108	16.2	-12.6	4.5	0.046	0.007
109	16.5	-12.3	4.6	0.039	0.006
110	16.8	-13.8	4.5	0.041	0.006
111	17.1	-14.5	4.5	0.039	0.006
112	17.4	-14.6	4.5	0.036	0.005
114	18.1	-15.4	4.5	0.032	0.005
115	18.4	-14.9	4.6	0.027	0.005
116	18.7	-15.4	4.6	0.027	0.004
117	19.0	-16.7	4.5	0.029	0.005
119	19.6	-15.6	4.6	0.027	0.005
120	20.0	-14.3	4.7	0.024	0.004
121	20.3	-14.9	4.6	0.025	0.005
122	20.6	-13.4	4.8	0.022	0.004
124	21.3	-16.1	4.6	0.031	0.005
125	21.6	-15.5	4.6	0.030	0.005
207	21.9	-15.6	4.6	0.031	0.006
206	22.3	-15.2	4.7	0.030	0.006
205	22.6	-14.7	4.7	0.029	0.006
202	23.6	-14.5	4.8	0.031	0.006
200	24.3	-14.6	4.8	0.033	0.007

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