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ANTARCTIC ICE SHEET SURFACE OXYGEN ISOTOPE VALUES

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ABSTRACT. Collected data on the mean annual surface values for $\delta^{18}O$ over Antarctica have been tabulated and also presented in map form. An additional map shows contours of constant $\delta^{18}O$ values.

RÉSUMÉ. *Teneurs en isotope de l'oxygène à la surface de la calotte glaciaire antarctique.* Les données recueillies sur les valeurs annuelles moyennes en surface pour la teneur en $\delta^{18}O$ dans l'ensemble de l'Antarctique ont été compilées et sont également présentées sous forme cartographique. Une carte supplémentaire montre les lignes d'égales teneurs en $\delta^{18}O$.

ZUSAMMENFASSUNG. *Werte für Sauerstoff-Isotope an der Oberfläche der antartischen Eisdecke.* Datenmaterial über die mittleren jährlichen Oberflächenwerte von $\delta^{18}O$ in Antarktika wurde tabuliert und auch in kartographischer Form dargestellt. Eine zusätzliche Karte enthält Linien konstanter $\delta^{18}O$-Werte.

INTRODUCTION

One of the difficulties in interpreting oxygen-isotope data from deep cores is in making allowance for the different place of deposition of the lower layers. If the direction and velocity of the ice flow is known, a first-order correction to the core data can be made by considering the variations in the present-day surface $\delta^{18}O$. For more sophisticated studies, however, changes in the surface isotope ratio which will have occurred with changes to the ice sheet also have to be considered and this presents considerable difficulty.

The prominent change in the $\delta^{18}O$ values found in the deep core data around 10 000 years B.P. (see e.g. Johnsen and others (1972)) is rather too large to be solely due to temperature and probably also reflects a general lowering of the ice sheet surface in conjunction with a retreat of the ice margin. Both the lowering and the reduction in area will reduce the depletion of ^{18}O in the surface snow but at present it is not easy to assign magnitudes to the changes.

The main idea behind this collection and presentation of data is to give a broad-scale picture of the surface $\delta^{18}O$ for comparison with core $\delta^{18}O$ profiles. A second use is that future examinations of the compiled data will enable a better understanding of the variations in the depletion in ^{18}O in Antarctic precipitation in terms of the temperature, elevation, continentality, etc. of the particular location.

The experimentally observed relationship between $\delta^{18}O$ and temperature arises because of the decrease in the saturation vapour pressure of water with temperature. A cooling air mass must precipitate water to avoid supersaturation and as this water will be enriched (*c.* + 8‰) in ^{18}O with respect to the vapour, the vapour will therefore become progressively depleted in ^{18}O. The mechanism, complicated by non-equilibrium transfers of water vapour, is affected by the path the air mass takes for instance over land, sea, or ice, its temperature and rate of temperature change, its turbulence, and other factors most of which are climatic variables and thus presumably will have varied in the past.

It is envisaged that the data presented here in Figs 1 and 2 and Table I may be used to obtain empirical values for the fractionation processes which affect precipitation falling on different parts of Antarctica and hence can be used to adjust deep core $\delta^{18}O$ data for such factors as changes in ice-sheet elevation and area.

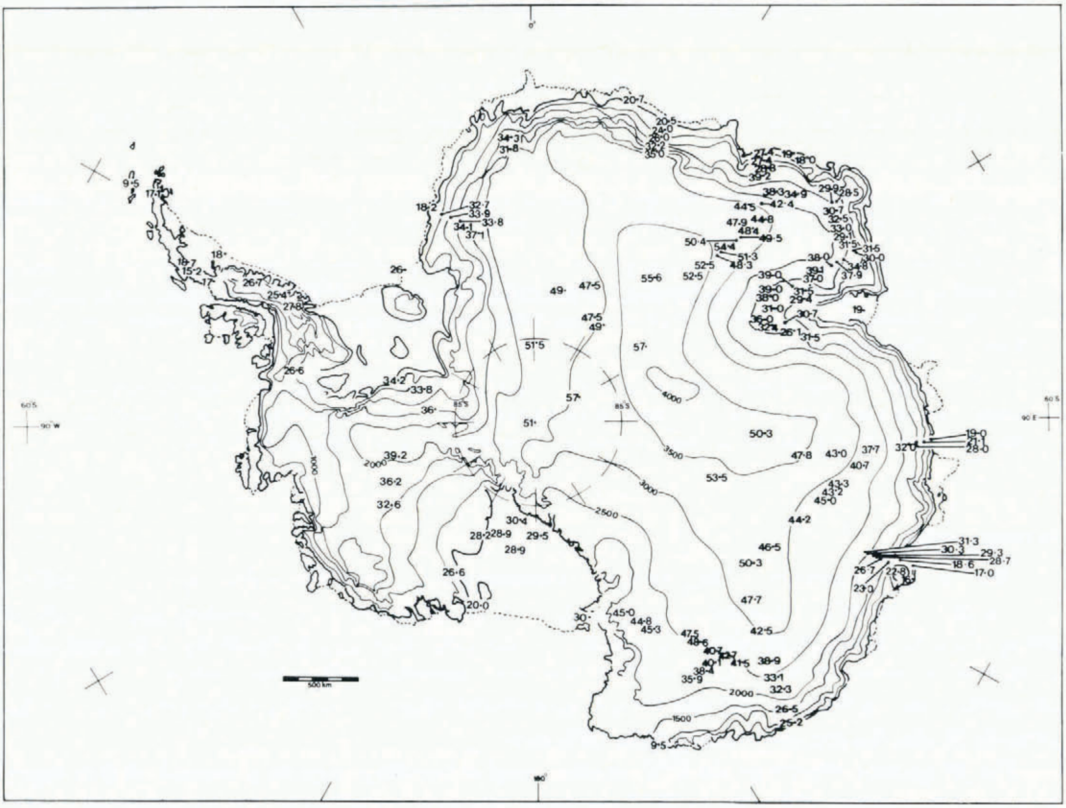

Fig. 1. Mean annual surface values of $\delta^{18}O$ in parts per thousand obtained from measurements in Antarctica.

Sample and data collection

The large seasonal δ^{18}O variability means that some form of averaging is required to obtain a value which approximates the long-term mean. Where deep bore-hole analysis data are available, this is effectively done by averaging values from the top 50 m or so of core. Where only shallow cores are obtained, e.g. by a hand auger or where pit samples are used, an even number of seasons' accumulation will probably not be collected and, due to the relatively small number of seasons represented, the δ^{18}O value will be biased away from the long-term mean.

We can obtain some idea of the magnitudes involved by examining a core from the Law Dome summit for which some detailed measurements have been made. (See Budd and Morgan, 1977). This location is probably representative of one of the more difficult places to sample because the high annual accumulation and the general lack of wind (for Antarctica) allows the large seasonal δ variation to be well preserved in amplitude. The accumulation is 0.6 Mg m^{-2}a^{-1} and the range of isotope values is 8‰ at 100 m depth, and probably about 12‰ near the surface. Assuming roughly equal amounts of summer and winter precipitation, the deviation in the δ value from the mean if an exactly odd number of seasons are sampled is:

$$\frac{\text{spread in } \delta}{2 \times \text{no. of seasons sampled}}.$$

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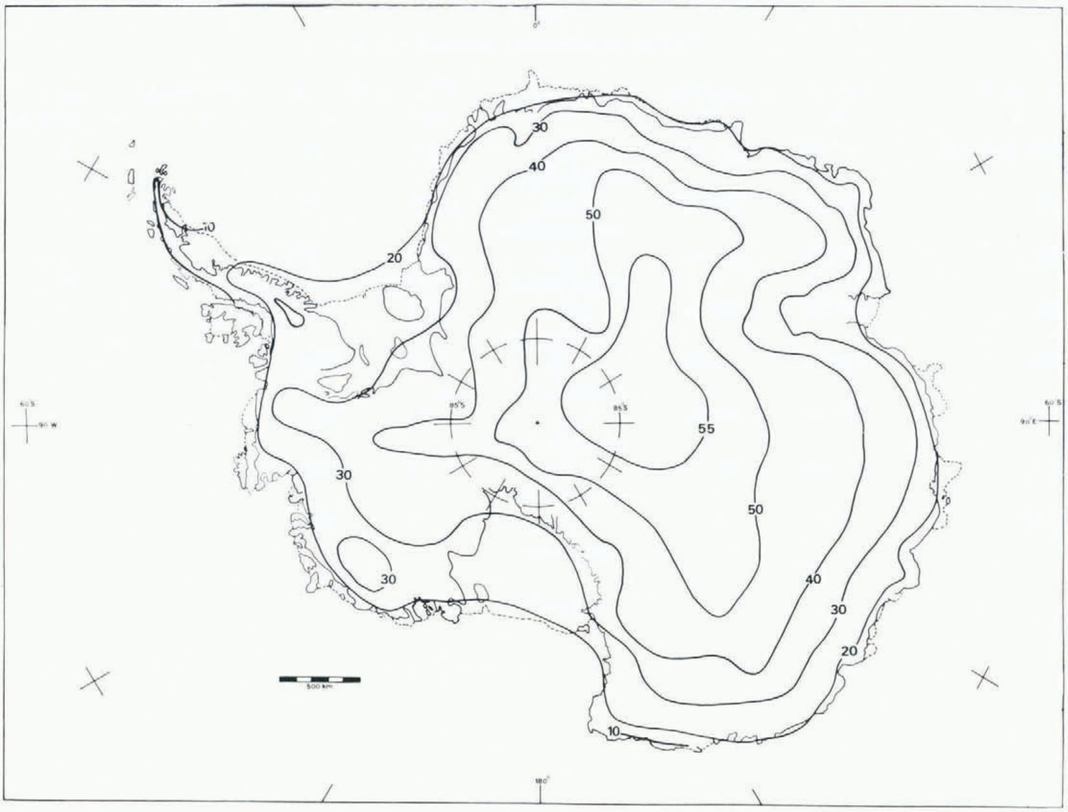

Fig. 2. Contours of constant mean annual surface values of $\delta^{18}O$ in parts per thousand derived from the point values in Figure 1.

To have a sample within 1‰ of the long-term in such a location requires that at least six seasons (i.e. three years) accumulation be sampled. This could cover a depth of 4 m in the near-coastal areas, but will be much less inland, where the accumulation rate is much smaller.

Some of the data used may be marginal in respect of sampling depth. Where possible the depth covered by the sample is noted in the listing of data.

The measurements are given as $\delta^{18}O$ with respect to SMOW, expressed as parts per mil deviation (see Craig, 1961). Where a number of measurements are closely spaced, e.g. on the Law Dome, the number of points has been reduced by averaging to give a reasonable spacing on the map (Fig. 1). The second map shows contours of constant $\delta^{18}O$ values (Fig. 2).

Acknowledgements

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TABLE I
ANTARCTIC ICE SHEET SURFACE DATA

Location	*Latitude* S	*Longitude* E	*Sample*	$\delta^{18}O$ ‰	*Elevation* m	*Temperature* °C	*Source* (see key below)
Roi Baudouin	70° 26′	24° 19′	1 year accumulation	−20.5	39		1
PL	69° 54′	18° 42′	1 year accumulation	−20.7	16		1
BRB	70° 24′	24° 12′	1 year accumulation	−21.9	22		1
ED	69° 39′	24° 36′	1 year accumulation	−21.0			1
W4	71° 00′	24° 06′	1 year accumulation	−24.0	590		1
W7	71° 27′	24° 00′	1 year accumulation	−26.0	900		1
G1	72° 00′	24° 18′	1 year accumulation	−32.2	1 500		1
BM	72° 36′	30° 54′	1 year accumulation	−36.2	2 000		1
13A	72° 18′	24° 21′	1 year accumulation	−35.0	2 400		1
	c. 84°	*c.* 1°		−51.5			2
	c. 82°	*c.* 11°		−49			2
	c. 81°	*c.* 21°		−47.5			2
	c. 82° 18′	*c.* 30°		−47.5			2
	c. 82° 06′	*c.* 32°		−49			2
	c. 83°	*c.* 60°		−57			2
H128	69° 25′	41° 36′	5	−27.4	1 359		3
S97	69° 35′	42° 48′	5	−28.8	1 605		3
Y100	71° 17′	46° 19′	2	−42.4	2 596		3
Y210	71° 45′	48° 57′	2	−44.8	2 880		3
I235	73° 49′	48° 33′	2	−50.8	3 200		3
I365	74° 55′	47° 56′	2	−51.3	3 310		3
I485	76° 00′	48° 06′	2	−52.5	3 383		3
J225	73° 01′	46° 22′	2	−47.9	3 039		3
J364	71° 50′	44° 45′	2	−44.5	2 613		3
W280	70° 13′	46° 34′	2	−38.3	2 405		3
W46	69° 33′	48° 56′	2	−34.9	1 958		3
Y200	71° 44′	48° 41′	shallow	−46.9	2 870		4
I100	72° 38′	48° 40′	sample	−48.4	3 026		4
I200	73° 30′	48° 29′	below	−49.5	3 184		4
I300	74° 22′	48° 07′	surface	−54.4	3 266		4
I400	75° 14′	47° 58′	snow	−48.3	3 329		4
I500	76° 08′	48° 05′	↓	−51.3	3 385		4
I600	77° 00′	48° 03′	↓	−52.5	3 408		4
S40	69° 05′	41° 07′	↓	−27.4	1 112		4
S84	69° 22′	42° 38′	↓	−30.9	1 518		4
S122	70° 01′	43° 07′	↓	−39.2	1 853		4
Molodezhnaya	67° 40′	45° 50′		−20.1		−10.9	5
GWAM	67° 35′	62° 50′		−26.1	*c.* 100		6
C10	68° 38′	62° 07′	2	−30.0	1 790		6
C64	69° 27′	62° 13′	2	−34.8	2 060		6
C344	69° 53′	62° 00′	2	−37.9	2 290		6

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TABLE I—*continued*

Location	*Latitude* S	*Longitude* E	*Sample*	$\delta^{18}O$ ‰	*Elevation* m	*Temperature* °C	*Source* (see key below)
C124	70° 15′	62° 12′	2	−38.0	2 340		6
C175	71° 00′	62° 10′	2	−39.1	2 220		6
C216	71° 29′	62° 51′	2	−37.0	1 815		6
C244	71° 52′	63° 26′	2	−29.2	1 840		6
C271	72° 14′	63° 59′	9	−31.48	1 545		6
GL1	72° 31′	65° 19′	2	−29.39	1 148		7
GL2	72° 16′	63° 58′	9	−31.48	1 607		7
GL3	72° 48′	62° 09′	2	−31.56	1 808		7
GL5	73° 43′	61° 11′	10	−38.96	2 000		7
GL6	74° 03′	61° 57′	2	−38.04	1 889		7
GL7	74° 14′	64° 13′	2	−30.97	1 556		7
GL8	74° 59′	66° 06′	9	−35.95	1 763		7
GL9	74° 45′	67° 58′	1	−32.39	1 710		7
GL10	74° 04′	68° 23′	1	−30.24	1 109		7
GL11	73° 44′	70° 37′	½	−26.13	1 462		7
GLF	72° 57′	72° 48′	2	−31.5	1 518		7
GE2	68° 39′	61° 58′	4	−31.53	1 862		8
GE3	68° 39′	60° 33′	4	−32.02	1 878		8
GE4	68° 36′	59° 21′	2	−29.10	1 921		8
GE5	68° 31′	57° 52′	4	−33.01	2 203		8
GE6	68° 24′	56° 30′	3	−32.48	2 054		8
GE7	68° 17′	55° 01′	4	−30.66	2 004		8
GE8	68° 01′	53° 52′	3	−28.51	2 133		8
GE9	68° 16′	53° 32′	3	−29.93	2 199		8
G1 (Amery)	69° 28′	71° 25′	*c.* 50	−19	64	−20.1	9
Plateau	79° 15′	40° 30′		−55			10
Pole of relative inaccessibility	82° 07′	55° 02′		−57			10
GM01	67° 01′	93° 18′	1	−21.13	914		11
GM02	67° 26′	93° 23′	1	−27.96	1 455		11
GM03	67° 52′	93° 45′	1	−31.95	1 758		11
GM07	70° 27′	97° 51′	5–10	−40.67	2 760	−39.0	11
GM10	71° 38′	101° 50′	5–10	−43.23	2 979	−47.5	11
GM13	73° 14′	110° 27′	5–10	−44.16	2 963	−52.9	11
GM14	72° 11′	105° 23′	5	−44.97	2 899		11
GM15	71° 54′	103° 19′	5	−43.32	2 988		11
GM20	73° 48′	114° 37′	5	−46.48	3 085		11
Dome C	74° 30′	123° 10′	*c.* 100	−50.3	3 240	−50.3	12
Mirny	66° 33′	93° 01′		−19.0		−12.4	5
Pionerskaya	69° 44′	95° 31′	10 years accumulation	−37.7	2 740	−37.4	13
Vostok 1	72° 08′	96° 36′	10 years accumulation	−42.8	3 250	−47.4	13
Komsomolskaya	74° 05′	97° 29′	10 years accumulation	−47.8	3 500	−53.9	13
Vostok	78° 27′	106° 48′	60–200	−53.5	3 490	−57.3	5
Watershed	75° 46′	93° 49′		−50.3	3 730	−57.7	13
BO03	66° 47′	112° 44′	< 10	−22.84	1 354		14
BO17	67° 25′	112° 01′	< 10	−22.24	830		14
BO18	67° 31′	111° 59′	< 10	−24.68	822		14
BO19	67° 36′	111° 58′	< 10	−22.24	1 001		14
BO22	67° 47′	111° 58′	< 10	−24.73	1 209		14
BO24	67° 58′	111° 57′	< 10	−27.26	1 365		14
BO25	68° 06′	111° 55′	< 10	−26.12	1 488		14

TABLE I—*continued*

Location	*Latitude* S	*Longitude* E	*Sample*	$\delta^{18}O$ ‰	*Elevation* m	*Temperature* °C	*Source* (see key below)
BO27	68° 21′	112° 01′	< 10	−28.24	1 606		14
BO28	68° 24′	112° 03′	< 10	−29.10	1 626		14
BO29	68° 31′	112° 04′	< 10	−28.11	1 702		14
BO30	68° 33′	112° 01′	< 10	−30.46	1 709		14
BO31	68° 38′	111° 50′	< 10	−28.97	1 779		14
BO32	68° 43′	111° 51′	< 10	−29.54	1 837		14
BO33	68° 52′	111° 50′	< 10	−30.54	1 902		14
AO34	68° 56′	112° 03′	< 10	−30.15	1 918		14
BO35	69° 03′	111° 52′	< 10	−31.29	1 962		14
A	66° 08′	110° 57′		−16.7	283	−10.1	15
F	66° 09′	111° 00′	40	−17.6	360	−12.4	15
P	66° 14′	111° 14′	*c.* 30	−18.9	620	−14.3	15
B	66° 18′	111° 27′	*c.* 63	−19.7	780	−15.7	15
Q	66° 23′	111° 44′	*c.* 40	−20.8	930	−19.0	15
D	66° 44′	112° 50′	30	−22.8	1 390	−21.3	15
J	65° 56′	113° 09′	*c.* 40	−17.1	379	−11.0	15
Dumont d'Urville	66° 40′	140° 01′	10 years accumulation	−16.9	40	−11.2	13
D18	66° 45′	139° 40′	10	−20	460	−16.3	16
D41	66° 50′	139° 19′	10	−22	975	−19.8	16
D45			10	−26	1 410	−24.0	16
D52			10	−30.5	1 850	−28.8	16
D59			10	−32.5	2 220	−34.3	16
D62			10	−34.5	2 290	−37.9	16
D80	70° 01′	134° 49′	10	−39	2 430	−42.1	16
D100			10	−42.5	2 810	−46.5	16
D113			10	−47.7	2 990	−46.5	16
D120	73° 04′	128° 44′	10	−47.9	3 010	−53.5	16
A3	66° 42′	139° 55′	10 years accumulation	−19.7	220	−14.5	13
A5	66° 43′	139° 55′	10 years accumulation	−20.0	230	−15.6	13
A14	66° 44′	139° 42′	10 years accumulation	−20.2	405	−16.1	13
A17	66° 45′	139° 36′	10 years accumulation	−19.5	470	−17.8	13
A28	66° 49′	139° 22′	10 years accumulation	−19.7	680	−19.3	13
A34(B10)	66° 50′	139° 15′	10 years accumulation	−19.3	790	−19.8	13
B11	66° 55′	139° 16′	10 years accumulation	−22.1	985	−22	13
B13	67° 05′	139° 16′	10 years accumulation	−21.8	1 210	−24.2	13
B16	67° 22′	139° 17′	10 years accumulation	−25.8	1 480	−26.9	13
B17	67° 26′	139° 17′	10 years accumulation	−28.2	1 530	−27.4	13
B18	67° 31′	139° 18′	10 years accumulation	−27.0	1 610	−28.3	13
B19	67° 37′	139° 13′	10 years accumulation	−26.7	1 670	−28.9	13
B22	67° 55′	139° 19′	10 years accumulation	−29.1	1 830	−30.4	13
B61	71° 07′	139° 15′	10 years accumulation	−41.3	2 510	−43.9	13
500	78° 02′	154° 06′	10 years accumulation	−44.8	2 280	−43.6	13
504	77° 02′	152° 19′	10 years accumulation	−44.6	2 440	−45	13
507	76° 27′	150° 24′	10 years accumulation	−45.7	2 480	−47.3	13
516	74° 27′	144° 15′	10 years accumulation	−47.3	2 590	−47.1	13
519	73° 44′	143° 28′	10 years accumulation	−48.5	2 540	−46.9	13
521	73° 07′	142° 30′	10 years accumulation	−43.3	2 515	−46.5	13
524	72° 28′	141° 21′	10 years accumulation	−40.5	2 500	−44	13
527	71° 50′	140° 15′	10 years accumulation	−42.5	2 470	−44.2	13
536	72° 06′	143° 11′	10 years accumulation	−39.8	2 360	−44.3	13

TABLE I—*continued*

Location	*Latitude* S	*Longitude* E	*Sample*	$\delta^{18}O$ ‰	*Elevation* m	*Temperature* °C	*Source* (see key below)
540	72° 07′	145° 53′	10 years accumulation	−38.2	2 290	−42.3	13
544	72° 08′	148° 12′		−35.7	2 220	−41.5	13
Leningradskaya	69° 30′	159° 25′		−9.5		−4.1	5
NZCS16	77° 51′	166° 45′	10 years accumulation	−30		−18	13
South Pole				−51	2 800	−50.7	17
		W					
Little America	78° 05′	162° 28′	5–20	−19.7	43	−24.2	18
Eights	75° 14′	77° 10′		−26.6	452		19
A	80° 55′	111° 05′	10 years accumulation	−36.5	1 700	−29.5	13
B	81° 35′	102° 40′		−38.9	2 200	−33.3	13
C	82° 05′	89° 30′		−41.0	1 800	−33.4	13
D	80° 32′	80° 55′		−35.2	950	−27.3	13
E	82° 48′	70° 40′		−33.5	500	−27.7	13
F	80° 57′	71° 20′		−34.8	150	−29.4	13
G	83° 54′	78° 30′		−35.8	1 150	−32.6	13
K (New Byrd)	80° 01′	119° 32′		−35.8	1 525	−28.2	13
Byrd				−32.6	1 530	−28.2	20
Bellingshausen	62° 15′	58° 50′		−9.5		−3.8	5
1	64° 05′	59° 35′	10	−17.13	1 806	−14.8	21
2	66° 25′	64° 57′	10	−19.08	1 937	−15.9	21
3	67° 32′	66° 00′	10	−18.70	1 750	−16.5	21
4	67° 46′	68° 55′	10	−14.92	377	−7.7	21
5	68° 11′	67° 00′	10	−15.25	380	−8.1	21
6	68° 46′	60° 56′	10	−17.90	290	−14.9	21
7	69° 30′	66° 16′	10	−16.80	870	−12.9	21
8	70° 01′	64° 29′	10	−27.13	2 131	−21.0	21
9	70° 37′	60° 44′	10	−19.61	396	−17.5	21
10	71° 07′	62° 20′	10	−25.94	1 050	−16.6	21
11	71° 14′	63° 22′	10	−26.68	1 752	−22.1	21
12	70° 50′	64° 27′	10	−26.48	1 987	−21.4	21
13	71° 15′	64° 30′	10	−25.43	2 010	−23.7	21
14	71° 18′	67° 29′	10	−13.19	290	−8.4	21
15	71° 23′	65° 30′	10	−23.90	1 547	−20.0	21
16	71° 29′	66° 58′	10	−18.00	946	−13.1	21
17	70° 00′	75° 20′	10	−12.60	595	−12.1	21
18	71° 42′	64° 05′	10	−24.72	1 886	−20.4	21
20	72° 30′	72° 50′	10	−16.55	488	−13.3	21
21	72° 47′	64° 30′	10	−25.40	1 797	−21.8	21
22	72° 50′	64° 30′	10	−16.69	539	−13.3	21
23	73° 42′	64° 47′	10	−27.84	2 007	−23.8	21
24	72° 12′	60° 20′	10	−21.42	130	−17.6	21
25	70° 53′	64° 57′	10	−25.77	1 835	−20.2	21
Ellsworth	77° 43′	41° 02′	New Snow	−26.6	20	−22.3	18
Halley Bay	75° 30′	26° 40′		−18.2			2
Traverse				−32.7			2
inland of				−33.9			2
Halley Bay	to	to		−33.8			2
				−34.1			2
	78° 36′	19° 36′		−37.1		*c.* −32	2

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