Basal melting of Ross Ice Shelf from solar heat absorption in an ice-front polynya

Craig L. Stewart,[1,2*] Poul Christoffersen,[1] Keith W. Nicholls,[3]
Michael J. M. Williams,[2] Julian A. Dowdeswell[1]

[1]Scott Polar Research Institute, University of Cambridge, UK
[2]National Institute of Water and Atmospheric Research, Wellington, NZ
[3]British Antarctic Survey, Cambridge, UK

March 15, 2019

Supplementary Materials

Tables S1 S2
Figures S1 S2

Table 1: ApRES basal melt and vertical strain rates: Ross Ice Shelf network. D is distance from the ice front, Δt the time between surveys. Site positions relate to the first visit.

Site	Lat	Lon	D	Start	Δt	Melt rate
			km	date	days	$\mathrm{m\,yr^{-1}}$
a01	77 28.423 S	171 33.735 E	7.2	16/01/13	359	1.57 ± 0.02
a02	77 28.176 S	171 16.584 E	7.4	17/01/13	360	1.56 ± 0.02
a03	77 27.986 S	171 00.917 E	6.6	17/01/13	360	1.69 ± 0.02
a05	77 27.497 S	170 25.999 E	5.5	17/01/13	360	2.94 ± 0.03
b01	77 36.395 S	171 37.627 E	21.0	24/01/13	358	0.99 ± 0.01
b02	77 36.150 S	171 20.484 E	22.1	24/01/13	358	0.92 ± 0.01
b03	77 35.915 S	171 04.932 E	21.2	24/01/13	358	1.35 ± 0.01
b04	77 35.652 S	170 48.587 E	20.7	24/01/13	358	1.66 ± 0.02
b05	77 35.339 S	170 30.402 E	16.0	24/01/13	358	2.08 ± 0.02
b06	77 35.057 S	170 14.804 E	13.0	24/01/13	357	2.37 ± 0.02
b07	77 34.740 S	169 58.370 E	11.2	24/01/13	357	2.03 ± 0.02
b08	77 34.481 S	169 45.471 E	11.0	24/01/13	357	1.20 ± 0.02
c01	77 45.654 S	171 39.892 E	37.6	25/01/13	359	0.71 ± 0.01
c02	77 45.320 S	171 22.572 E	38.2	25/01/13	359	0.80 ± 0.01
c03	77 45.000 S	171 06.976 E	37.9	25/01/13	359	1.13 ± 0.01
c04	77 44.651 S	170 50.572 E	34.7	25/01/13	359	1.30 ± 0.01
c05	77 44.246 S	170 32.466 E	31.2	25/01/13	359	1.93 ± 0.02
c06	77 43.872 S	170 16.881 E	29.0	25/01/13	360	1.76 ± 0.02
c07	77 43.458 S	170 00.031 E	27.1	25/01/13	360	1.80 ± 0.02
c08	77 43.088 S	169 45.431 E	26.5	25/01/13	360	1.16 ± 0.02
c09	77 42.735 S	169 31.991 E	27.0	25/01/13	360	1.12 ± 0.02
c10	77 42.450 S	169 21.719 E	27.2	25/01/13	360	1.42 ± 0.01
c11	77 42.144 S	169 10.693 E	26.8	25/01/13	360	2.01 ± 0.02
d01	78 01.072 S	171 39.241 E	65.6	26/01/13	360	0.64 ± 0.01
d02	78 00.639 S	171 21.830 E	65.8	26/01/13	360	0.60 ± 0.01
d03	78 00.244 S	171 06.435 E	63.2	26/01/13	360	0.46 ± 0.01
d04	77 59.800 S	170 49.997 E	60.3	27/01/13	358	0.83 ± 0.02
d05	77 59.315 S	170 32.525 E	57.9	27/01/13	358	1.05 ± 0.01
d06	77 58.860 S	170 16.681 E	55.9	27/01/13	358	1.37 ± 0.01
d08	77 57.827 S	169 42.892 E	53.4	28/01/13	358	1.34 ± 0.01
d09	77 57.361 S	169 28.167 E	53.3	28/01/13	359	1.44 ± 0.01
d10	77 56.909 S	169 14.582 E	53.7	28/01/13	359	1.62 ± 0.02
d11	77 56.418 S	168 59.948 E	49.8	28/01/13	359	1.07 ± 0.03
e07	78 13.596 S	169 53.847 E	77.7	29/01/13	358	1.40 ± 0.02
e09	78 12.277 S	169 23.637 E	66.5	28/01/13	358	0.90 ± 0.01
e10	78 11.664 S	169 10.061 E	61.4	28/01/13	358	0.90 ± 0.01
e11	78 10.969 S	168 54.814 E	55.8	28/01/13	358	1.09 ± 0.01
e12	78 10.290 S	168 40.435 E	50.5	28/01/13	359	1.18 ± 0.01

Table 2: ApRES basal melt and vertical strain rates: Ross Ice Shelf frontal transects. D is distance from the ice front, Δt the time between surveys. Site positions relate to the first visit.

Site	Lat	Lon	D	Annual			Summer 2013			Summer 2014		
				Start	Δt	Melt rate	Start	Δt	Melt rate	Start	Δt	Melt rate
			km	date	days	$\mathrm{m\,yr^{-1}}$	date	days	$\mathrm{m\,yr^{-1}}$	date	days	$\mathrm{m\,yr^{-1}}$
tab_00000	77 26.037 S	172 26.591 E	0.6	17/01/13	360	3.15 ± 0.03	-	-	-	-	-	-
tab_00500	77 26.229 S	172 26.742 E	0.9	17/01/13	360	2.43 ± 0.02	-	-	-	-	-	-
tab_02500	77 27.311 S	172 28.832 E	2.7	17/01/13	360	1.52 ± 0.02	-	-	-	-	-	-
tab_05000	77 28.570 S	172 28.117 E	5.0	17/01/13	360	0.84 ± 0.02	-	-	-	-	-	-
ta_09000	77 30.775 S	172 24.062 E	9.1	16/01/13	360	1.37 ± 0.01	-	-	-	-	-	-
tb_00000	77 24.416 S	171 31.045 E	0.3	16/01/13	363	4.85 ± 0.05	16/01/13	7.1	13.9 ± 0.1	11/01/14	3.07	12.5 ± 0.2
tb_00500	77 24.684 S	171 31.198 E	0.7	16/01/13	364	4.06 ± 0.04	16/01/13	7.12	10.8 ± 0.1	11/01/14	4.09	11.0 ± 0.1
tb_01000	77 24.953 S	171 31.380 E	1.1	16/01/13	364	3.53 ± 0.04	16/01/13	7.12	9.9 ± 0.1	11/01/14	4.08	8.3 ± 0.2
tb_01750	77 25.359 S	171 31.620 E	1.8	16/01/13	364	2.97 ± 0.03	16/01/13	7.13	7.92 ± 0.08	11/01/14	4.16	5.4 ± 0.3
tb_02500	77 25.764 S	171 31.913 E	2.5	16/01/13	364	2.68 ± 0.03	16/01/13	7.14	6.85 ± 0.08	11/01/14	4.19	3.79 ± 0.09
tb_03500	77 26.301 S	171 32.271 E	3.5	16/01/13	364	2.32 ± 0.02	16/01/13	6.21	5.43 ± 0.07	11/01/14	4.21	2.0 ± 0.1
tb_05000	77 27.113 S	171 32.814 E	4.9	16/01/13	364	1.91 ± 0.02	16/01/13	6.22	3.44 ± 0.09	11/01/14	4.24	1.6 ± 0.1
tb_07000	77 28.191 S	171 33.550 E	6.8	16/01/13	364	1.58 ± 0.02	16/01/13	6	2.76 ± 0.08	11/01/14	4.11	2.1 ± 0.1
a01	77 28.423 S	171 33.735 E	7.2	16/01/13	359	1.57 ± 0.02	-	-	-	-	-	-
tb_09000	77 29.273 S	171 34.243 E	8.6	15/01/13	366	1.38 ± 0.01	15/01/13	6.04	1.9 ± 0.1	10/01/14	5.94	1.9 ± 0.1
tb_12000	77 30.900 S	171 35.166 E	11.4	15/01/13	366	1.23 ± 0.01	15/01/13	6.02	1.3 ± 0.2	10/01/14	6	2.10 ± 0.09
tc_n00130	77 24.298 S	170 42.122 E	0.1	18/01/13	360	7.71 ± 0.08	18/01/13	4.89	53.3 ± 0.5	-	-	-
tc_00000	77 24.371 S	170 42.179 E	0.3	18/01/13	360	7.07 ± 0.07	18/01/13	4.86	45.9 ± 0.5	-	-	-
tc_00500	77 24.635 S	170 42.340 E	0.7	18/01/13	360	5.46 ± 0.05	18/01/13	4.86	29.6 ± 0.3	-	-	-
tc_01000	77 24.911 S	170 42.525 E	1.2	18/01/13	360	4.72 ± 0.05	18/01/13	4.86	24.5 ± 0.2	-	-	-
tc_01750	77 25.314 S	170 42.792 E	1.9	18/01/13	360	3.89 ± 0.04	18/01/13	4.86	18.6 ± 0.2	-	-	-
tc_02500	77 25.724 S	170 43.064 E	2.7	18/01/13	360	3.28 ± 0.03	18/01/13	4.86	14.5 ± 0.1	-	-	-
tc_03500	77 26.265 S	170 43.397 E	3.6	18/01/13	360	2.76 ± 0.03	18/01/13	4.86	10.7 ± 0.1	-	-	-
tc_05000	77 27.072 S	170 43.957 E	5.1	17/01/13	360	2.23 ± 0.02	17/01/13	5.07	6.4 ± 0.2	-	-	-
tc_07000	77 28.148 S	170 44.677 E	7.0	17/01/13	360	1.92 ± 0.02	17/01/13	5.07	6.1 ± 0.1	-	-	-
tc_09000	77 29.232 S	170 45.367 E	9.0	18/01/13	360	1.78 ± 0.02	18/01/13	4.91	2.5 ± 0.3	-	-	-
tc_12000	77 30.858 S	170 46.346 E	12.0	18/01/13	360	1.75 ± 0.02	18/01/13	4.91	3.6 ± 0.2	-	-	-

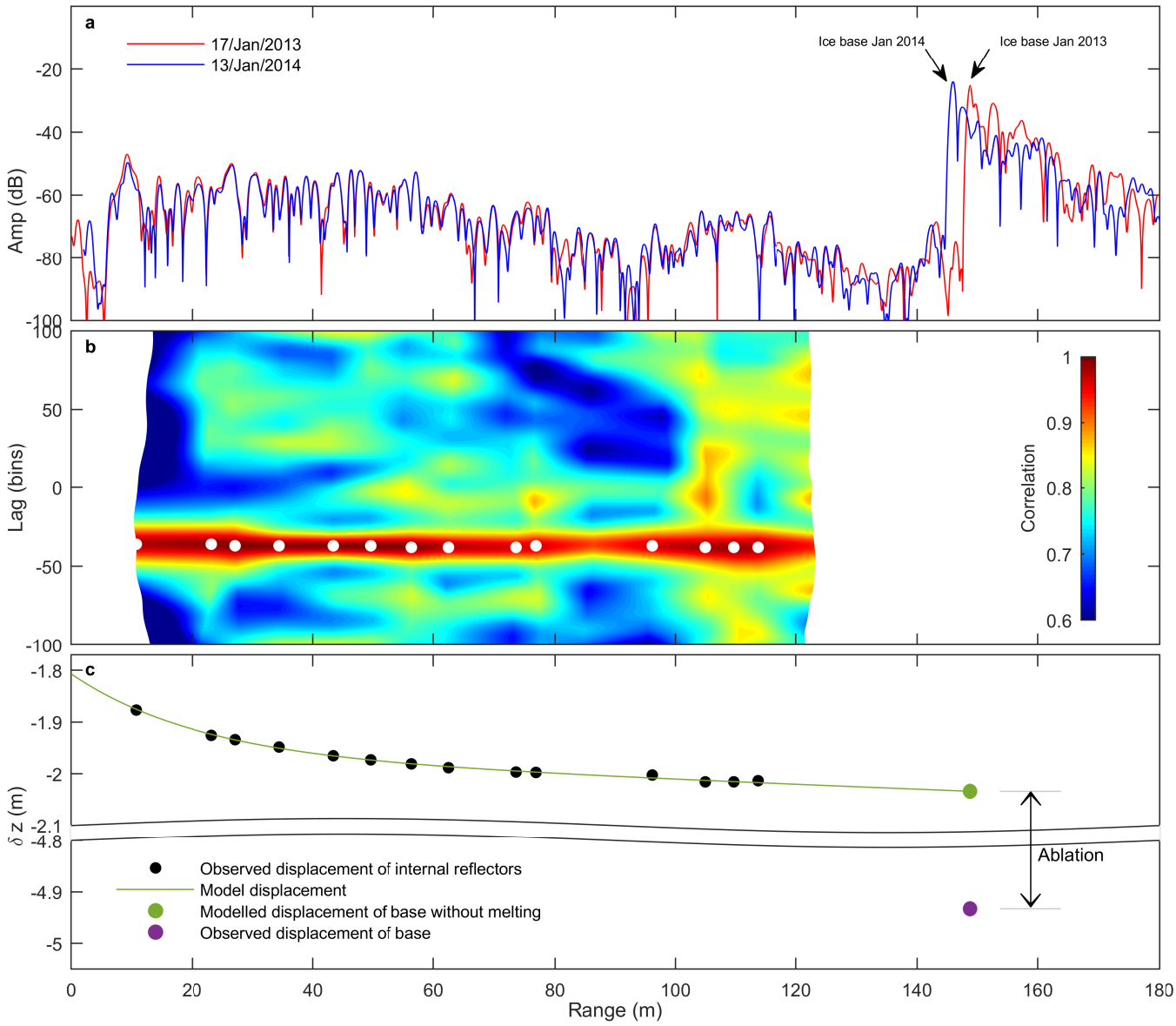

Figure 1: Radar observations for site A05. (a) Spectrum amplitude for the January 2013 (red) and January 2014 (blue) site occupations. The repeat profile has been shifted 2 m right to align the profiles for clarity. (b) Correlation of profile segments as a function of range and lag between profiles (coloured shading), with the lag of maximum correlation (white dots). A lag of 50, implies an increase in range of 2.685 m. (c) Vertical displacement observations for internal reflectors (black) and the ice-ocean interface (purple). Also shown are the vertical displacement model (green line), and the predicted vertical displacement of the ice-ocean interface that results from the deformation of the ice column (green dot). Note the y axis is broken to show details of compaction and strain within the ice shelf (upper panel), and the much larger displacement of the base (lower).

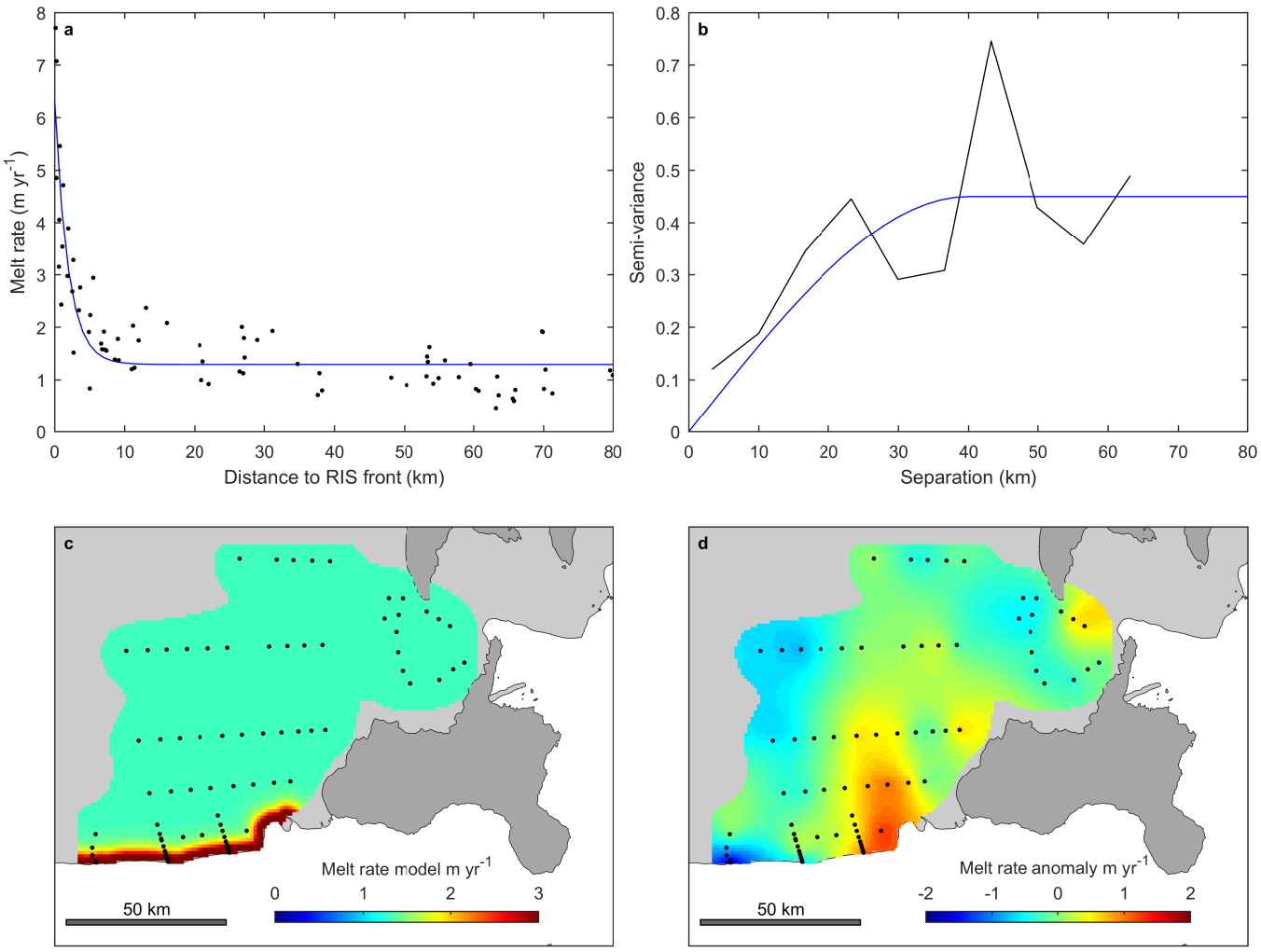

Figure 2: Melt rate interpolation methods. (a) Observed basal melt rates as a function of frontal distance (black dots) with the melt rate model (blue line). (b) Spatial covariance of the melt rate anomaly (black) and the spherical semi-variogram used in Kriging (blue). (c) Component of basal melting predicted by a simple model including spatially constant and exponential frontal melt enhancement terms. (d) The interpolated (observation-model) melt rate anomaly. Blacks dots in (c) and (d) indicate radar sites.