Rapid Changes in Outlet Glaciers on the Pacific Coast of East Antarctica Driven by Climate

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Supplementary Tables:

Supplementary Table 1: Data sources and total number of glaciers mapped at each time-step.

Time -Step	Imagery Dates	Imagery Type	Spatial Resolution (m)	Number of Glaciers Mapped	Source
1963	1963	KH-5 Argon (missions 9058A & 9059A)	140	38	Reference 33. Byrd Polar Research Center (http://bprc.osu.edu/rsl/index_files/BPRCData.htm)
1974	1972-75	Landsat 1 (MSS)	60	136	United States Geological Survey (USGS) Earth Resources Observation and Science Center (EROS): http://glovis.usgs.gov/
1990	1988-91	Landsat 4/5 (TM)	30	169	
2000	1999-02	Landsat 7 (ETM)	30 (15 in band 8)	175	
2006	2006-07	Landsat 7 (ETM)	30 (15 in band 8)	165	
2010	2009-2012	Landsat 7 (ETM)	30 (15 in band 8)	171	

Supplementary Table 2: Wilcoxon tests for significant differences between glacier terminus position change between 1974-1990 and 1990-2000. Tests are performed on all glaciers and sub-samples of those less than 15 km wide and those facing the western Pacific and Ross Sea, respectively.

Sample	**Sample**	**Epoch**	***n***	**Rate of terminus position change ($m\ a^{-1}$)**				**P-value[#]**
				Min.	**Median**	**Mean**	**Max.**	
All glaciers	Unpaired	1974-1990	131	-1611.7	-12.5	-43.3	678.9	**0.0000**
		1990-2000	168	-1591.4	19.7	43.1	1605.4	
	Paired	1974-1990	131	-1611.7	-12.5	-43.3	678.9	**0.0000**
		1990-2000	131	-1591.4	13.5	29.6	1605.4	
All glaciers < 15 km	Unpaired	1974-1990	115	-1091.5	-12.5	-25.3	341.4	**0.0000**
		1990-2000	143	-491.1	18.4	27.6	265.1	
	Paired	1974-1990	115	-1019.5	-12.5	-25.3	341.4	**0.0000**
		1990-2000	115	-491.1	11.9	22.0	265.1	
Pacific	Unpaired	1974-1990	87	-1611.7	-21.4	-85.2	678.9	**0.0000**
		1990-2000	123	-1591.4	23.8	48.3	1605.4	
	Paired	1974-1990	87	-1611.7	-21.4	-85.2	678.9	**0.0000**
		1990-2000	87	-1591.4	17	29.7	1605.4	
Ross	Unpaired	1974-1990	44	-302.6	7.5	39.6	518.0	0.8503
		1990-2000	45	-380.9	7.2	28.8	528.8	
	Paired	1974-1990	44	-302.6	7.5	39.6	518.0	0.4343
		1990-2000	44	-380.9	7.8	29.4	528.8	

[#] P-values <0.05 are significant and highlighted in red

Supplementary Table 3: Wilcoxon tests for significant differences between glacier terminus position change between 1990-2000 and 2000-2010. Tests are performed on all glaciers, and sub-samples of those less than 15 km wide and those facing the western Pacific and Ross Sea, respectively.

Sample	**Sample**	**Epoch**	***n***	**Rate of terminus position change (m a^{-1})**				**P-value[#]**
				Min.	**Median**	**Mean**	**Max.**	
All glaciers	Unpaired	1990-2000	168	-1591.4	19.7	43.1	1605.4	**0.0135**
		2000-2010	171	-6913.7	8.4	-17.9	1759.2	
	Paired	1990-2000	165	-1591	20.6	44.3	1605.4	0.0827
		2000-2010	165	-6913.7	8.4	-19.6	1759.2	
All glaciers < 15 km	Unpaired	1990-2000	143	-491.1	18.4	27.6	265.1	**0.0130**
		2000-2010	144	-795.4	6.5	-6.9	350.9	
	Paired	1990-2000	140	-491.1	18.9	28.7	265.1	**0.0296**
		2000-2010	140	-795.4	6.5	-9.5	350.9	
Pacific	Unpaired	1990-2000	123	-1591.4	23.8	48.3	1605.4	**0.0000**
		2000-2010	129	-6913.7	4.9	-13.9	1759.2	
	Paired	1990-2000	123	-1591.4	23.8	48.3	1605.4	**0.0443**
		2000-2010	123	-6913.7	4.9	-16.0	1759.2	
Ross	Unpaired	1990-2000	45	-380.9	7.2	28.8	528.8	0.8503
		2000-2010	42	-795.4	14.1	-30.3	747.7	
	Paired	1990-2000	42	-380.9	8.6	32.5	528.8	0.9154
		2000-2010	42	-795.4	14.1	-30.3	747.7	

[#] P-values <0.05 are significant and highlighted in red

Supplementary Table 4: Two-tailed *t*-test results for significant differences in mean austral summer (December, January, February) temperatures between 1974-1990 and 1991-2000, and 1991-2000 and 2001-2010. All tests are unpaired and allow unequal variances.

Station	Epoch	Mean summer temperature (° C)	Standard Deviation	P-value[#]
Mirny	**1974-1990**	**-3.0**	**0.63**	**0.0496**
	1991-2000	**-3.8**	**1.05**	
	1991-2000	-3.8	1.05	0.0884
	2001-2010	-3.1	0.70	
Casey	**1974-1990**	**-0.8**	**0.50**	**0.0114**
	1991-2000	**-1.7**	**0.85**	
	1991-2000	-1.7	0.85	0.2411
	2001-2010	-1.3	0.53	
Dumont d'Urville	**1974-1990**	**-1.8**	**0.59**	**0.0124**
	1991-2000	**-2.7**	**0.86**	
	1991-2000	-2.7	0.86	0.1160
	2001-2010	-2.2	0.55	
Scott	1974-1990	-6.8	0.78	0.1569
	1991-2000	-7.3	0.72	
	1991-2000	-7.3	0.72	0.1797
	2001-2010	-6.8	0.51	

[#] P-values <0.05 are significant and highlighted in red

Supplementary Table 5: Wilcoxon tests for significant differences between glacier terminus position change between 1974-1990 and 1990-2000 in each of the major drainage basins within the study area.

Sample	Sample	Epoch	*n*	Rate of terminus position change (m a^{-1}) Min.	Median	Mean	Max.	P-value[#]
DB12	Unpaired	1974-1990	5	-1611.7	-13.2	-326.6	382.6	0.6847
		1990-2000	7	-1591.4	8.9	-326.6	1605.4	
	Paired	1974-1990	5	-1611.7	-13.2	-326.6	382.6	0.6858
		1990-2000	5	-1591.4	-49.6	-19.3	1605.4	
DB13	Unpaired	1974-1990	15	-406.8	-49.4	-83.5	96.7	**0.0002**
		1990-2000	37	-265.8	54.9	65.8	359.7	
	Paired	1974-1990	15	-406.8	-49.4	-83.5	96.7	**0.0199**
		1990-2000	15	-137.2	27.4	52.8	217.0	
DB14	Unpaired	1974-1990	24	-1388.2	-43.5	-161.7	678.9	**0.0001**
		1990-2000	35	-772.5	30.3	-161.7	1054.2	
	Paired	1974-1990	24	-1388.2	-43.5	-161.7	678.9	**0.0007**
		1990-2000	24	-772.5	24.0	19.6	713.1	
DB15	Unpaired	1974-1990	69	-302.6	-3.5	2.1	341.4	**0.0001**
		1990-2000	70	-289.5	12.6	30.5	265.1	
	Paired	1974-1990	69	-302.6	-3.5	2.1	341.4	**0.0092**
		1990-2000	69	-289.5	11.9	30.5	265.1	
DB16	Unpaired	1974-1990	18	-87.7	7.5	52.8	518	0.7382
		1990-2000	19	-380.9	1.8	32.3	528.8	
	Paired	1974-1990	18	-87.7	7.5	52.8	518	0.7439
		1990-2000	18	-380.9	4.5	34.2	528.8	

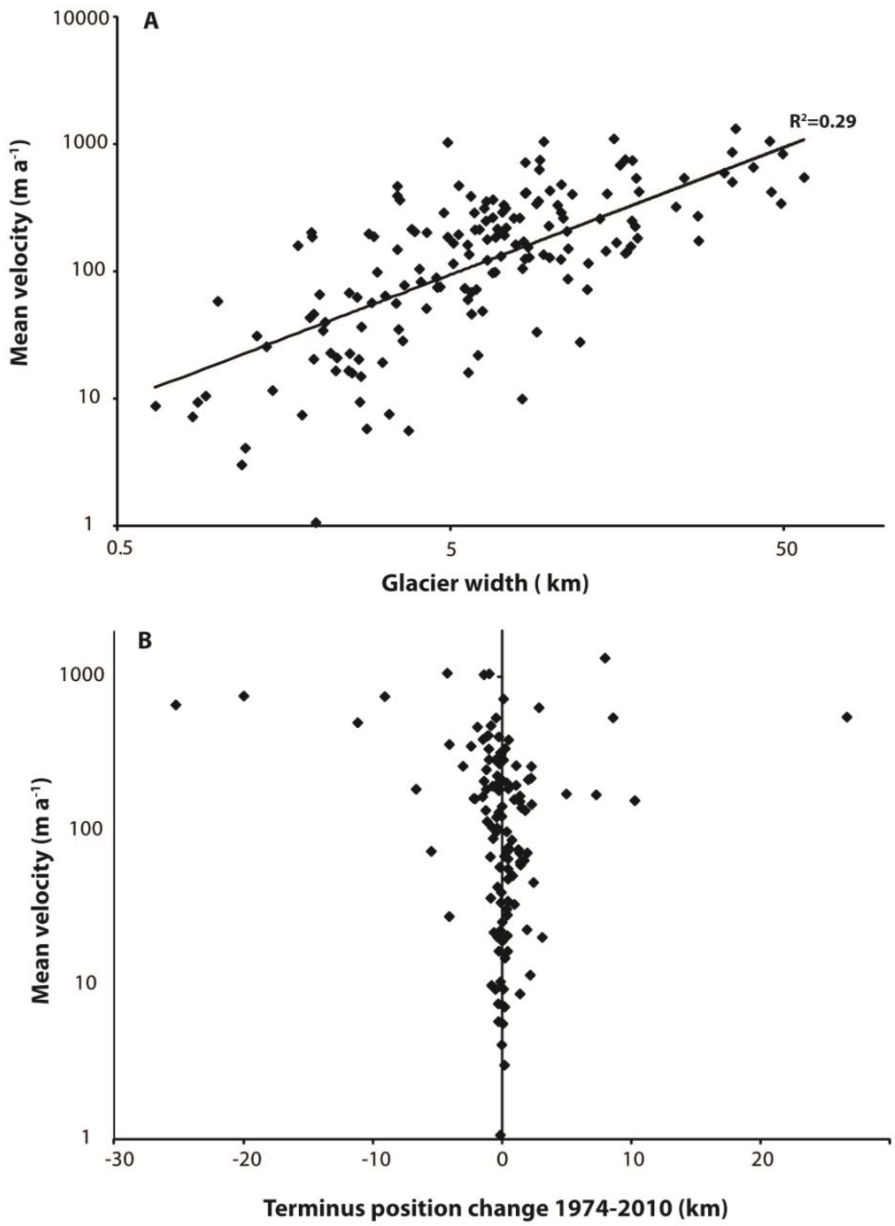
[#] P-values <0.05 are significant and highlighted in red

Supplementary Table 6: Wilcoxon statistical tests for significant differences between glacier terminus position change between 1990-2000 and 2000-2010 in each of the major drainage basins within the study area.

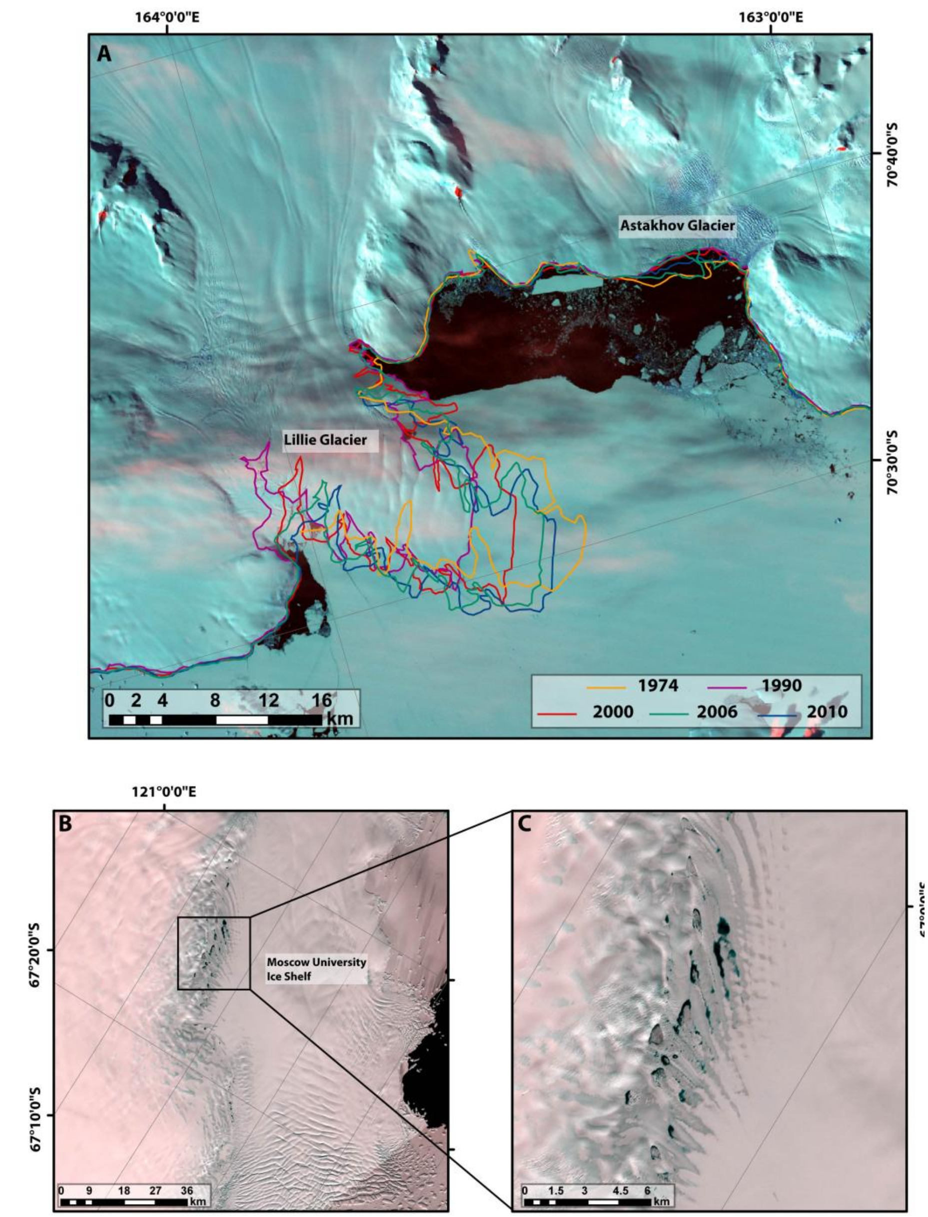
Sample	**Sample**	**Epoch**	***n***	**Rate of terminus position change (m a^{-1})**				**P-value#**
				Min.	**Median**	**Mean**	**Max.**	
DB12	Unpaired	1990-2000	7	-1591.4	8.9	17.5	1605.4	0.5628
		2000-2010	8	-255.1	44.9	281.5	1759.2	
	Paired	1990-2000	7	-1591.4	8.9	17.5	1605.4	0.3980
		2000-2010	7	-255.1	15.5	311.1	1759.2	
DB13	Unpaired	1990-2000	37	-265.8	54.9	65.8	359.7	**0.0000**
		2000-2010	39	-336.5	-63.6	-54.2	479.2	
	Paired	1990-2000	37	-265.8	54.9	65.8	359.7	**0.0004**
		2000-2010	37	-336.5	-63.6	-50.8	479.2	
DB14	Unpaired	1990-2000	35	-772.5	30.3	55.2	1054.2	0.7999
		2000-2010	38	-6913.7	19.4	-91.5	834.7	
	Paired	1990-2000	35	-772.5	30.3	55.2	1054.2	0.9217
		2000-2010	35	-6913.7	16.3	-106.8	834.7	
DB15	Unpaired	1990-2000	70	-289.5	12.6	30.5	265.1	0.8787
		2000-2010	71	-795.4	20.6	12.2	346.7	
	Paired	1990-2000	70	-289.5	12.6	30.5	265.1	0.3788
		2000-2010	70	-795.4	20.6	12.6	346.7	
DB16	Unpaired	1990-2000	19	-380.9	1.8	32.3	528.8	0.8167
		2000-2010	16	-778.2	10.9	-42.4	747.7	
	Paired	1990-2000	16	-380.9	4.5	42.6	528.8	0.7174
		2000-2010	16	-778.2	10.9	-42.4	747.7	

P-values <0.05 are significant and highlighted in red

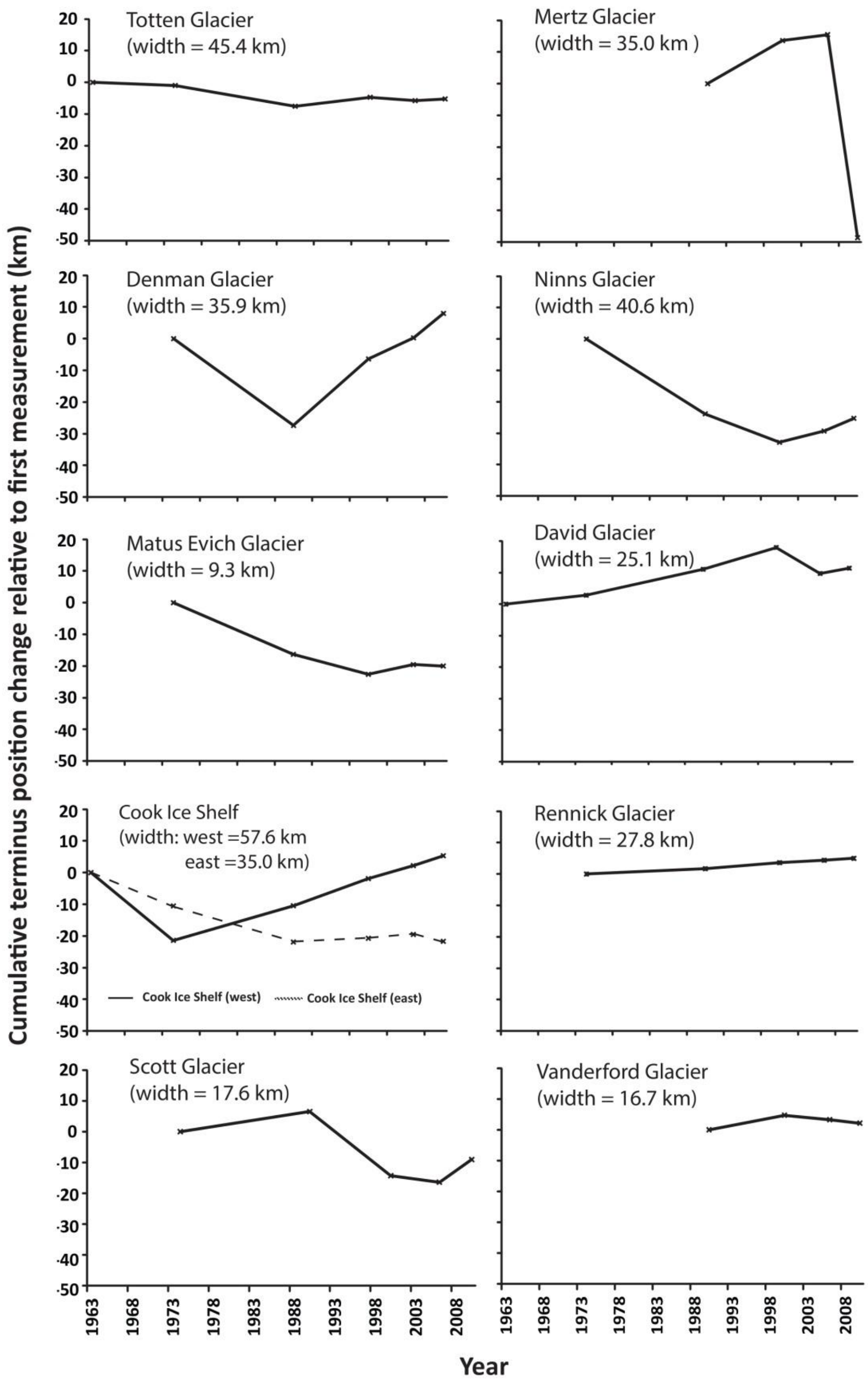
Supplementary Figures:



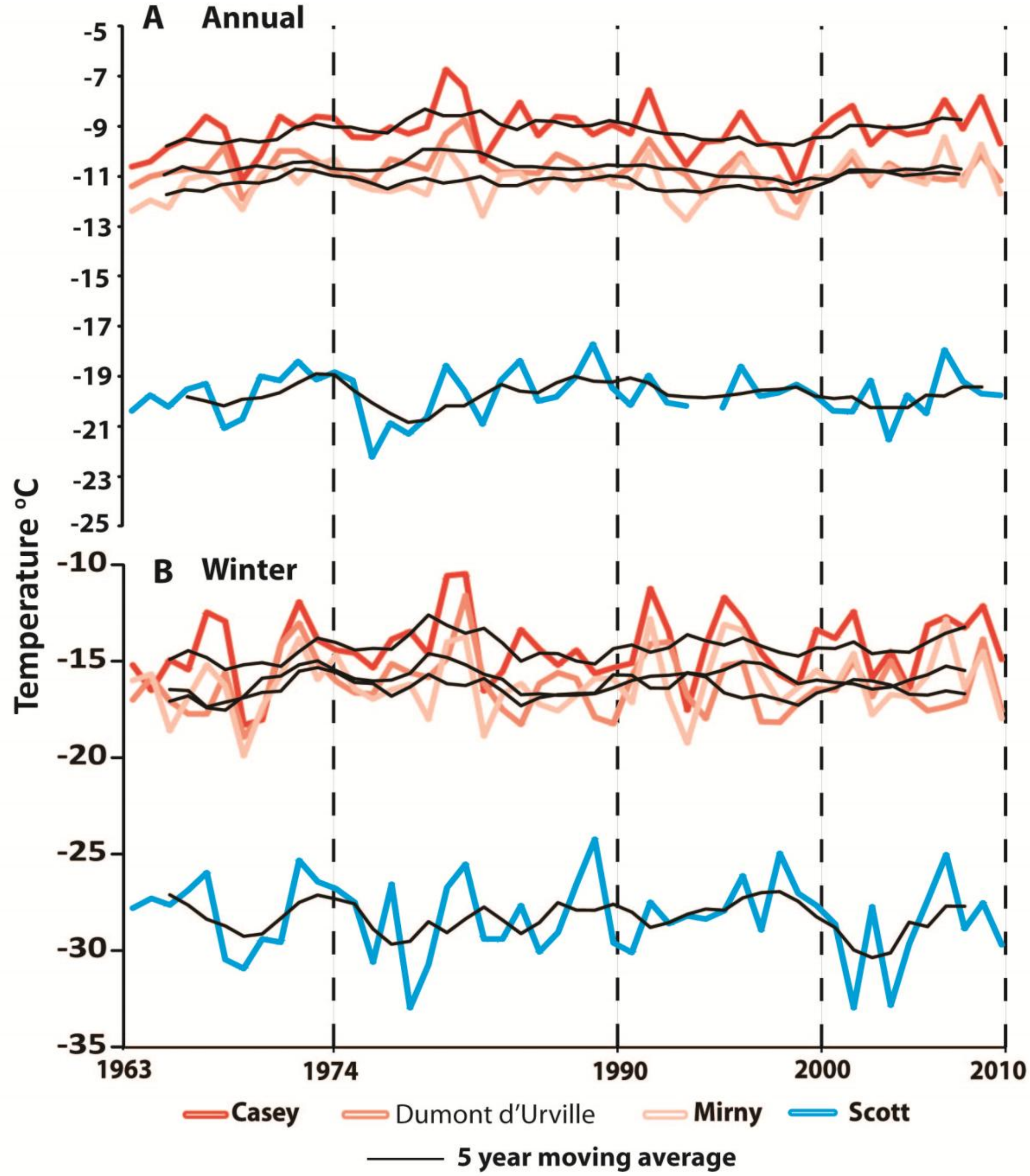
Supplementary Figure 1: Correlation between glacier width, mean velocity, and terminus position. The magnitude of advance or retreat is clearly dependent on glacier size (here expressed as width), which is correlated with glacier velocity (A). Thus, we find that glaciers which flow faster undergo the largest changes in terminus position, in both advance and retreat (B). Ice velocity data were obtained from a high resolution digital mosaic of ice motion in Antarctica[31,32]



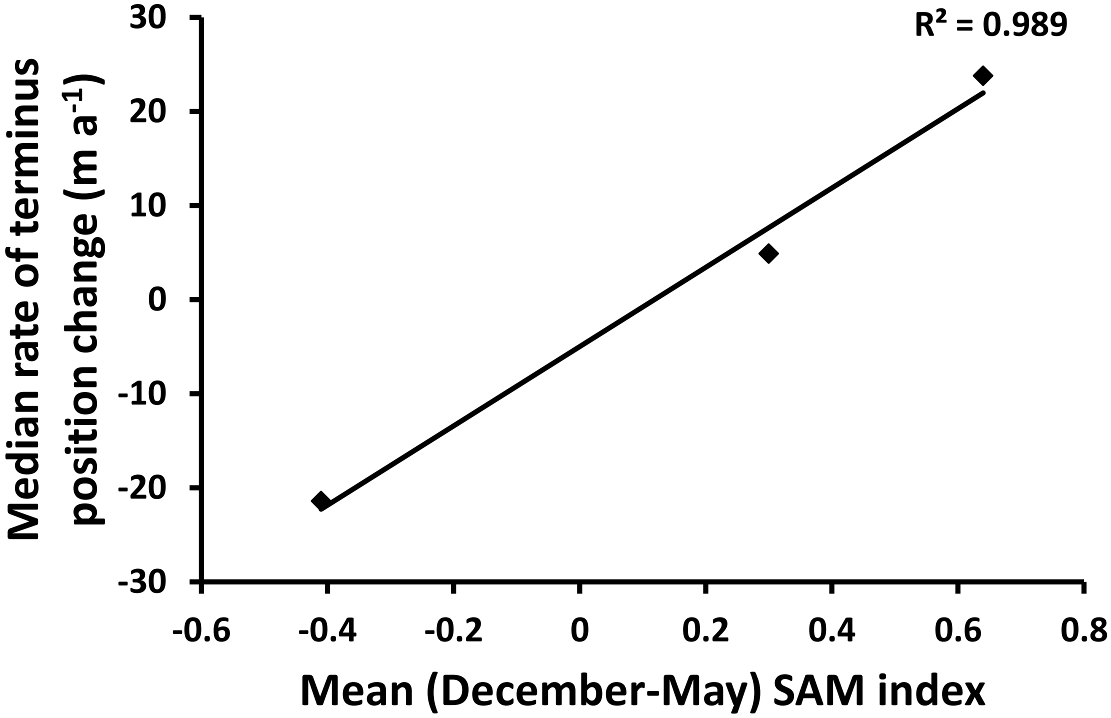
Supplementary Figure 2: Landsat satellite imagery showing fluctuations in terminus position on Lillie Glacier and Astakhov Glacier, Oates Land, and putative melt ponds on Moscow University Ice Shelf, Wilkes Land. Data from Lillie Glacier and Astakhov Glacier, follow the broad trends revealed in our analysis, i.e. retreat from 1974 to 1990, followed by advance during more recent epochs (A). The background is a Landsat image from the austral summer of 1990. Meltwater ponds on the surface of Moscow University Ice Shelf (B and C), located in between the two warmest stations at Casey and Dumont d'Urville, Wilkes Land. Such ponds may enhance the opening of crevasses on floating ice tongues close to the glacier terminus through a process of hydraulic-fracturing[21,22], supporting the observed link between glacier retreat and above average summer temperatures (Fig. 3, Supplementary Figure 6), as reported for similar studies on the Antarctic Peninsula[17].



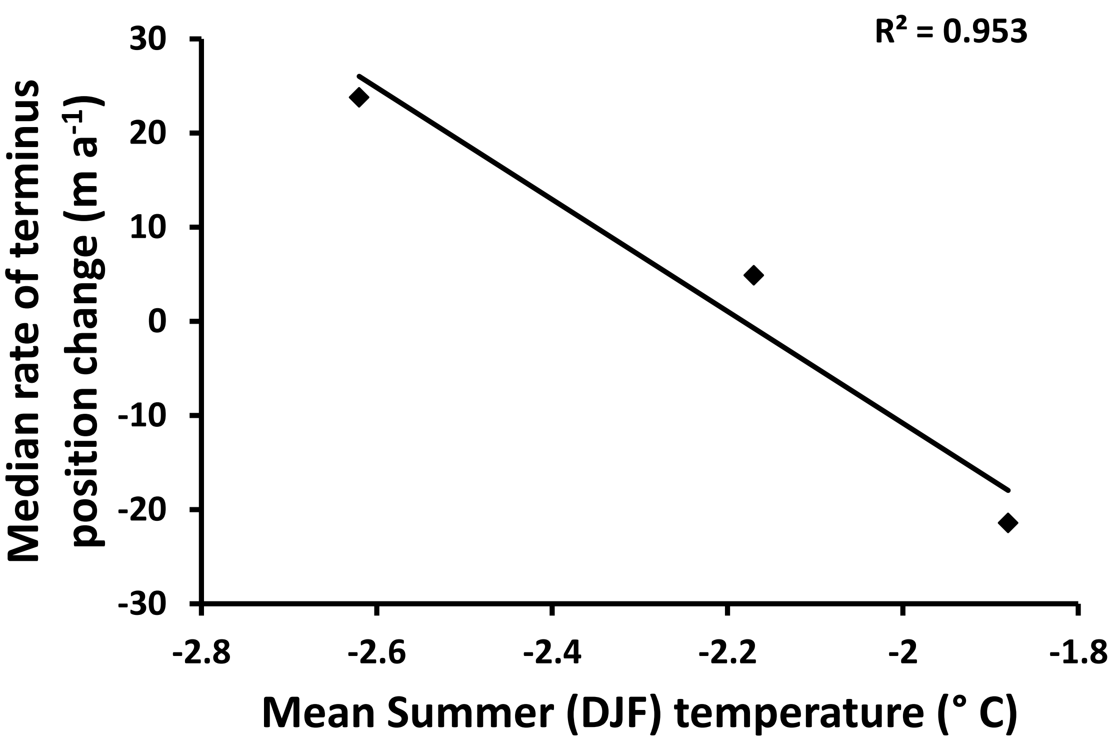
Supplementary Figure 3: Evolution of terminus positions with time on ten large, rapidly-flowing outlet glaciers. Note the large magnitude of change (10s of kms) associated with major (potentially stochastic) calving events and typically followed by re-advance. Locations shown on Figure 1.



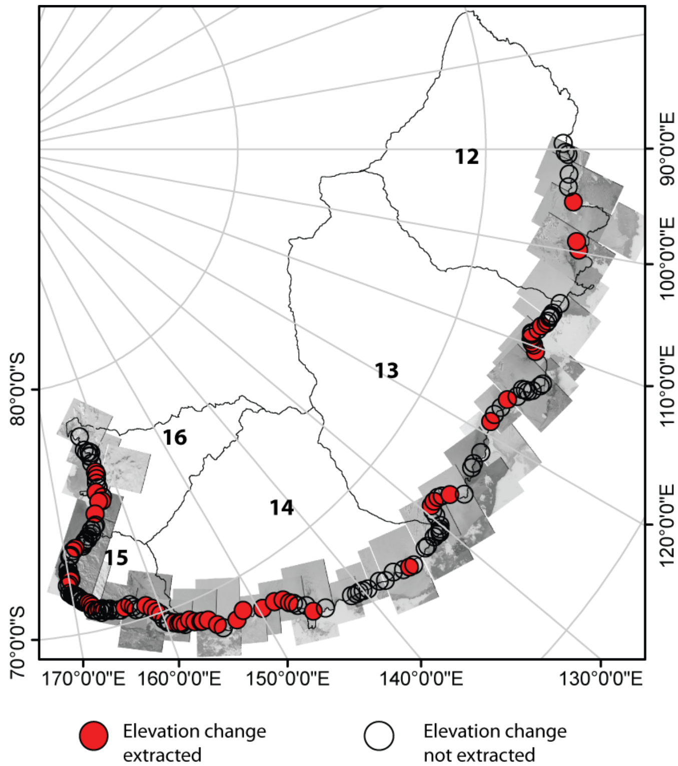
Supplementary Figure 4: Mean annual and mean winter air temperature trends from four East Antarctic stations within the study area. Mean annual temperatures are shown in (A). Mean winter temperatures (B) are calculated from mean monthly values of June, July and August.

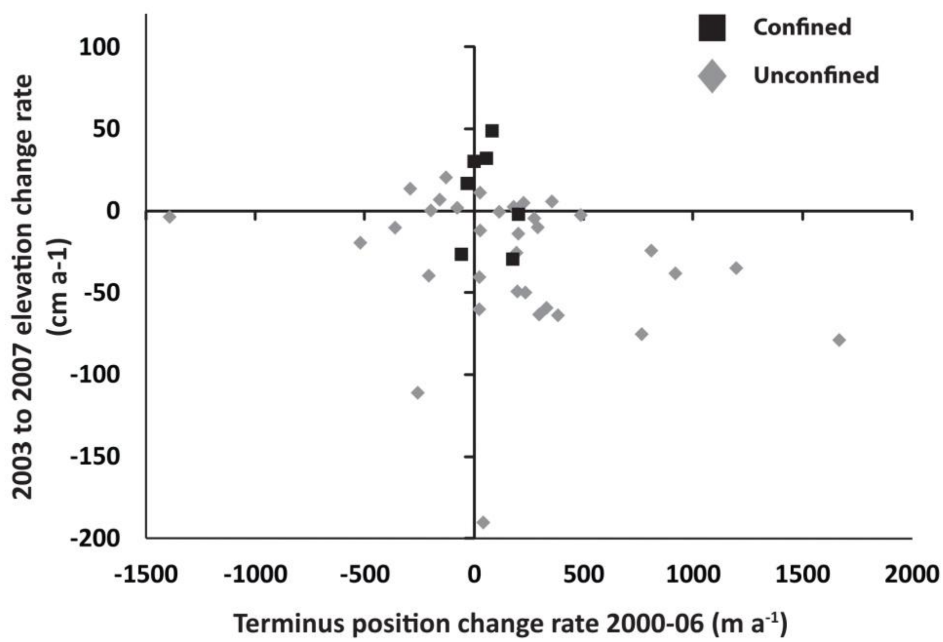


Supplementary Figure 5: Southern Annular Mode (SAM) index plotted against median terminus position change along the western South Pacific Coast. SAM data are derived from the mean austral summer/autumn (December to May) index and median terminus position change uses all Pacific-facing glacier measurements available for the epochs 1974-1990, 1990-2000 and 2000-2010. December to May represents the period of most significant change in the SAM index and has been shown to be contributing to near surface temperatures in East Antarctica[24]. With only three data-points, the relationship is necessarily tentative.



Supplementary Figure 6: Mean summer temperature plotted against median terminus position change for glaciers along the western South Pacific Coast. Mean austral summer temperatures are derived from monthly data (December, January, February) at the three Pacific stations, and median terminus position change uses all Pacific-facing glacier measurements available for the epochs 1974-1990, 1990-2000 and 2000-2010. With only three data-points, the relationship is necessarily tentative.





Supplementary Figure 7: Rate of glacier terminus position change (2000 to 2006) plotted against the rate of elevation change (2003 to 2007). (A) shows the location of glaciers where data on elevation change between 2003 and 2007 were extracted (see Methods), representing 24% of the total population spread throughout the study area. These were compared with our data on glacier retreat from 2000 to 2006, shown in (B). Laterally constrained versus unconstrained glacier termini are shown by black squares and grey diamonds, respectively.

Appendix

Table A1: Data on Glacier Terminus Position Change

[1]ID	[2]Name	[3]Ross or Pacific	[4]DB	[5]Width	[6]Terminus position change (m a^{-1})							[7]Velocity (m a^{-1})	[8]Elevation change (cm a^{-1})
					1963-2010	1974-2010	1974-1990	1990-2000	2000-2010	2000-2006	2006-2010		
1	Ferrar	R	16	6		-17	-49	-33	30	17	56	22	
2	Debenham	R	16	8			-26	-44		17		10	
3		R	16	1			6	8		20			
4	New	R	16	1						16			
5	Mackay	R	16	3			94	-33		249		148	
6	Hunt	R	16	1		-14	-47	2	9	-1	22	9	
7	Bens on	R	16	3		-8	-31	-3	15	15	15	8	
8	Hedblom	R	16	6				-1	18	10	30	16	
9	Mawson	R	16	8		191	185	187	207	224	182	171	5
10	Marin	R	16	3		-23	-12	-64	13	-34	80	37	
11	Harbord	R	16	4		13	43	7	-26	56	-143	78	
12		R	16	6		12	34	19	-28	55	-147	49	
13	Geikie	R	16	12		-107	27	-381	48	1140	-1501	28	
14	David	R	16	25	236	220	518	529	-651	-1393	402	540	-3
15	Larsen	R	16	5		-38	-88	120	-165	-463	257	166	
16	Reeves	R	16	8		-56	197	194	-778	200	-2168	162	-14
17	Priestley	R	16	17		271	114	133	748	1196	-112	157	-35
18	Campbell	R	16	7		-37	-25	-35	-64	-199	155	210	1
19		R	16	2		-9	9	10	-77	-128	6	20	
20	Tinker	R	16	6		5	1	-1	23	-11	78	68	

21	Aviator	R	15	12		25	341	-290	-216	-1106	1226	159	
22	Parker	R	15	3		29	-46	129	46	-362	707	197	
23		R	15	1		-5	-39	193	-193	-74	-336	58	
24	Icebreaker	R	15	13		50	72	72	-22	65	-127	72	
25	Wylde	R	15	6		-140	70	47	-795	-1543	102	74	
26		R	15	1		56	231	173	-441	-451	-430	12	
27	Suter	R	15	3		80	224	-11	-86	386	-653	20	
28	Ridgeway	R	15	9		25	78	38	-99	54	-282	33	
29	Mariner	R	15	17		39	71	-11	40			141	-276
30	Langevad	R	15	16		35	-82	117	160	210	100	168	
31		R	15	3		6	-24	28	35	36	35	15	
32		R	15	3		12	-4	26	24	31	15	35	
33		R	15	1		9	-12	13	47	40	54	31	
34	Tucker	R	15	9		36	41	-51	156	108	235	155	
35	Arneb	R	15	2		-9	37	-135	74	154	-57	43	
36	Edisto	R	15	3		-7	13	-44	2	-3	12	6	
37	Manhaul	R	15	4		11	20	-25	44	38	55	28	
38	-	R	15	2		0	0	3	-4	-7	1	7	
39		R	15	1		2	2	-1	8	5	14		
40		R	15	1		2	1	1	7	10	3		
41		R	15	1		6	4	6	9	4	18		
42		R	15	1		9	5	-4	40	46	29		
43		R	15	2		51	80	28	21	23	16	23	
44	Ironside	R	15	3		13	-303	265	347	295	432	187	-63
45	Burnette	R	15	3		37	30	13	88	75	110	63	
46	Moubray	R	15	10		47	-18	100	115	116	115	135	
47	Newnes	P	15	2		-3	-18	19	-4			1	
48	Murray/Dugdale	P	15	4		22	-18	44	79	75	86	51	

49	Egeberg	P	15	1		5	-1	6	18			3	
50	Nielsen	P	15	2		1	-5	11	1				
51	Ommanney	P	15	2		11	-28	-20	143	123	176	21	
52	Haffner	P	15	2		11	2	8	39				
53	Frank Newnes	P	15	1		37	30	15	84			9	
54	Shipley	P	15	1		1	-13	5	25			26	
55		P	15	4		2	1	6	-3			6	
56		P	15	1		9	9	3	15	14	16		
57		P	15	2		-1	-9	2	11	20	-4	40	
58	Frendley	P	15	2		21	-23	12	133	108	176		
59	Simpson	P	15	3		6	8	0	10	5	18	16	
60		P	15	2		1	1	-2	6	149	-232	0	
61	Denis Toun	P	15	6		38	21	5	125	55	241	60	32
62		P	15	3		3	-1	9	2	-13	18	9	
63	Barnett	P	15	5		33	-22	57	96	80	113	76	49
64		P	15	1		5	5	-2	14	26	2	7	
65		P	15	1		-3	-38	21	27	87	-33	11	
66		P	15	1		-1	0	6	-12	-4	-19		
67	Fortenberry	P	15	1		0	0	-8	7	121	-161	4	
68	O'Hara	P	15	2		63	-78	131	219	173	288	46	
69	Chapman	P	15	2		-3	-13	6	1	-24	38	23	
70		P	15	1		5	3	17	-8	-29	24		
71	Kirkby	P	15	3		44	-21	119	66	-768	1299	64	
72	McMahon	P	15	2		-2			-21	-15	-30	34	
73		P	15	2		11	-5	43	1	-42	83	17	
74	Zykov	P	15	8		-20	-24	8	-50	35	-212	105	
75		P	15	6				33	-6	-15	10	46	

76	Lillie	P	15	10		-10	-261	233	160	196	63	227	-49
77	Astakhov	P	15	5		-19	-65	15	21	63	-92	195	
78		P	15	3		12	-7	20	34	23	63	57	
79	Barber	P	15	4		55	-21	-25	239	285	158	214	
80	Gannutz	P	15	5		13	-78	80	75	90	48	75	
81	Rennick	P	15	28		138	110	150	171	192	150	173	-25
82		P	15	6		3	-11	-9	51	40	61	288	-190
83	Prior	P	15	6		14	-23	54	21	-60	101	389	-26
84	Suvorov	P	15	11		-28	-17	-73	22	4	40	289	
85	Manna	P	15	11		0	-4	10	-11	1	-22	124	
86		P	15	6		-35	-39	156	-330	69	-720	136	
87		P	15	6		37	-25	100	58	102	15	72	
88	Tomlin	P	15	7		62	84	134	-95	-294	101	220	14
89	Paternostro	P	15	3		-12	-32	29	-37			99	
90	McLeod	P	15	4		10	-28	21	68	354	-219	205	6
91		P	15	3		0	3	2	-7	-6	-8	19	
92	Jmaes Forbes	P	14	2		-7	-13	-2	-1	4	-6	17	
93	Matus Evich	P	14	9		-541	-1020	-491	325	764	-105	748	-75
94		P	14	5		-31	-114	-15	107	179	36	115	3
95		P	14	18		-33			66	273	-136	249	-4
96		P	14	7		30			284	329	241	264	-59
97		P	14	6		-65	-28	23	-266	-34	-493	354	17
98		P	14	8		-29	-33	12	-67	-159	51	415	7
99		P	14	5		-19	-28	-21	0	6	-7	89	
100	Cook ice shelf (W)	P	14	58	113	722	679	713	810	808	813	546	-24
101	Cook ice shelf (E)	P	14	35	-471	-310	-707	128	-90	175	-567	503	-29

102	Williams	P	14	15		0	-192	220	55	26	95	144	-12
103		P	14	49		7	-478	265	449	113	838	341	0
104	Ninns	P	14	41		-663	-1388	-773	835	918	773	655	-38
105		P	14	11		60	-29	241	-6	486	-373	261	-2
106		P	14	11		21	15	40	3	6	-1	87	
107		P	14	10				-67	213	185	259	128	
108	AAE	P	14	13				148	5	181	-332	116	
109	Mertz	P	14	35	-1298			1054	-6914	381	-16032	862	-64
110		P	14	6	20	-11	-12	30	-70	-64	-77	122	
111	Zelee	P	14	5	-4	-32	-10	-25	-82	-118	-39	186	
112		P	14	6	9	1	-14	9	16	-4	45	212	
113		P	14	2		-9	-54	31	19	68	-44	202	
114	Astrolabe	P	14	8		-31	-66	116	-160	-334	65	410	
115	Liotard	P	14	5	5	-13	-65	25	31	9	58	288	
116		P	14	8		3	15	-156	205	371	-8	715	
117	Marret	P	14	7				51	-19	-110	101	332	
118	Commandant	P	14	5		-37	-1	-95	-27	73	-159	1028	
119		P	14	11	-63	-23	-164	113	50	-7	120	480	
120		P	14	18	-21	-12	-90	68	21	201	-207	539	-2
121	Dibble	P	14	15	-40	-7	-84	14	103	179	5	407	
122		P	14	9	6			46	45	44	46	129	
123	Freeman	P	14	8	-2			19	-17	42	-75	261	
124	Harrison	P	14	11	-12			106	-88	-124	-51	151	
125		P	14	7	-13			54	6	-6	18	185	
126	May	P	14	6	-7			-92	201	103	308	213	
127		P	14	10	-13			118	351	560	124	430	

128		P	14	6	-28			24	217	-117	707	249	
129	Morse	P	13	7	-9			63	-42	-127	83	97	
130		P	13	7	-75			-15	-164	-348	107	291	
131		P	13	9	-13			256	-178	-39	-383	356	
132	Frost	P	13	15	-179			230	-209	-2	-512	1098	31
133		P	13	16	-6			206	213	25	488	682	11
134		P	13	14	-13			224	-107	-159	-31	259	
135	De Haven	P	13	12	-77			-266	-287	43	-772	403	
136	Holmes	P	13	50	26			-29	479	233	842	835	-50
137		P	13	18				215	175	274	29	225	
138	Thompson	P	13	7				59	-41	-26	-69	313	
139		P	13	6	13			57	110	23	284	178	
140		P	13	33	-108				-229			592	
141		P	13	46	6			-103	53	22	91	420	-60
142		P	13	11	-56			-69	-152	308	-576	206	
143		P	13	28	1	-5	97	-137	4	-80	88	271	
144	Totten	P	13	45	-110	-114	-407	217	-64	-259	132	1052	-111
145	Elliot	P	13	7		10	50	-28	-8	23	-35	99	
146	Williamson	P	13	5		-50	-156	22	36	648	-758	471	
147	Whittle	P	13	9		-27	-90	-21	77	-97	304	339	
148	Fox	P	13	6		-2	-17	138	-176	-240	-94	312	
149		P	13	8		-79	-172	55	-107	-214	31	262	
150		P	13	7				81	-24	-56	17	192	
151		P	13	8				70	47	43	51	125	
152	Vanderford	P	13	17	-39			360	-321	-363	-280	755	-10
153		P	13	17	-43			35	-114	-209	33	139	-39
154	Adams	P	13	18	-44			-24	-96	-130	-43	422	21

155	ANZAC	P	13	7	13			131	-90	-69	-124	216	
156		P	13	4	-21				-5	-79	110	83	2
157	Bond	P	13	7	-9			47	41	17	77	365	
158		P	13	4				60	-56	-152	92	202	
159		P	13	3				56	-74	40	-251	56	
160	Underwood	P	13	10		-26	-45	24	-60	289	-695	1042	-10
161	Hawkins	P	13	2		12	-23	171	-134	-352	263	66	
162	Robinson	P	13	2		-24	-55	50	-67	-102	-3	68	
163	Snedeker	P	13	6		-56	-134	27	-28	-6	-70	161	
164		P	13	4		-109	-208	195	-336	-287	-430	363	
165		P	13	4		-10	-36	18	-3	-54	95	104	
166	Du Beau	P	13	3		-40	-49	25	-108	132	-561	392	
167		P	13	7		-7	-4	36	-67	-51	-87	131	
168	Scott	P	12	18		-237	383	-1591	642	-522	1759	742	-19
169	Denamn	P	12	36		208	-1612	1605	1759	1667	1848	1318	-79
170	Roscoe	P	12	24		-3	37	-70	15	22	3	321	-40
171	Helen	P	12	9		77			74	-177	551	628	
172	Annenkova	P	12	18		-7	-13	9	-16	-1	-44	182	
173	Burton Island	P	12	2		-185	-428	-50	103	-48	452	186	
174		P	12	3				206	-255	-220	-337	466	
175		P	12	10				13	-71	58	-369	331	
	MIN			0.65	-1298	-663	-1612	-1591	-6914	-1543	-16032	1	-276
	MEDIAN			5.92	-12.9	0.7	-12.5	19.7	8.4	19.7	17.9	156	-13
	MEAN			8. 9	-61.2	-2.7	-43.3	43.1	-17.9	31.3	-77.4	225	-29
	MAX			58	236	722	679	1605	1759	1667	1848	1318	49

[1]Arbitrary glacier number used in this study

[2]Glacier name, where known, obtained from the Scientific Committee on Antarctic Research (SCAR) Composite Gazeteer of Antarctica (https://data.aad.gov.au/aadc/gaz/scar/)

[3]Glaciers are grouped according to whether they face the Ross Sea (R) or western South Pacific Ocean (P). See Figure 1 for location.

[4]For cross-reference to previous studies[10, 12], glaciers are grouped according to the major drainage basins

[5]Measured glacier width close to the terminus, i.e. within a few kilometres of the grounding line

[6]Glacier frontal position changes between two time-steps measured using areal changes within a reference box, divided by glacier width (see Methods Summary)

[7]Glacier velocity data obtained from Refs 30, 32. Note that the coarse resolution of the velocity data (900 x 900 m cell size) may have generated some unrealistically low values (e.g. <20 m a^{-1}) for some small glaciers (e.g. < 2 km wide), but this is unlikely to meaningfully influence the relationships shown in Supplementary Fig. 1.

[8]Glacier elevation change data obtained from Ref 1.

Table A2:Landsat satellite images used in this study

[1]Satellite	Path	Row	ID Number	Date
L1 MSS	64	112	LM10641121972333AAA04	Nov-72
L1 MSS	64	111	LM10641111972333AAA04	Nov-72
L1 MSS	118	107	LM11181071972334AAA04	Nov-72
L1 MSS	118	106	LM11181061972334AAA04	Nov-72
L1 MSS	53	116	LM20571161975319AAA04	Dec-72
L1 MSS	67	110	LM10671101972336AAA04	Dec-72
L1 MSS	102	107	LM11021071972354AAA04	Dec-72
L1 MSS	121	107	LM11211071972337AAA04	Dec-72
L1 MSS	89	107	LM10891071973028AAA05	Jan-73
L1 MSS	90	107	LM10901071973029AAA05	Jan-73
L1 MSS	109	108	LM11091081973031AAA04	Jan-73
L1 MSS	109	107	LM11091071973031AAA04	Jan-73
L1 MSS	109	106	LM11091061973031AAA04	Jan-73
L1 MSS	121	106	LM11211061973025AAA02	Jan-73
L1 MSS	76	109	LM10761091973051AAA05	Feb-73
L1 MSS	92	107	LM10921071973049AAA05	Feb-73
L1 MSS	124	107	LM11241071973046AAA04	Feb-73
L1 MSS	88	107	LM10881071973063AAA04	Mar-73
L1 MSS	88	108	LM10881081973063AAA04	Mar-73
L1 MSS	72	110	LM10721101973299AAA04	Oct-73
L1 MSS	94	107	LM10941071973303AAA04	Oct-73
L1 MSS	107	107	LM11071071973299AAA05	Oct-73
L1 MSS	114	107	LM11141071973288AAA02	Oct-73
L1 MSS	78	109	LM10781091973305AAA02	Nov-73
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L1 MSS	96	106	LM10961061973305AAA05	Nov-73
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L1 MSS	62	113	LM10621131974014AAA04	Jan-74

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L1 MSS	101	106	LM11011061974017AAA02	Jan-74
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L1 MSS	119	107	LM11191071974054AAA05	Feb-74
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L4-5 TM	105	107	LT41051071989316XXX03	Nov-89
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L7 ETM+ SLC-off	70	109	LE70701092006341EDC00	Dec-06
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L7 ETM+ SLC-off	73	109	LE70731092006362EDC00	Dec-06
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L7 ETM+ SLC-off	84	107	LE70841072006359EDC00	Dec-06
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L7 ETM+ SLC-off	93	107	LE70931072007010EDC00	Jan-07
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L7 ETM+ SLC-off	116	106	LE71161062007011EDC00	Jan-07
L7 ETM+ SLC-off	117	107	LE71171072007018EDC00	Jan-07
L7 ETM+ SLC-off	86	107	LE70861072007056EDC00	Feb-07
L7 ETM+ SLC-off	87	107	LE70871072007047EDC00	Feb-07

L7 ETM+ SLC-off	88	107	LE70881072007038EDC00	Feb-07
L7 ETM+ SLC-off	92	107	LE70921072007051EDC00	Feb-07
L7 ETM+ SLC-off	92	106	LE70921062007051EDC00	Feb-07
L7 ETM+ SLC-off	94	106	LE70941062007049EDC00	Feb-07
L7 ETM+ SLC-off	94	107	LE70941072007049EDC00	Feb-07
L7 ETM+ SLC-off	98	107	LE70981072007285EDC00	Oct-07
L7 ETM+ SLC-off	65	110	LE70651102007309EDC00	Nov-07
L7 ETM+ SLC-off	80	108	LE70801082007318EDC00	Nov-07
L7 ETM+ SLC-off	108	107	LE71081072007307EDC00	Nov-07
L7 ETM+ SLC-off	61	114	LE70611142007345EDC00	Dec-07
L7 ETM+ SLC-off	62	111	LE70621112007336EDC00	Dec-07
L7 ETM+ SLC-off	62	112	LE70621122007336EDC00	Dec-07
L7 ETM+ SLC-off	62	113	LE70621132007336EDC00	Dec-07
L7 ETM+ SLC-off	68	110	LE70681102007346EDC00	Dec-07
L7 ETM+ SLC-off	104	107	LE71041072007343EDC00	Dec-07
L7 ETM+ SLC-off	104	106	LE71041062007343EDC00	Dec-07
L7 ETM+ SLC-off	109	107	LE71091072007346EDC00	Dec-07
L7 ETM+ SLC-off	109	106	LE71091062007346EDC00	Dec-07
L7 ETM+ SLC-off	114	107	LE71141072007365EDC00	Dec-07
L7 ETM+ SLC-off	114	106	LE71141062007365EDC00	Dec-07
L7 ETM+ SLC-off	115	107	LE71151072007340EDC00	Dec-07
L7 ETM+ SLC-off	115	106	LE71151062007340EDC00	Dec-07
L7 ETM+ SLC-off	115	105	LE71151052007340EDC00	Dec-07
L7 ETM+ SLC-off	116	107	LE71161072007363EDC00	Dec-07
L7 ETM+ SLC-off	116	105	LE71161052007363EDC00	Dec-07
L7 ETM+ SLC-off	118	107	LE71181072007345EDC00	Dec-07
L7 ETM+ SLC-off	118	106	LE71181062007345EDC00	Dec-07
L7 ETM+ SLC-off	111	107	LE71111072008027EDC00	Jan-08
L7 ETM+ SLC-off	111	106	LE71111062008027EDC00	Jan-08
L7 ETM+ SLC-off	98	106	LE70981062008064EDC00	Mar-08
L7 ETM+ SLC-off	94	106	LE70941062009342EDC00	Dec-09
L7 ETM+ SLC-off	94	107	LE70941072009358EDC00	Dec-09
L7 ETM+ SLC-off	96	106	LE70961062010007EDC00	Jan-10
L7 ETM+ SLC-off	96	107	LE70961072010007EDC00	Jan-10
L7 ETM+ SLC-off	118	107	LE71181072010017EDC00	Jan-10
L7 ETM+ SLC-off	118	106	LE71181062010017EDC00	Jan-10
L7 ETM+ SLC-off	93	106	LE70931062010050EDC00	Feb-10
L7 ETM+ SLC-off	93	107	LE70931072010050EDC00	Feb-10
L7 ETM+ SLC-off	62	112	LE70621122010328EDC00	Nov-10
L7 ETM+ SLC-off	76	108	LE70761082010314EDC00	Nov-10
L7 ETM+ SLC-off	99	106	LE70991062010316EDC00	Nov-10

L7 ETM+ SLC-off	116	106	LE71161062010323EDC00	Nov-10
L7 ETM+ SLC-off	62	113	LE70621132010344EDC00	Dec-10
L7 ETM+ SLC-off	62	111	LE70621112010344EDC00	Dec-10
L7 ETM+ SLC-off	68	110	LE70681102010338EDC00	Dec-10
L7 ETM+ SLC-off	71	109	LE70711092010343EDC00	Dec-10
L7 ETM+ SLC-off	82	108	LE70821082010340EDC00	Dec-10
L7 ETM+ SLC-off	82	107	LE70821072010340EDC00	Dec-10
L7 ETM+ SLC-off	91	106	LE70911062010339EDC00	Dec-10
L7 ETM+ SLC-off	91	107	LE70911072010339EDC00	Dec-10
L7 ETM+ SLC-off	92	106	LE70921062010347EDC00	Dec-10
L7 ETM+ SLC-off	92	107	LE70921072010363EDC00	Dec-10
L7 ETM+ SLC-off	98	106	LE70981062010357EDC00	Dec-10
L7 ETM+ SLC-off	98	107	LE70981072010357EDC00	Dec-10
L7 ETM+ SLC-off	102	107	LE71021072010337EDC00	Dec-10
L7 ETM+ SLC-off	61	113	LE70611132011020EDC00	Jan-11
L7 ETM+ SLC-off	62	115	LE70621152011027EDC00	Jan-11
L7 ETM+ SLC-off	70	110	LE70701102011019EDC00	Jan-11
L7 ETM+ SLC-off	70	109	LE70701092011019EDC00	Jan-11
L7 ETM+ SLC-off	74	109	LE70741092011015EDC00	Jan-11
L7 ETM+ SLC-off	87	107	LE70871072011010EDC00	Jan-11
L7 ETM+ SLC-off	90	107	LE70901072011015EDC00	Jan-11
L7 ETM+ SLC-off	90	106	LE70901062011015EDC00	Jan-11
L7 ETM+ SLC-off	95	107	LE70951072011003EDC00	Jan-11
L7 ETM+ SLC-off	95	106	LE70951062011003EDC00	Jan-11
L7 ETM+ SLC-off	99	107	LE70991072011015EDC00	Jan-11
L7 ETM+ SLC-off	104	107	LE71041072011002EDC00	Jan-11
L7 ETM+ SLC-off	105	107	LE71051072011025EDC00	Jan-11
L7 ETM+ SLC-off	105	106	LE71051062011025EDC00	Jan-11
L7 ETM+ SLC-off	108	107	LE71081072011030EDC00	Jan-11
L7 ETM+ SLC-off	111	107	LE71111072011003EDC00	Jan-11
L7 ETM+ SLC-off	111	106	LE71111062011003EDC00	Jan-11
L7 ETM+ SLC-off	116	107	LE71161072011006EDC00	Jan-11
L7 ETM+ SLC-off	78	108	LE70781082011059EDC00	Feb-11
L7 ETM+ SLC-off	84	107	LE70841072011053EDC00	Feb-11
L7 ETM+ SLC-off	86	107	LE70861072011035EDC00	Feb-11
L7 ETM+ SLC-off	88	107	LE70881072011049EDC00	Feb-11
L7 ETM+ SLC-off	100	107	LE71001072011038EDC00	Feb-11
L7 ETM+ SLC-off	106	107	LE71061072011032EDC00	Feb-11
L7 ETM+ SLC-off	107	107	LE71071072011055EDC00	Feb-11
L7 ETM+ SLC-off	109	106	LE71091062011037EDC00	Feb-11
L7 ETM+ SLC-off	109	107	LE71091072011037EDC00	Feb-11

L7 ETM+ SLC-off	110	106	LE71101062011044EDC00	Feb-11
L7 ETM+ SLC-off	112	107	LE71121072011058EDC00	Feb-11
L7 ETM+ SLC-off	112	106	LE71121062011058EDC00	Feb-11
L7 ETM+ SLC-off	114	107	LE71141072011056EDC00	Feb-11
L7 ETM+ SLC-off	114	106	LE71141062011056EDC00	Feb-11
L7 ETM+ SLC-off	65	110	LE70651102011320EDC00	Nov-11
L7 ETM+ SLC-off	89	106	LE70891062011328EDC00	Nov-11
L7 ETM+ SLC-off	103	107	LE71031072011315EDC00	Nov-11
L7 ETM+ SLC-off	103	106	LE71031062011315EDC00	Nov-11

[1]MSS is the Multispectral Scanner, TM is Thematic Mapper, ETM+ is Enhanced Thematic Mapper Plus with Scan Line Corrector on (SLC-on) and off (SLC-off)