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IMMEDIATE SCIENTIFIC REPORT OF THE ROSS SEA ICEBERG PROJECT 1988/89

by

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CONTENTS

1. ABSTRACT

A large quantity of icebergs were again detected in the coastal fast ice zone between Cape Adare and Blue Glacier during a second year's survey from a dedicated RNZAF C-130. 1569 bergs were detected north of Drygalski Ice Tongue, only 13% fewer than last year. 312 bergs were detected between Nordenskjold Ice Tongue and Blue Glacier, 20% more than last year, due to localised production of mainly small icebergs. These changes are probably well within natural variability.

The significance of fast sea ice persisting into two or more summers became apparent this year. 1400 km^2 of ice between Mariner and Aviator Glacier Tongues in Lady Newnes Bay has trapped over 700 icebergs there for several seasons. Many of the thinner bergs have become covered with snow. The C-130 support has enabled far more of these bergs to be detected which is probably the main reason for the large apparent increase in the numbers of bergs seen last year. Similarly, sea ice remaining in a 5 km^2 area beneath a relatively fast moving area of glacier ice between Turks Head and Glacier Tongue has enabled a build-up of bergs forming the iceberg tongue reported last year.

Sea ice persistence provided further opportunities to quantify bulk detection rates by oblique aerial photography. Close to 79% of the bergs detected in Bay of Sails this year were in the same place last year. Comparisons with the 1987 bergs still present and last years data indicates that the bulk detectability in the SPOT image area was about 87% this year with poor surface definition and would have been about 94% under the good lighting conditions last year.

The supergiant iceberg B-9 has now drifted over kilometres around eastern Ross Sea. The formation and drift of B-9 have produced valuable new data on how icebergs are formed and the currents in Ross Sea. Another large berg calved from near Cape Crozier in early December 1988 drifted into eastern and out of western Sound. Its northward drift speed reached 14 km/day off Butter Point in early January.

2. INTRODUCTION

The Ross Sea Iceberg Project aims to determine the distribution, sources, movement and sizes of icebergs in the Ross Sea. These characteristics have previously not been well known but are important because icebergs are a significant part of both the Antarctic marine environment and the mass balance of the Antarctic ice sheet which effect the global environment. Icebergs are also a major natural hazard. Field work on the Project was completed this year after two seasons ground-based work (1983/4, 1984/5), and three other years of monitoring (1985/6, 1986/7, 1987/8). Previous Immediate Reports give more background to the work and results and conclusions from it.

3. PROPOSED PROGRAMME

Oblique aerial photography was planned, to cover icebergs in fast ice along the entire Ross Sea coast of Victoria Land (ca 1000 km) from a special RNZAF C-130 aircraft flying at 2400 m with additional photography on an opportunity basis in the pack ice zone between Ross, Beaufort, Franklin and Coulman Islands and north to Cape Adare. The scientific objectives of this programme were:

1) to monitor the distribution of bergs in known locations and elsewhere in fast ice along the entire western Ross Sea coast and in Iceberg Tongue (Ross Island), in particular to assess the significance of a very large increase in the quantity of bergs detected north of Drygalski Ice Tongue on 8/12/87;

2) to monitor the quantity and distribution of bergs in the pack ice zone, particularly across the main iceberg drift paths and upcurrent of McMurdo Sound (and if possible to determine berg types and concentration for comparison with data for the fast ice zone);

3) to determine movement patterns of bergs by comparison with last year's photography and identification of iceberg sources or other characteristics.

Monitoring the drift of supergiant iceberg B-9, which calved off the eastern Ross Ice Shelf in October 1987 was continued throughout the year using data supplied by the US Navy-NOAA Joint Ice Center in Maryland, USA. A visit to the Weather Division at MAC Center, McMurdo Station, was also planned to obtain recent satellite images of the pack ice surrounding it.

4. ITINERARY

2 December: Keys to Scott Base. Briefing with RNZAF pilots, navigator etc in evening.
3 December: C-130 flight postponed due to bad weather. Keys plus J. Alexander and K. Paterson (Scott Base) visit Iceberg Tongue.
4 December: RNZAF C-130 flight monitoring icebergs (Fig. 1). Visit MAC Center in evening.
5 December: Keys to NZ, making further iceberg observations en route.

5. SCIENTIFIC ACHIEVEMENTS

5.1 Iceberg monitoring from RNZAF C-130

Distribution:
A large quantity of icebergs were again detected in the coastal fast ice zone between Cape Adare and Blue Glacier. Berg locations were similar to those delineated previously (Tables 1, 2). 1569 bergs were detected north of Drygalski Ice Tongue, only 13% fewer than last year (Table 1). 312 bergs were detected between Nordenskjold Ice Tongue and Blue Glacier, 20% more than last year, due to production of mainly small icebergs (Table 2). 48 bergs were seen outside fast ice, although up to 8 of these may have been repeat sightings (Tables 2, 3). Altogether, about 2100 bergs were detected, 20% fewer than last year. The distribution of bergs in Robertson Bay and up the Oates Coast seemed generally similar to previous years.

The bay between Cape Washington and Campbell Glacier Tongue in northern Terra Nova Bay continues to yield valuable baseline data, although berg numbers are relatively low. The bay contained 18% fewer bergs than last year after last year's 340% increase above the previous 3-year average (38) quantity of bergs detected (Table 4). Moubray Bay contained up to 41% fewer bergs this year although undercast cloud this year makes the comparison of lesser value.

The total count for the coast between Nordenskjold Ice Tongue to Spike Cape was up 44% on last year (Table 4). Year to year changes are shown in Figure 2.

Bergs visible in the main iceberg drift paths up-current of the Victoria Land coast were too few and far away from the aircraft to give reliable information on concentration, shape or size. However, the information obtained was similar to last year and consistent with our previous conclusions.

Re eat high quality photos in Lady Newnes Bay showed that 1400 km^2 of ice between Mariner and Aviator Glacier Tongues has trapped over 700 icebergs there for several seasons. Many of the thinner bergs have become covered with snow. In fact more than about 90% of bergs detected in Lady Newnes and Wood Bays this season were also there last season. There was about 20% difference between the 1987 and 1988 repeat counts of these same bergs in Lady Newnes Bay.

Specific berg changes:
"Landsat" berg (DSS/84-1 to CR/87-9) and "Helen" berg (Mackay Glacier Tongue to 83-24 to CA/86-2), whose positions have been known since 1975 and 1982 respectively, were not present this year. "New" berg (New Glacier to 83-27 to 83-27 to GI/88-5) and Mackay Glacier bergs still grounded along the southern edge of "Iceberg bank" near Fry Glacier are now the oldest documented bergs, originating in calving events in 1982/83. However, other bergs are probably as old or older, including berg no. BS/88-47 (alias "Lynn" or 83-58) and several others in Bay of Sails, plus at least three bergs at Cape Roberts and some in Iceberg Tongue (see below). The longest bergs in the fast ice zone are now two new horizontal tabular bergs (DG/88-4 and SC/88-2) between Glacier and Spike Cape. These bergs are 2-3 km long with freeboards of 20-30 m and 10-15 m respectively.

Movement patterns:
A small number of bergs were tracked between 1987 and 1988. Three drifts of less than 5 km past Marble Point, at Cape Roberts and in Bay of Sails produced similar information on local drifts as previously. A drift of about 2 km of berg from off Cape Phillips westwards into Mandible Cirque may represent a similar local drift or eddy. An uneven tabular berg (DP/88-9) off Daniel Peninsula probably came north up the coast from one of the glaciers in Lady Newnes Bay, possibly Borchgrevink Glacier Tongue. No Mackay Glacier Tongue bergs were positively identified outside the main monitoring area. A further possible Mackay berg was present near Cape Washington but again similarities with bergs calved from Campbell Glacier Tongue preclude definite drift identification.

Bulk detection rates:
Sea ice persistence provided further opportunities to quantify bulk detection rates by oblique aerial photography. Close to 79% of the bergs detected in Bay of Sails this year were in the same place last year (or vice versa, 83% of the 1987 bergs were still in the same places in 1988). Only 6% of the 1987 bergs were able to drift out in the 1987/88 open water season. Apparently, the sea ice within 1-2 km of the shore in the southern two-thirds of the Bay did not break-out, consistent with observations on the ice by Alex Pyne (personal communication). Comparisons with the 1987 bergs still present and last years data indicates that the bulk detectability in the area of the 11/11/87 SPOT image was about 87% this year with poor surface definition and would have been about 94% under the good lighting conditions last year.

This (90±4)% rate for detecting icebergs using oblique aerial photos taken with a 600x450 mm camera from the flight deck of a C-130 at 2400 m can be directly compared with bulk detection rates determined last year. A rate of 94% was obtained using near-vertical aerial photos taken using a 35 mm Pentax camera from a helicopter at 2400 m. Rates of for all icebergs wider than 10 m and 100% for icebergs wider than 30 m were obtained using a SPOT panchromatic band image with a 10x10 ground sampling interval.

5.2 Icecube Iceberg Tongue

The visit to Iceberg Tongue was made on an opportunity basis to interpret last years aerial photo, determine the sea ice type and make reconnaisance measurements of tongue and berg dimensions. The tongue is 2 km wide and up to a km long. It contains about 50 bergs longer than about 30m, the size decreasing towards the south due to the feeder glacier flowing round and over a rock bluff near the Glacier Tongue. Complex shearing interaction occurs between the tongue and the sea ice especially to the south. One uneven tabular berg and three irregular shaped bergs were produced and added to the tongue between 8/12/87 and 4/12/88.

5.3 B-9 and "Comma" bergs

The supergiant iceberg B-9 has now drifted over 1000 kilometres around eastern Ross Sea. The formation and drift of B-9 have produced valuable new data on how icebergs are formed and the currents in Ross Sea. Ice shelf rifting seems confirmed as important

to the calving process. B-9 has been pushed at an average speed of about 2.5 km/day by a succession of ocean currents. Between late June and mid December 1988 it went round in a huge circle, over 100 kilometres across. This may be the first proof that a huge current gyre exists in the Ross Sea.

A large comma shaped berg calved from the Ross Ice Shelf at Cape Crozier in early December 1988, as was called Comma berg by the staff of Weather Division at MAC Center (Bill McIntosh and Robert Writner, personal communications). During December it drifted generally west and passed between and Ross Islands into McMurdo Sound in early January 1989. This drift is the first direct verification that we know of for our deductions that the western Ross Ice Shelf is the source of many of the "Ross Ice Shelf" type bergs observed in the fast ice zone south of the Nordenskjold. Its subsequent drift at up to 14 km/day (Table 5, Figure 3) has provided valuable comparisons with our previous deductions of slower mean drift velocities in the fast ice zone.

6. PRELIMINARY CONCLUSIONS

1) The special C-130 flights over the last two seasons have enabled far more of the numerous bergs normally present in fast ice north of Cape Washington to be detected. This is probably the main reason for the large apparent increase in the numbers of bergs seen last year.

2) There have been three to four times as many bergs in the bay between Cape Washington to Campbell Glacier Tongue over the last two seasons than were present in the previous three years. This may have been due to localised bergs entering the bay. Such clusters are not uncommon in the pack ice zone (eg Table 3). The year to year changes in berg quantities, summarised in Table 4, are probably well within natural variability.

3) The significance of fast sea ice persisting into two or more summers became apparent in several ways this year. It has trapped more bergs for longer than usual south of Butter Point and in Bay of Sails, as well as in Lady Newnes Bay and Wood Bay. Year to year changes in quantities of bergs in these areas need to be interpreted with caution.

4) The 20% difference between repeat counts of the same bergs remaining in Lady Newnes Bay for at least two years indicates that our survey effort in this large area has been insufficient to give an accurate census. The long residence time due at least partly to persistant fast ice suggests that annual surveys of this area are unnecessary.

5) Bulk detectability of icebergs from oblique aerial photography was able to be measured in Bay of Sails where fast ice persisting since 1987/88 meant last year's data could be used for comparison with this year's data. The detection rate, (90±4)% is similar that for other methods used.

6) No change was detected between the positions of the larger southern and outermost bergs in Iceberg Tongue. These bergs are quite ablated and have been in the tongue

for several years. From its ablated appearance and uneven surface the fast sea ice in the vicinity also appears to be more than several years old. Sea ice remaining in a 5 km^2 area beneath a relatively fast moving area of glacier ice between Turks Head and Glacier Tongue has enabled a build-up of bergs forming the iceberg tongue.

7) The drift of large icebergs calved from Ross Ice Shelf has verified and extended our picture of regional current patterns and iceberg sources in Ross Sea.

7. PUBLICATIONS

Five publications are in press at present, including two major reviews. Two are in volume 12 of Annals of Glaciology. A manuscipt on B-9 has been submitted to Iceberg Research. A manuscript on detection, interannual variability, size distributions and volumes of bergs is being prepared for Cold Regions Science and Technology.

As in previous years the iceberg data in Tables 1-3 will be sent to the Norwegian Polar Institute. Data is presented to the Institute on standard blue forms and is used in the Antarctic iceberg database managed by Olav Orheim, the chairer of the Glaciology Working Group of SCAR. The database is providing information which is very relevant to understanding the mass balance of the Antarctic ice sheet, the possible influence of the greenhouse effect on Antarctica and hence the rest of the world, and iceberg distribution Antarctic-wide.

8. FUTURE WORK

This was the last year of fieldwork for this project. Future work will be finishing the writing up (as above). B-9 and hopefully Comma bergs will continue to be monitored using satellite-derived data.

A proposal to look for early consequences of the greenhouse effect on the equilibrium of Ross Ice Shelf, particularly its dynamics relating to bottom melting and ice front position, has been given a high priority by the Department of Conservation. Discussions at Harewood and McMurdo with Dr Charles Swithinbank, world renown glaciologist formerly with the British Antarctic Survey, confirmed the viability and overall practicality of the proposal. It would be an international project and a contribution to IGBP. Intensive use of satellite imagery and radio echo sounding would be required during the first and fifth years of such a project. 15-20 hours helicopter time and probably a few hours C-130 time, as well as 1-2 skidoos and camping equipment would also be required in these years.

Acknowledgements

I am grateful to the Department of Conservation, Antarctic Division DSIR, RNZAF and to the pilots (Bruce Gault, John Marriot), navigator (Edward Poot) and crew of the C-130 for supporting this project. The C-130 support was again invaluable. Thanks also to Peter Wilson and Bruce Thomas for their excellent photography and photographic assistance and to staff at Scott Base.

Figure 1. Map of western Ross Sea showing the C-130 routes flown on 4.12.87 (lines shown dotted and solid) and north of Moubray Bay en route to New Zealand on 5.12.87. The Iceberg Project's work was concentrated flying southwards over the fast ice zone (solid line), although worthwhile information was obtained over the pack ice between Ross, Beaufort and Franklin Islands.

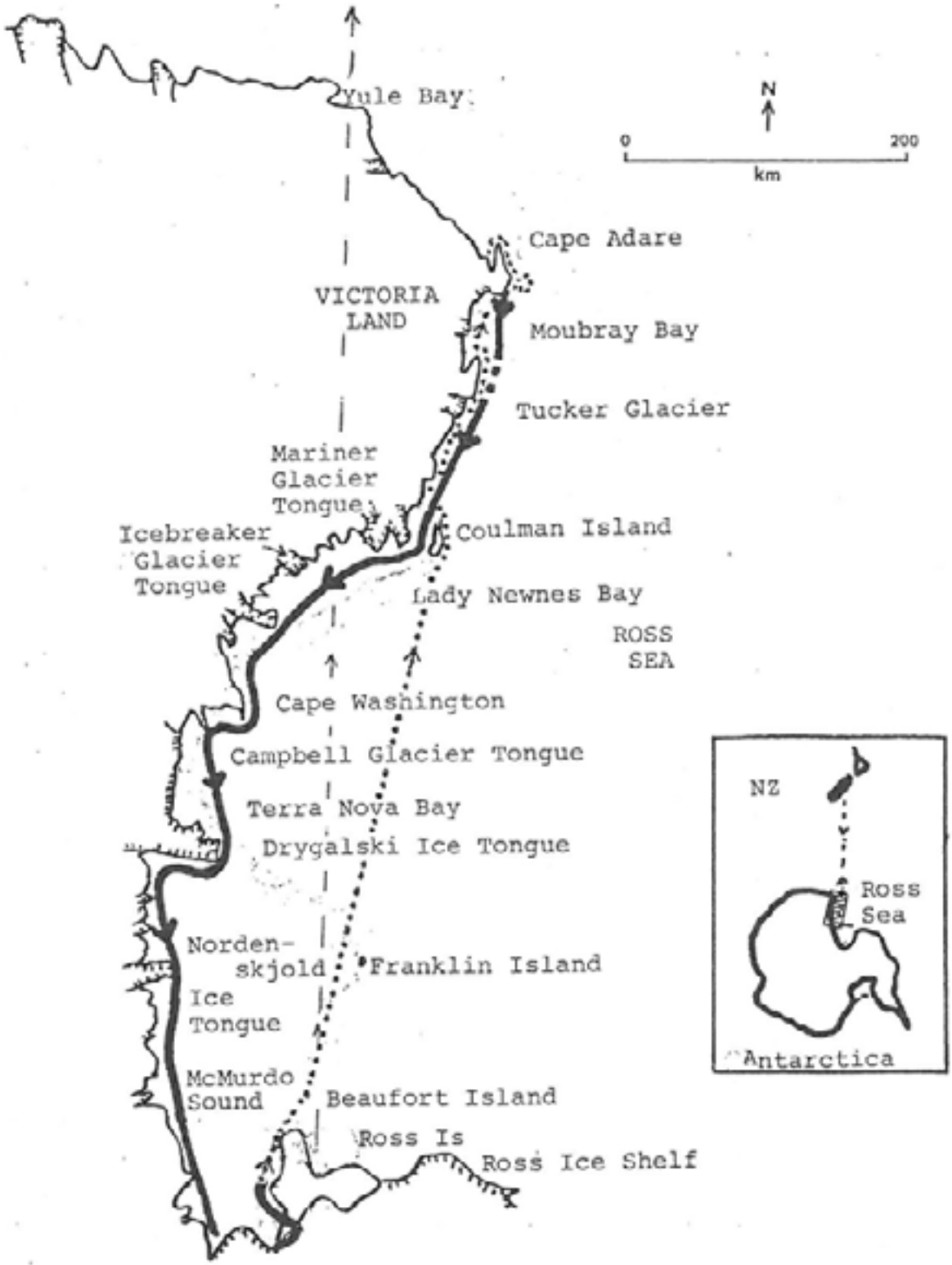
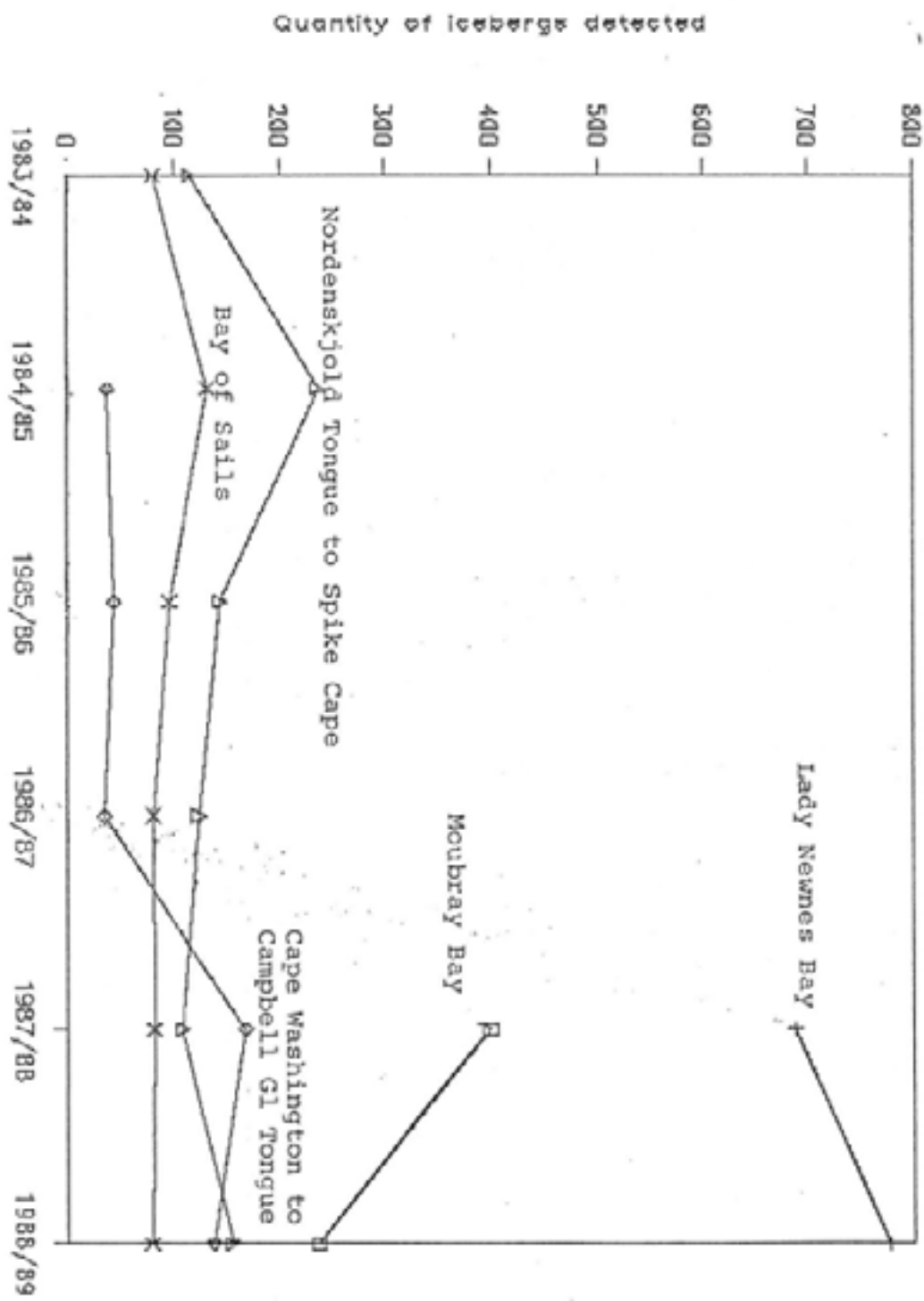


Figure 2. Multiyear records of iceberg quantities along western Ross Sea coast



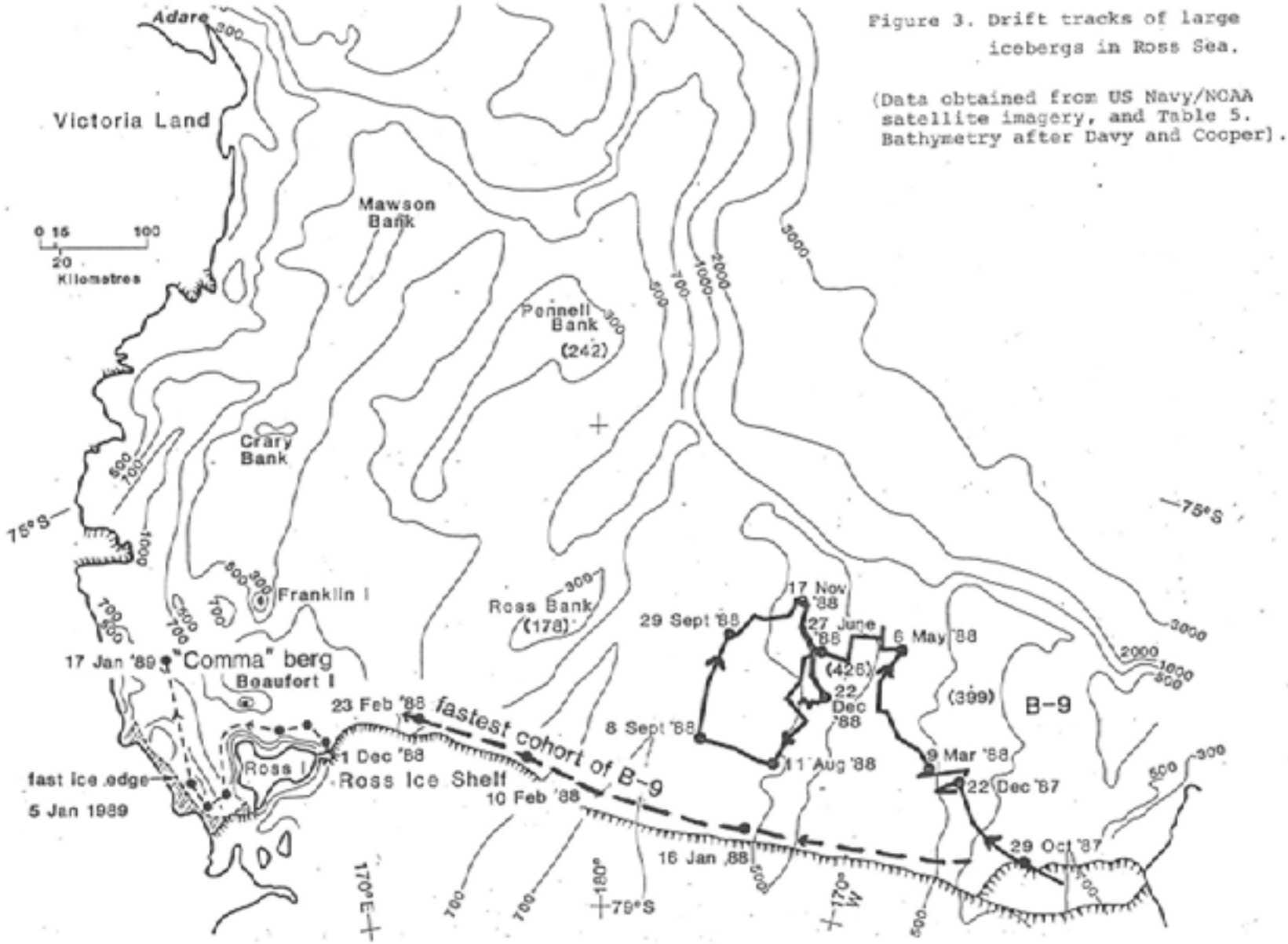


Figure 3. Drift tracks of large icebergs in Ross Sea.

(Data obtained from US Navy/NOAA satellite imagery, and Table 5. Bathymetry after Davy and Cooper).

Table 1. Census of icebergs in fast ice along the Victoria Land coast north of Drygalski Ice Tongue, from RNZAF C-130 flight, 4 December 1988.

(+ shows some distant bergs not resolved, u shows undercast cloud present which obscured some bergs, v indicates count made visually, not from photos.)

Position in fast ice strip	Locations of icebergs	Number of icebergs detected in 1988	Sublocations	8/12/87	4/12/88
71°18'S, 170°13'E to 71°30'S and 170 31'E	Cape Adare to saddle south of Hansen Peak	50±20(v)			
71°59'S, 170°E to 72°26'S, 169°45'S, and 170°21'E	Cape Roget to C. Hallett(1)	236+ (some u)		399+	236+
			NE Moubray Bay	28	40
			NW Moubray Bay	50+	15
72°19'S and 170°21'E to 73°16'S and 169°30'E	C. Hallett to C. Wheatstone	100±20(v)	SE end of Burnette GT) E side	ca 20	30(u, some v)
	C. Wheatstone to Tucker Gl.	22+(u)	to Hedgehog Is) W side	ca 115	72+
	C. Daniel to Tucker Gl. area	6 (v)	Hedgehog Is – C. Hallett	168	60+(u)
	C Daniel to C. Phillips	19+	Edisto Inlet	8	3+
	C. Phillips to C. Jones	24+	NE of C. Hallett	10	16(u)
ca.73°16'S and 169° 30'E to 73°45'S and 168°25'S	Glacier Strait to Mariner G.T.	96+		48	95
			SW Cape Coulman Is.	17	25
			Gl Strait-Borchgrevink G.T.	31+	69+
168°25'E to 165°40'E and from 74°S north to coast (73°30'S to 73°50'S	Lady Newnes Bay	776 plus ca.110+ inshore		688+85+	776+110+
			Mariner G.T.–Icebreaker G.T.	208+	294+(2)
			Ditto : inshore	ca 15+	ca 40+
			Icebreaker-Aviator G.T.	480+	482+
			Ditto : inshore	ca 70+	ca 70+
74°S and 166°30'E to 74°30'S, 165°30'E	Wood Bay	99+		127+	99+
			Aviator-Tinker G.T.	60+	55+(2)
			Tinker-C. Washington	67+	44+
165°24'E to 164°35'E and from ca 74°40'S north to coast (74°30'S)	C. Washington to Campbell Glacier Tongue	137+		167+	137+
			E of Markham Is – Oscar Pt	82+	67
			W of " "	70)	40
			Near Campbell G.T.	15)	
			By and off C. Washington	(incl)	30
74°40'S, 164°25'E to ca.74°45'S, 164°10'E	Eastern Gerlache Inlet	5(v)			
	TOTAL	1569 plus ca.110 discernable nearshore in distance (cf. 1797 + 85 in 1987).			

Footnotes: (1) Similar number of bergs to those present in 1987 in pack ice near Capes McCormack, Hallett and outer Possession Is.
(2) In first year fast ice in 1988 there were 36 bergs in 1987 and 42 in 1988 off the Mariner–Icebreaker Tongues, and 32 and 21 respectively off the Aviator-Tinker Tongues.

Table 2. Census of icebergs in fast ice south of Drygalski Ice Tongue (including main monitoring area south of Nordenskjold Ice Tongue) from RNZAF C-130 flight, 4 December 1988

(u indicates undercast cloud present, p indicates poor surface definition, v indicates visual count)

Position of fast ice edge (approx)	Locations of icebergs	Number of icebergs detected 1987	1988
75°31'S, 163°30'E to 75°10'S	Drygalski Ice Tongue to Nordenskjold I.T.	17	27+(1)
76°10'S, 163°30'E to 76°51'S, 163°20'E	Nordenskjold I.T. to "Cape Iceberg"	4+	49+(1)
	"Iceberg bank" area		
	- north and central parts	12	4
	- southern edge	24	26
	East and SE of Fry G.T.	3	6
	Tripp Is to Cape Ross	5	3
	Cape Ross to Gregory Is	3	1
	Gregory Is to Cape Archer	8	7
76°51'S, 163°20E to 77°19'S, 164°E	Granite Harbour		
	- north and west parts	10	10
	- south and east parts	-	5(v)
	"YUWAE bank"	0	0(v)
	Cape Roberts	20	21+(1)
	Debenham Glacier to Dunlop Is	9	12
	Dunlop Is and Strait	9+	4+
	South of Dun. Is group to Spike Cape	0	7
77°19'S, 164°E to 77°30', 164°30'E	Bay of Sails	81+	78+
	Gneiss to Marble Points	13+	8
	Bernacchi Bay	13+	6
	Cape Bernacchi	14	6+
	"Drillhole submarine spur"	2	[2][2]
77°30'S, 164°30'E to 77°52'S, 164°45'E (not edge of fast ice)	New Harbour	9+	4+[p]
	Butter Point to Strand Moraines	ca 7	4 (u,p)
	Blue Glacier	ca 10	49+(1)
	Others	2	-
	Main monitoring area, total	ca 257+	312+
	South Victoria Land coast, total	ca 267+	335+
	Beaufort Island icefoot etc	6	20
	Franklin Island icefoot etc	4	-
	Lewis Bay (fast ice only)	18+	-
	C. Evans to Erebus G.T.	3+	3
	"Icecube Iceberg Tongue"	ca 50	ca 54
	TOTAL	ca. 357+	416+

Sublocations	1987	1988
	17+	27+
Geike Inlet-Lamplugh Is	3+	2+
L. Is-Cheetham Gl	2	1
Cheetham-Harbord Gl	1	13+(1)
Bay south of Harbord Gl	7	5
C. Hickey-Nord. I.T.	4	6

Footnotes (1) A significant proportion of these bergs were from recent calvings of piedmont or glaciers.

Table 3. Icebergs counted in pack ice cone

Cape Bird to Beaufort Is		6 ± 2	(4/12/88)
Beaufort Is to west of Franklin is		4	(4/12/88)
Terra Nova Bay polynya		2	(4/12/88)
Capes Crozier -Tennyson to Franklin Is		8	(5/12/88)
Large floes south of Lady Newnes Bay		26(1)	(5/12/88)
Southern Ocean at	63°05'S, 169°55'E	40+ in 15M radius	
	62.5°S, 169.9°E	50 in 15M radius	

(i.e. loose cluster containing about 70 bergs per 1000 km^2).

(1) 132+ bergs were detected in such floes last year.

Table 4. Summary of interannual iceberg monitoring (1983/84 to 1988/89) showing the quantities of icebergs detected each summer in key areas in the fast ice zone along the coast of western Ross Sea, and recent changes in the quantities (percent) in these areas.

AREA	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	Average '84/5–'86/7	Change % '87/88 cf '84/5–'86/9 average	Change % '88/89 cf '87/88
Moubray Bay					399	236			–41
Glacier Strait to Cape Washington					863	970			+12
Lady Newnes Bay only					688	776			+13
Cape Washington to Campbell Glacier Tongue		37	43	34	167	137	38	+339	–18
Nordenskjold Ice Tongue to Spike Cape	116	237	144	124	108	155	168	–35	+44
Bay of Sails	80	132	96	80	81	78	103	–21	–4

Table 5. Drift data for 'comma' berg, based on position data and satellite imagery obtained from Bill McIntosh (SO81), Weather Division at MAC Centre and Alex Pyne (K042) and NZARP surveyors.

DATE	POSITION/ LAT-LONG	CUMULATIVE DAYS SINCE CALVING	DISTANCE Km	SPEED Km/day	MEAN SPEED Km/day
1 Dec '88	E of C. Crozier	?	0.0	0.0	0.0
12 Dec '88	10 km NE of C. Crozier	12	16	1.3	1.3
	30 km N of C. Crozier	?	25		
23 Dec '89	15km N of C.Tennyson	23	29	4.9	3.0
	Off C. Bird	?	45		
3 Jan '89	15 km SW of C. Royds	34	61	9.6	5.2
5 Jan '89	17km SE of Butter Pt	36	17	8.5	5.4
7 Jan '89	12km E of C.Bernacchi	38	28	14.0	5.8
17 Jan '89	76°26'S 164°47'E	48	116	11.6	7.0