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19

SEA ICE MEASUREMENTS AT MAWSON AND DAVIS, 1954 – 58.

by

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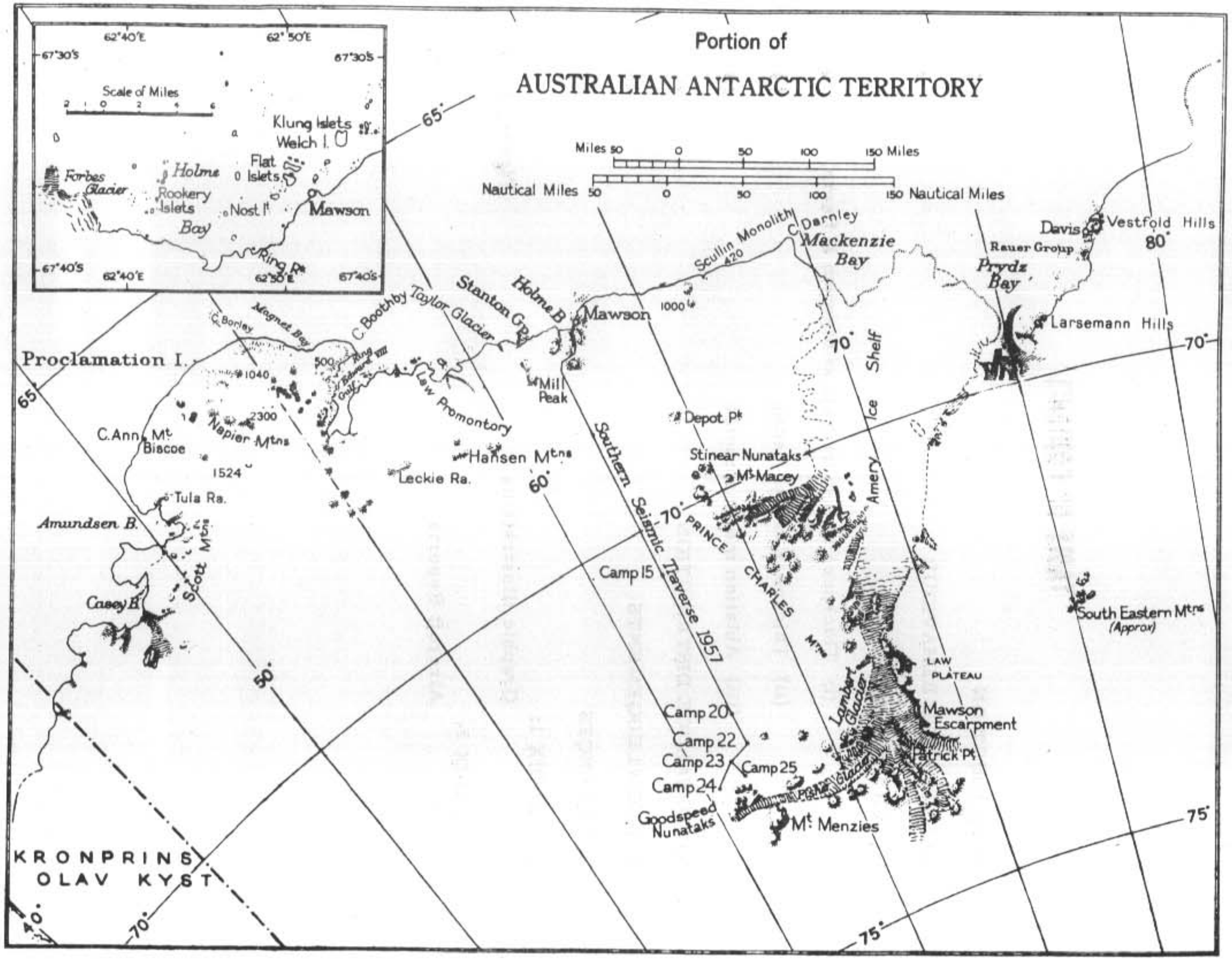
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Mawson
Ring Pt
Proclamation I.
C. Borley
Magnet Bay
C. Boothby
Taylor Glacier
Stanton Gp.
Holme B.
Mawson
Scullin Monolith
C. Darnley
Mackenzie Bay
Davis
Vestfold Hills
Rauer Group
Prydz Bay
Larsemann Hills
Amery Ice Shelf
Law Promontory
Mill Peak
Depot Pt
Stinear Nunataks
Mt Macey
Hansen Mtns
Leckie Ra.
Napier Mtns
C. Ann
Mt Biscoe
Tula Ra.
Amundsen B.
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Southern Seismic Traverse 1957
Camp 15
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Goodspeed Nunataks
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PRINCE CHARLES Mtns
Lambert Glacier
LAW PLATEAU
Mawson Escarpment
Patrick Pt
South Eastern Mtns (Approx)
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INTRODUCTION

Since the first permanent ANARE base was established on the Antarctic mainland in 1954 sea ice records have been kept in varying degrees of detail. The observations have generally been casual and not directed to any specific end, but, although no one year's work has constituted a significant sea ice study, the accumulated records provide a useful source of data. The collected information has a certain value for operational planning and may also be of interest to scientific workers in various disciplines; with this in mind the following report has been compiled.

The information included in the report is taken from the notebooks and records of the following men: Robert Dovers (Mawson 1954), Peter Crohn (Mawson 1955 & 1956), John Bunt (Mawson 1956), Malcolm Mellor (Mawson 1957), Robert Dingle (Davis 1957), and Ian McLeod (Mawson 1958 - radio messages). Summer ice observations from expedition ships are not included.

The distribution observations cover the coastline between 45° E and 80 °E and the detailed measurements were made at Mawson (67° 36' S, 62° 52' E) and Davis (68° 34' S, 77° 57' E). Meteorological statistics for these two stations will be available in ANARE Reports, Series D. The data for 1957 have already been published in Volume X, Series D.

GENERAL ICE BEHAVIOUR

Sea ice along the coasts of Enderby Land, Kemp Land, MacRobertson Land and Princess Elizabeth Land is generally of an annual type. Ice of more than one year's growth (bay ice) is rare, but there are certain localities where the sea ice may persist without a breakout for several years. Even though the ice becomes soft and weak in December, a narrow belt of fast ice often remains well into January where bays and islands provide anchorage and protection, and a blow more fierce than the normal katabatic wind is usually required to break up this ice. If the form or direction of the coast in a certain area affords a particularly good protection from wind and waves, the ice may survive the summer and build up to a greater thickness the following winter. The existence of bay ice in the vicinity of ice shelves lends weight to the belief that bay ice constitutes a stage in the formation of ice shelves.

On the other hand, there are areas where stable sea ice never forms, new freezes being rapidly broken up and dispersed by violent and persistent downslope winds blowing off the continent. The northern edges of large peninsulas seem particularly prone to sudden breakouts, presumably because the ice has little protection from cyclonic gales. The positions of these areas in relation to the location of zones of stationary cyclones may also be significant. There are other areas where sea ice formation is slow and subject to breakout without any cause being immediately apparent. It may be that mechanical and thermal effects of ocean currents are responsible, or there may be meteorological reasons.

During the months of December and January the mean air temperature is above the freezing point of sea water and large scale formation of new ice is therefore most unlikely. The coasts under discussion are usually substantially free of fast ice by February, and along those stretches subject to strong katabatic winds the brash and floes are driven away from the shore. By early March the pack ice further from shore has been almost completely dispersed in many sea areas and ice-bergs form the only ice hazard to navigation.

In February the mean air temperature falls below the freezing point, but a freeze-over of the sea is unlikely along wind-swept stretches of coast. In calm conditions (calm sea and no wind) a thin surface layer of the sea may be cooled below the freezing point so that frazil crystals form. These crystals take the form of thin plates or spicules of "fresh" ice, the salts having been excluded during the freezing. Ice so formed in February is unlikely to survive for long, as daytime incoming radiation is still strong, the normally windy conditions cause attrition and dispersal of the crystals, and turbulent mixing brings warmer water from below. In February, 1958 these unstable freezes occurred when the sea temperature was -1.9° C at the surface and -1.4° C and -1.0° C at 1 cm and 50 cm below the surface respectively.

Girdles of spray ice form round the shores of islands and peninsulas in February and continue to grow until the sea freezes. Strong winds churn up the surface of the sea and whip spray from the wavetops, depositing it on the shore of any island or promontory which may lie downwind (Plate 1). Spray ridges develop stalagmite-fashion on the cold rock and, as successive clouds of spray stream over the ridges, an onion-layer formation is built up. Measurements made at Mawson in 1957 showed the spray ice to have a salinity of 14 $^{\circ}$/oo against the sea water salinity of 34 $^{\circ}$/oo.

In March the intensity of incoming radiation declines rapidly and heat loss from the sea is accelerated. By late March the sea will usually be cold enough for a stable freeze-over and this event is delayed only by the wind, which agitates the surface and disperses the ice. A calm day in late March will permit a freeze-up: frazil crystals form on the surface

FORMATION OF SPRAY ICE AT MAWSON, MARCH 1957.

ANARE PHOTO BY M. MELLOR

and aggregations of these soon produce a heavy slush. The slush consolidates, but gentle movement by the swell will often break the resulting ice into "pancakes" which develop raised edges from mutual collisions. The pancakes eventually merge into an unbroken ice cover whose growth is rapid for the first few days (when the temperature gradient is steep), and from this time on the ice in many inshore embayments continues to thicken until the spring. In the windy conditions of Mac Robertson Land, however, breakouts of the ice a few miles offshore are common between April and the end of June, and the ice cannot be considered safe for travel before the end of July.

In 1957 the sea froze at Mawson on 31st March, when the wind dropped after blowing strongly for some time. Pancakes formed in a matter of hours and shortly before the ice cover became complete the sea temperature was -1.85° C at 30 cm depth and -2.0° C between the pancakes, where the brine concentration had been increased by the freezing process.

If the effects of ocean currents are ignored, the rate of accretion is dependent on the temperature gradient through the ice and on the thermal conductivity of the ice. During the winter the mean water temperature at the base of the ice is -1.9° C, but the temperature of the upper surface of the ice varies with the air temperature. For a given air temperature and ice thickness, the temperature gradient through the ice will be increased by winds and decreased by a snow cover on the ice. A thick winter snow cover will thus restrict the ice growth and result in a maximum thickness less than that attained by snow-free ice under the same climatic conditions. The maximum thickness reached will depend on the total heat loss between the freeze-up and the end of the accretion period. Methods for ice thickness prediction are based on the use of a time-temperature combination to estimate total heat loss.

Thermal conductivity of the sea ice has not been measured at Mawson. Malmgren (1927) suggested variations of thermal conductivity with depth in the sea ice, but later work supported a constant value of about 0.005, which is the figure for pure ice.

Rough salinity measurements made in June gave values of 13°/oo to 15°/oo in the top 6 inches (15cm) of the ice. Measurements made in October gave salinity values of 11°/oo to 13°/oo.

For calculations involving the latent heat of sea ice a round figure of 50 cals/grm was taken, using the results of Malmgren as a basis for estimation.

Direct density measurements made on sea ice taken from a depth of 6 inches (15 cm) in September gave a mean value of 0.915 grm/cc. At the period when the ice thickness was around one metre, measurements of the free water level in holes through the ice gave an overall mean density of 0.914 grm/cc. This mean value includes readings made at Davis.

The temperature gradient in the ice has never been recorded regularly at ANARE stations so that no detailed analysis of the accretion process can be attempted. Temperature profiles through the ice were taken on two occasions in 1957 using lagged mercury thermometers in narrow kerosene-filled holes, but a permanent installation was not feasible. Daily measurements of ice thickness were made for the first six weeks of the accretion period at Mawson in 1957 and in Fig. 1 these measurements are plotted against daily mean air temperatures taken at screen level (2 metres). The high air temperatures experienced between April 17th and 29th resulted in a virtual cessation of ice growth.

In addition to rising and falling with the tides, the ice at Mawson was found to respond to ocean swells, even when the ice edge was more than 200 miles (320 km) north of the base. The ice confined in Mawson harbour remained flat at all times, flexure and shear being limited to the tide cracks round the shoreline. The continental ice cliffs adjacent to

Mawson cause considerable buckling and overthrusting of the sea ice by their seaward movement during the winter. Thrust structures identical to those described by Weeks and Anderson (1958) and loosely referred to by the present writer as "square waves", were formed in many offshore areas during the early stages of the freeze-up, but once the ice had thickened there did not appear to be any further development of the structures until the ablation began to intensify in spring.* Preferential ablation appeared to occur along the "square waves" but observations ceased with the writer's departure inland.

During August, September and October the ice off MacRobertson Land is usually secure and the ice edge in September is probably not less than 200 miles north of the coast. The maximum thickness reached by the late-forming ice is less than that of the ice which formed early and remained undisturbed. On other coasts the ice may be less secure; open water is usually present at all seasons in Prydz Bay and off the north coast of the Enderby Land peninsula, and a shore polynya exists between Scullin Monolith and Cape Darnley (Plate 2).

In October pools begin to form in certain places and water appears in the tide cracks. Previously intact expanses of fast ice are crossed by numerous water-filled leads ranging from a few inches to tens of feet in width. It becomes necessary for vehicles travelling on the ice to cross the leads on bridging timbers, but the ice within 20 miles of the coast is otherwise quite sound. Large numbers of Weddell seals congregate along the open cracks accompanied by their pups, by then a few weeks old.

Examination of the ice thickness records shows that ice growth at Mawson ceases at the end of September and thinning begins in early October. The maximum thickness of inshore ice is about 150 cm in the Mawson area and about 165 cm close to Davis. In places where stable ice formation is delayed until July a thickness of over 100 cm may still be reached.

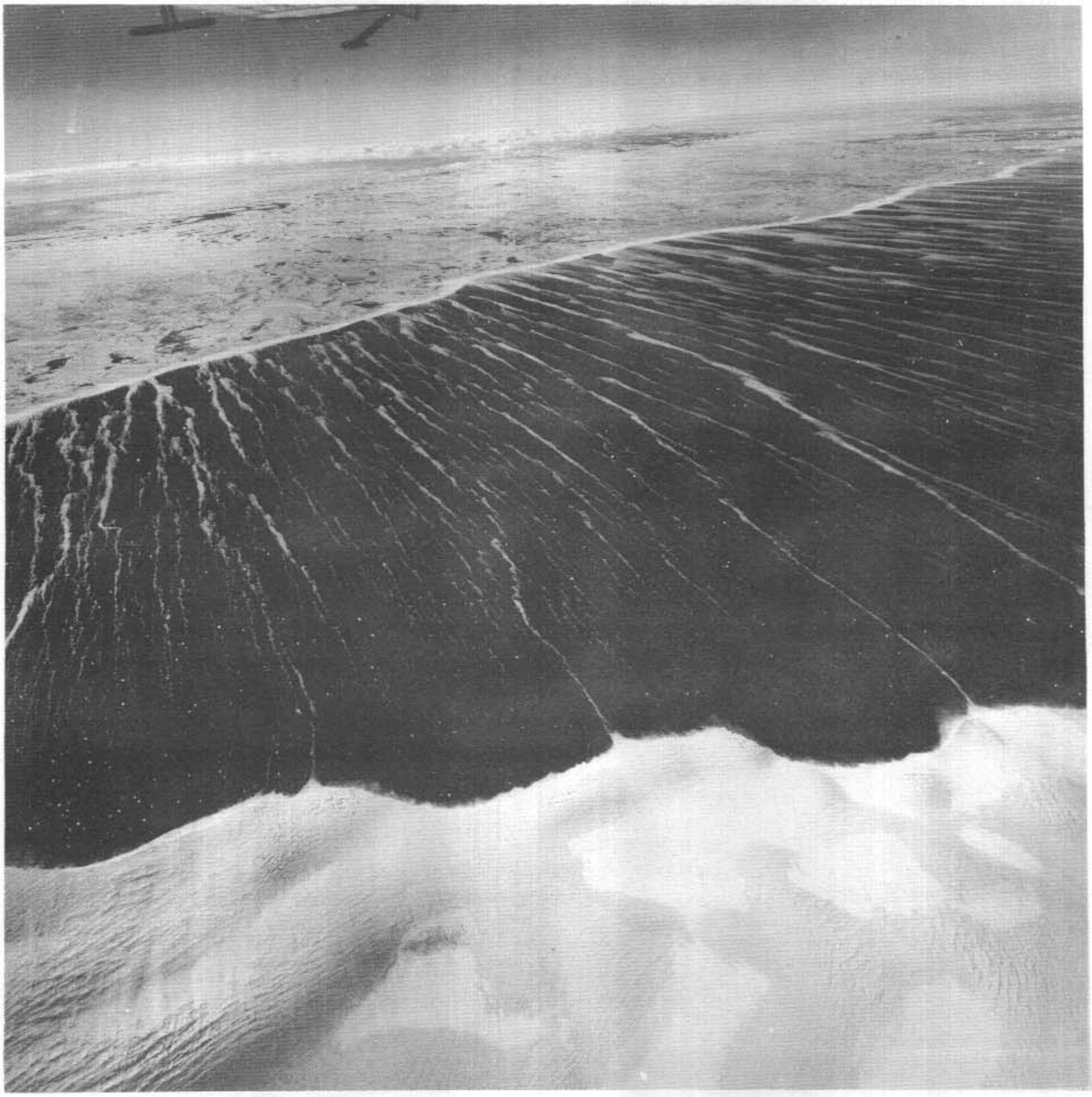
At the time when the ice thickness begins to decline the mean air temperature of the ice surface is elevated by the absorption of incoming radiation, which becomes strong after the equinox. It seems likely that the sea starts to warm up about this time under the influence of inflowing currents.

Throughout the winter, evaporation from the ice surface proceeds and the records show a high gross ablation. In some areas, such as Mawson, the sea ice suffers a considerable net loss, whilst in other places, such as Davis, it is the snow cover which is ablated, the ice below being protected. The evaporation rate varies with the temperature and humidity of the air and with the wind speeds. In spite of low winter temperatures the relative humidity is generally low and strong winds prevent the formation of a saturated air layer above the ice surface, so that substantial evaporation occurs. As air temperatures rise and radiation intensifies during the spring the ablation rate increases. During the early stages of the thinning process at Mawson the ice loss is due almost entirely to ablation at the surface, as can be seen from Fig. 9.

Although a heavy snow cover on the ice can reduce ice growth by its insulating effect, a thin snow cover in the spring serves to protect the ice from both evaporation and radiation. Measurements made at Mawson in 1957 showed the bare sea ice to have an albedo of 0.65 whilst snow-covered sea ice had an albedo of over 0.8. This may go some way towards explaining why the sea ice at Davis continues to thicken until later in the year than does that at Mawson.

It is unfortunate that ablation measurements on the sea ice have always ceased at the end of November due to the falling of stakes. Without this information it is not possible to assess the relative importance of surface ablation to basal melting in the month of December, when the ice decay is at its height.

* The B.P. film of the Trans-Antarctic Expedition includes a good movie shot of overthrusting in new ice.



SHORE POLYNYA BETWEEN SCULLIN MONOLITH, AND CAPE DARNLEY, OCTOBER 1956.

ANARE PHOTO AT 19,000 FEET.

By late October the lower layers of the ice are becoming soft and wet and in early November the more northerly stretches of fast ice begin to break up. In December the deterioration becomes more pronounced as the tide cracks widen, the ice becomes soft and slushy, and fragmentation of the fast ice accelerates. With the rise in temperature the brine cells in the ice melt before the purer crystals and the cells become interconnecting pores through which the water can seep. With the melting of the brine cells the ice above the free water level thus becomes less dense and also less saline.

Although it has become soft and spongy by January, it appears that the fast ice along the coast of MacRobertson Land would not melt completely before the autumn in most years, and it is a mechanical dispersal brought about by wind and currents which is responsible for the final removal of the inshore ice. In most years, so far, the main inshore break-up has taken place in January, and the ice in the immediate vicinity of Mawson has usually cleared in the last week of January, the fragments being blown away from the shore by the katabatic winds.

OBSERVATIONS

(i) Thickness measurements at Mawson & Davis.

Mawson, 1954. The summer of 1953-54 was unusual in that the breakout of ice occureed late. In January 1954 a belt of fast ice 15 to 20 miles (24 to 32 kilometres) wide remained along the coast, and this ice only broke back gradually during February. The final breakout at Mawson and around the nearby islands occurred during the first week of March. Although the breakout was late the new ice formed at the normal time, the freeze-up beginning on 1st April, 1954. The ice continued to thicken until the end of September, thereafter decreasing in thickness and rotting until the final clearance at the end of January, 1955. The winter snow cover was patchy and only an inch or two (2 to 5 cm) deep, except in areas subject to excessive drifting. Ice thicknesses are given below and are plotted in Fig. 2.

Date	Thickness (cm)
3-4-54	9
4-4-54	20
7-4-54	28
10-4-54	34
17-4-54	44
26-4-54	56
16-5-54	66
29-6-54	99
27-7-54	117
30-8-54	135
2-10-54	171
31-10-54	164
2-12-54	145
15-12-54	133
17-12-54	132

Mawson, 1955. Mawson harbour froze over completely for the first time on 4th March, 1955, and the sea around the nearby island was completely frozen by 16th March. No open water showed in the tide cracks after early April and ice began riding up over the beach, reaching heights of 6 to 8 feet (12 metres) in places. Patchy snow covers appeared during the winter, the depth of snow not usually exceeding one or two inches (2 to 5 cm). Water was showing in the tide cracks at the beginning of December and at the same time the ice became soft and water-logged. Open water was first seen 15 miles (24 km) north-west of Mawson on December 20th, and the fast ice broke back until only small areas remained by 25th January, 1956. The following thicknesses were measured. (See also Fig. 3).

Date	Thickness (cm)
20-3-55	8
3-4-55	38
27-4-55	69
5-6-55	74
15-7-55	99
27-8-55	137
25-9-55	152
20-10-55	146
14-12-55	133

Mawson, 1956. During the autumn of 1956 the formation of sea ice was considerably delayed by a series of heavy gales which swept the coast in late March, April and early May. Local accumulations of thin ice were noticed in sheltered areas on 14th March, but these were swept away by strong winds on 18th March. By 26th March ice had re-formed to a thickness of 11 inches (28 cm) between the islands, but a breakout on 29th March removed all but the ice in the immediate vicinity of Mawson. Similar breakouts also occurred on 12th April, 29th April and 13th May. Another partial breakout on 22nd May produced pools of open water between the islands, but by 27th May the thickness of the undisturbed ice within Mawson harbour had reached 36 inches (91 cm).

The snow cover was again patchy and generally did not exceed two inches (5 cm) in depth, although drifts and sastrugi up to four feet ($1\frac{1}{4}$ metres) in height were seen in some areas. The early breakouts resulted in the formation of zones of old rafted floes cemented together in a matrix of newer ice.

In mid-October sea water began to seep up through the tide cracks and open water appeared in the tide cracks in late November. By early January the ice at Mawson was no longer safe to walk on. The final break-up occurred in mid-January and by 22nd January, 1957, Mawson was clear of ice. The ice thicknesses given below were measured on ice which formed late (1/3 km north of Mawson harbour). Fig. 4 gives the ice thickness curve.

Date	Thickness (cm)
6-6-56	38
20-6-56	64
9-7-56	71
22-7-56	84
15-8-56	98
5-9-56	109
17-9-56	117
12-10-56	117
3-11-56	108
17-11-56	97
29-11-56	91
8-12-56	91
13-12-56	91
16-12-56	85

Additional measurements were made in Mawson Harbour by biologist John Bunt. These are given below.

Date	Thickness (cm)
27-11-56	136
8-12-56	123
13-12-56	118
16-12-56	116
18-12-56	103
20-12-56	96
21-12-56	88
23-12-56	74
25-12-56	67
28-12-56	60
1- 1-57	55
3- 1-57	52
4- 1-57	50
6- 1-57	47
8- 1-57	38

Mawson, 1957. At the beginning of February, 1957, only small floes and brash remained along the coast near Mawson, the main belt of pack being 15 to 20 miles (24 to 32 km) offshore. By mid-February spray ice was beginning to appear on lee shores and ice was forming at the high-water mark. In the second half of February spray ice developed rapidly into the characteristic ridges and by the end of February the first signs of freezing were appearing on the surface of the sea. On calm days slush formed in sheltered bays and was soon transformed into pancake ice. On 31st March the wind dropped and there was a rapid freeze during which the slush and pancakes consolidated to give a complete ice cover. Some pools remained around the local islands until the latter part of April and more distant open pools were indicated on certain days by the cumulus-capped thermals which they produced. Frost smoke was frequently seen over open pools.

A blizzard during the first week of June caused a large-scale breakout beyond the islands surrounding Mawson and four weeks elapsed before the ice re-formed.

The ice in Mawson harbour continued to thicken until the end of September and the ice depth began to decrease during the second week of October. Trickles of water and slush began to appear on the ice along tide cracks in early October and in the following weeks the cracks gradually opened.

On December 20th the ice was soft and wet and the thickness varied considerably. By 27th December the ice was breaking up round the tide cracks and pools were opening. On 3rd January the ice was unsafe to walk on and by 10th January a moat 50 yards (46 metres) wide had developed at the tide crack. The ice was grey in colour and in an advanced state of decay by 17th January and the final clearance occurred during a blow on 29th January, 1958. The thickness measurements are shown in Fig. 5.

Date	Thickness (cm)
31-3-57	First complete freeze
6-4-57	20.5
8-4-57	23
10-4-57	27
15-4-57	42
16-4-57	43
17-4-57	45
18-4-57	46.5
19-4-57	47.5
21-4-57	49
22-4-57	49
23-4-57	48.5
24-4-57	49
25-4-57	49.5
26-4-57	49.5
27-4-57	50
28-4-57	50
29-4-57	51
30-4-57	51.5
1-5-57	53.5
2-5-57	54.5
3-5-57	56.5
4-5-57	58
5-5-57	59
6-5-57	61

Date	Thickness (cm)
7-5-57	62
8-5-57	64
9-5-57	64
10-5-57	64.5
13-5-57	67
14-5-57	68.5
31-5-57	84.5
10-6-57	89
19-6-57	95
12-7-57	108
21-7-57	118
19-7-57	124.5
2-8-57	127.5
9-8-57	132
17-8-57	136.5
23-8-57	141
31-8-57	143.5
14-9-57	150.5
16-9-57	151
20-9-57	153
27-9-57	155
4-10-57	155
12-10-57	154.5
18-10-57	152.5
26-10-57	151
1-11-57	152
8-11-57	148
15-11-57	147
22-11-57	146
30-11-57	140
6-12-57	137
13-12-57	135
20-12-57	127 (varying between 89 and 127)

Mawson, 1958. Spray ice was forming round the islands again during the second week of February, and on 20th February accumulations of frazil crystals were seen in sheltered bays. On 23rd March sea ice formed on the windward side of the islands, but on 24th March there was a breakout. On 27th March there was 7 inches (18 cm) of ice between the islands east of Mawson and by 31st March the ice was re-forming at, and north of, Mawson. On 5th April there were still a few small pools, but by 8th April Mawson harbour was completely covered. On 14th April there was a strip of water about one mile (1.6 km) wide running parallel to the coast about 3 miles (4.8 km) north of Mawson. After several minor breakouts the sea was completely refrozen by 21st April and sea ice stretched to the horizon. In mid-July there was an extensive breakout north-west of Gibbney Island but the area was completely re-frozen one week later. There were no breakouts in the Mawson area but water sky was often visible a few degrees above the horizon N.N.W. of the base. By late November there was open water 20 miles (32 km) north of the camp. The thickness measurements which have been received by radio since the writer left Mawson are given below. (See Fig. 6).

Date	Thickness (cm)
7-4-58	23
10-4-58	30

Date	Thickness (cm)
17-4-58	46
30-4-58	63
28-5-58	86
25-6-58	102
23-7-58	109
20-8-58	130
19-9-58	145
8-10-58	155
22-10-58	150
29-10-58	149
5-11-58	147
12-11-58	145
19-11-58	142
22-12-58	137

Davis, 1957. By 12th January, 1957, there was no fast ice remaining at Davis and the sea was clear apart from icebergs and bergy bits. The first definite signs of the freeze-up appeared on 15th March, when sludge and light pancakes formed. At this time certain other bays had already frozen over. The ice dispersed and re-formed several times up to 21st March, when the ice cover became more coherent. On 22nd March the ice was safe to walk on and thereafter steadily increased in thickness. A blizzard on 27th March broke out the ice beyond the islands but the inshore ice remained intact.

In late December the fast ice began to break up and the final dispersal of the ice inside the islands took place gradually in mid-January. Fig. 7 gives the ice thickness curve.

Date	Thickness (cm)
22-3-57	14
23-3-57	16
25-3-57	23
26-3-57	24
31-3-57	28
7-4-57	34
14-4-57	39
21-4-57	44
28-4-57	56
5-5-57	58
12-5-57	72
19-5-57	77
26-5-57	85
2-6-57	86
9-6-57	89
23-6-57	101
6-7-57	105
20-7-57	114
3-8-57	131
17-8-57	140
31-8-57	147
14-9-57	147
27-9-57	160
12-10-57	165
26-10-57	162

Date	Thickness (cm)
9-11-57	169
23-11-57	168
7-12-57	154

Davis, 1958. The sea was freezing over by 9th March and on 17th March the ice was 4 inches (10 cm) thick. The thickness had increased to 7 inches (18 cm) by 25th March, but the ice was broken up and dispersed by a blizzard on 29th March. New ice began re-forming on 3rd April and there were no further breakouts of the inshore ice. On 30th May the fast ice extended for 5 miles (8 km) north of Davis, but the ice broke back during a blizzard on 28th June and open water was then visible 2 miles (3.2 km) north of the station. Another blizzard in mid-July caused further damage to the ice and open water was within 1½ miles of the shore. In the low temperatures which followed, however, the sea rapidly re-froze. In mid-October open sea was still visible beyond the local islands after further blizzards. The measurements given below have been plotted in Fig. 8.

Date	Thickness (cm)
7-4-58	18
11-4-58	30
22-4-58	41
2-5-58	58
16-5-58	66
13-6-58	89
11-7-58	109
8-8-58	127
5-9-58	147
7-10-58	165

(ii) Ice thickness comparisons. Measurements of ice thickness were made in a number of localities at the same time in 1957 in order to compare thicknesses reached by ice areas which had formed at different dates.

On 3rd August measurements were made along a line running north from Mawson. In places where old floes and breakout debris had been re-frozen the thinnest sections were measured.

Position	Thickness (cm)
Mawson harbour	128
0.5 km north of Mawson harbour	123
2.7 "	127
(________ line of breakout (June)	_____)
2.9 "	74
4.0 "	76
4.8 "	87
5.6 "	95
6.4 km north of Mawson harbour	69
7.2 "	94
8.0 "	96

On 5th August, 1957 measurements were made between Mawson and the Stanton Group, 35 miles (56 km) west of Mawson.

Position	Thickness (cm)
2 miles (3.2 km) E of Gibbney Island	69
4 miles (6.4 km) W " "	77
4 miles (6.4 km) E of Oldham Island	66
1 mile (1.6 km) SE " "	102

Around the time when the ice at Mawson was at its thickest, measurements were made at a few other points along the coast.

Position	Date	Thickness (cm)
Mawson harbour	4-10-57	155
0.3 km north of Mawson harbour	4-10-57	151
1.5 km "	27- 9-57	150
2.7 km "	4-10-57	154
4.8 km "	4-10-57	109
Taylor, remote station, 55 miles (88 km) W of Mawson.	21- 9-57	128
Magnet Bay, 220 miles (350 km) WNW of Mawson	25- 9-57	122

(iii) Ablation measurements. In the Mawson region large expanses of sea ice flanking the coastal ice cliffs receive only thin and occasional snow covers due to the strength and persistence of the wind. Ablation measurements made on stakes in this area therefore give a good idea of the evaporation rate, the measured net ablation being only a little below the gross ablation. The sea ice off the Vestfold Hills, however, receives a good deal of snow, and stake measurements probably give a fair idea of the precipitation in this region of light winds. The figures presented for Davis, 1957, are of limited value since density has not been considered and compaction of new snow has not been allowed for. In all the tables accumulation is shown as a negative ablation.

Mawson, 1954

Period	Net Ablation (mm)	Net Ablation Rate (mm/day)
26- 4-54		
	51.8	0.46
16- 8-54		
	-6.7	-
30- 8-54		
	22.5	0.80
27- 9-54		
	4.9	0.23
18-10-54		
	15.5	1.19
31-10-54		
	-2.8	-
15-11-54		
	21.9	3.13
22-11-54		

In 1956, ablation lowered the surface of the ice around an "ice tube", installed by John Bunt at Mawson, by 23 cm between May and December.

Mawson, 1957.

Period	Net Ablation (mm)	Net Ablation Rate (mm/day)
31- 5-57		
	38.2	2.01 (some snow)
19- 6-57		
	16.1	0.70
12- 7-57		
	9.5	0.56
29- 7-57		
	-3.3	-
9- 8-57		
	9.7	0.69
23- 8-57		
	3.2	0.32
2- 9-57		
	6.3	0.25
27- 9-57		
	38.1	1.32
26-10-57		
	12.7	1.07
7-11-57		
	95.0	4.54
28-11-57		

In 1957 some ablation measurements were made at Cape Bruce, about 60 miles (96 km) west of Mawson. Conditions in this area are rather less windy than at Mawson and more snow lies on the sea ice. The figures probably give a fair idea of winter and spring ablation rates.

Period	Net Ablation (mm)	Net Ablation Rate (mm/day)
7- 7-57		
	25.4	0.23
23-10-57		
	114	3.00
30-11-57		

Davis, 1957.

Period	Net Ablation (mm)	Net Ablation Rate (mm/day)
31- 3-57		
	0	0
7- 4-57		
	-12.7	-
14- 4-57		
	12.7	1.81
21- 4-57		
	0	0
28- 4-57		

Period	Net Ablation (mm)	Net Ablation Rate (mm/day)
19- 5-57		
	-63.4	-
26- 5-57		
	12.7	1.81
2- 6-57		
	38.1	5.44
9- 6-57		
11- 6-57		
	0	0
17- 6-57		
	-25.4	-
21- 6-57		
	-9.5	-
28- 6-57		
	31.8	4.54
5- 7-57		
	2.9	0.32
14- 7-57		
	0.6	0.07
22- 7-57		
	-3.2	-
31- 7-57		
	1.6	0.23
7- 8-57		
	4.1	0.32
20- 8-57		
	8.4	1.05
28- 8-57		
	3.2	0.46
4- 9-57		
	-19.8	-
12- 9-57		
	12.1	1.73
19- 9-57		
	1.0	0.14
26- 9-57		
	3.2	0.46
3.10-57		
	-12.4	-
10-10-57		
	5.4	0.77
17-10-57		
	29.2	3.65
25-10-57		
	-12.7	-
31-10-57		
	-5.1	-
7-11-57		
	-0.3	-
14-11-57		
	9.5	1.36
21-11-57		
	45.6	6.51
28-11-57		

In the vicinity of Mawson ablation removes a considerable amount of ice during the winter and the occasional thin snow covers which are deposited on the ice serve only to reduce the net ablation. Fig. 9 gives the graph of ice thickness against time, and the ablation loss has been added to the thickness to give the upper line. It can be seen from this graph that the ice loss during the early stages of the thinning is due almost entirely to surface ablation.

The sea ice off Davis has a snow cover which persists through the winter and prevents appreciable ablation of the actual sea ice. Ablation proceeds throughout the year, but the snow cover is replenished by fresh falls from time to time and in 1957 evaporation approximately balanced precipitation between the end of March and the end of November. In December and January virtually all the snow was removed by strong radiation and high air temperatures and, as only a negligible amount of precipitation was recorded in those months, it seems that there may be an overall precipitation deficit.

REGIONAL ICE DISTRIBUTION

Although two years' unsystematic observations do not provide a sound basis for defining regional ice behaviour along the coasts of Enderby, Kemp, MacRobertson and Princess Elizabeth Lands, some strong impressions may be formed about certain areas. A summary of the observations is given for various stretches of coast and a tentative conclusion is reached for each region.

Amundsen and Casey Bays. In the winter of 1956 the ice in both these bays was continuous and intact and was deemed suitable for landing Beaver aircraft and setting down field parties for short periods. The ice was still good in mid-October. In 1957 the ice in both bays was sound in mid-September and aircraft (Beavers) landed then and on several subsequent occasions, laying fuel depots and transporting field groups. At the end of November the ice in the bays was still solid and no open water was visible. In mid-February, 1958, the ice had broken out from the mouths of both bays but the ice inside Casey Bay was still intact. Fast ice still held on the west side of Amundsen Bay and the rest of the bay was littered with floes.

No strong winds were experienced in this area and when the writer was in Casey Bay in early October, 1957 the sea ice had a cover of soft snow two feet (60 cm) deep. Several areas of shelf ice around Casey Bay may further indicate stable sea ice.

51° to 57° E longitude. In 1956 open water was reported off the north coast of the Enderby Land peninsula from the beginning of August to mid-October. We can infer that no fast ice formed after October, 1956, and it also seems doubtful that much fast ice formed before 1st August. In 1957 the first flight to Enderby Land was in mid-September and at this time open water was reported off Mt. Biscoe. Rafted ice at Proclamation Island suggested an earlier breakout. By late September the ice north of the peninsula had broken back and there were extensive areas of open water. There was still open water off this coast at the end of November. In mid-February, 1958 there was continuous open water from Proclamation Island (limit of visibility) to longitude 51° E. There is, therefore, ample evidence that the sea ice off the north coast of the Enderby Land peninsula is liable to break out at any time.

King Edward VIII Gulf. In 1956 the ice at the gulf was good throughout the winter flying season and a depot was laid on an island at its northern end. The ice was sound during the winter of 1957 and the previous year's ice had not broken out at the depot. The ice was still intact in mid-December, 1957. Shelf ice is common in inlets and embayments around the gulf and it seems that bay ice could persist over the whole gulf.

58° E to Mawson. The numerous observations made in 1956 and 1957 suggest that the ice along this stretch of coast is fairly stable between July and November and open water is not likely to be closer than 20 miles from the shore. Certain areas seem more susceptible to breakouts than others whilst the ice is still thin. These areas lie between Mawson and the Jelbart Glacier, the stretch between Gibbney Island and Jelbart Glacier being particularly prone to breakouts. The only open water seen in this area between late July and November, 1957 was a persistent pool 30 miles (48 km) north of Byrd Head. The U.S. Hydrographic Office chart No. 6643 shows a small area of shallow water in this position, the sounding being 83 fathoms (152 metres).

Mawson to Cape Darnley. Both 1956 and 1957 observations show the ice to be sound for 80 miles (130 km) east of Mawson between July and November. From Scullin Monolith to Cape Darnley a coastal strip of open water, or shore polynya, seems to be a normal feature. It is suggested that strong and persistent katabatic winds are responsible for this polynya (see Plate 2).

Mackenzie Bay. In 1956 open water in Mackenzie Bay was reported in September and October. In 1957 the bay was reported as being open or only partially frozen in May and August, but thin ice had formed in late September. It is believed that this ice broke out again in October. Mackenzie Bay thus appears to be an area where stable sea ice does not form.

Prydz Bay. Large areas of open water were reported in the bay in October, 1956. In 1957 Prydz Bay was open, except for narrow fringes of fast ice round the islands and coastal hills, until late August. A thin freeze on the bay was reported in early September after the last flight of the season in that area, but ground observers at Davis record that another breakout followed and stable ice was never formed beyond the inshore islands. In 1958 repeated breakouts occurred and open water was visible outside the islands near Davis up to mid-October (the time of writing this report).

It therefore seems that Prydz Bay is generally free of fast ice at all times of the year. No definite reason for this can be given at the moment, but two relevant comments may be made. Russian meteorologists list the Mackenzie Bay - Prydz Bay region as an area of stationary cyclones, and their systematic sea ice observations show that drift ice distribution is affected by such cyclonic zones. However, no conclusions regarding the effects of cyclonic zones on ice formation have been published so far. The rapid movement of icebergs off the Vestfold Hills indicates that there are strong currents in the bay, and it may be that these affect ice formation.

The above summary gives definite evidence that there are wide differences in ice conditions along the various stretches of coast and it may be that further information of this kind could lead to an extension of the navigation season for shipping in certain areas.

ACKNOWLEDGEMENTS

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R. Dingle - O.I.C., Davis, 1957
I. McLeod - Geologist, Mawson, 1958
M. Flutter - O.I.C., Davis, 1958

Valuable contributions were also made by the following R.A.A.F. pilots:

S/Ldr. D. Leckie
F/O J. Seaton
S/Ldr. P. Clemence
F/Lt. D. Johnston

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APPENDIX 1.

Graphical Illustrations

Figures 1 To 9

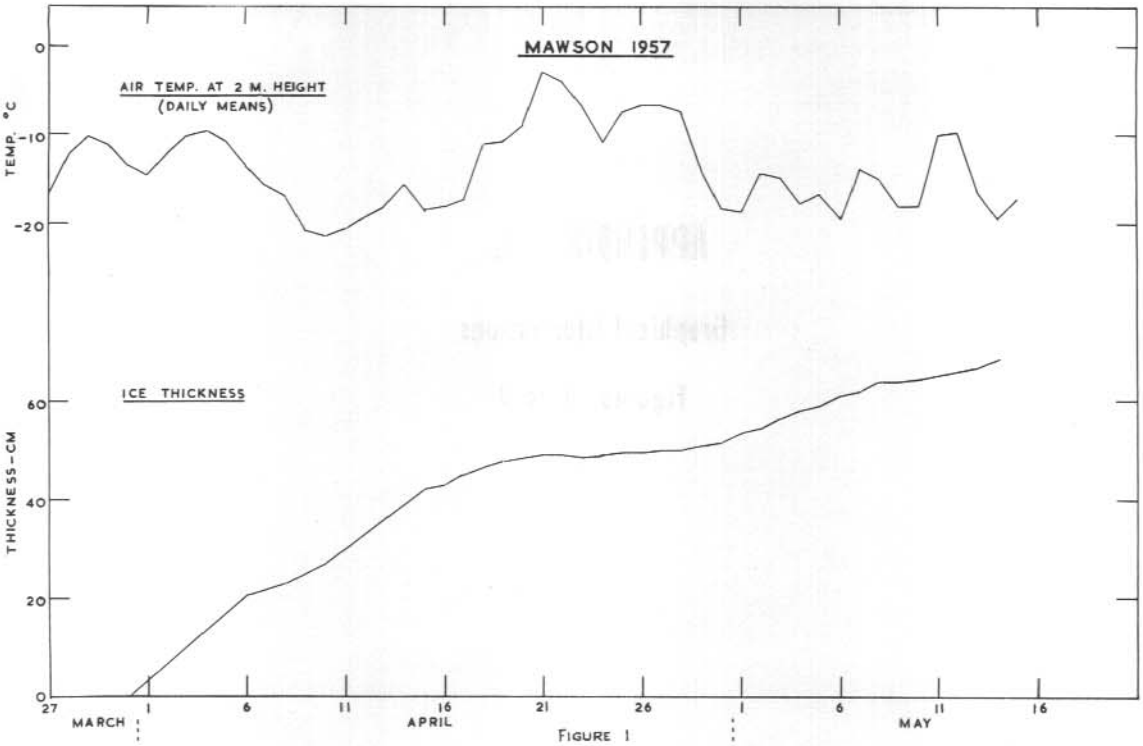

FIGURE 1

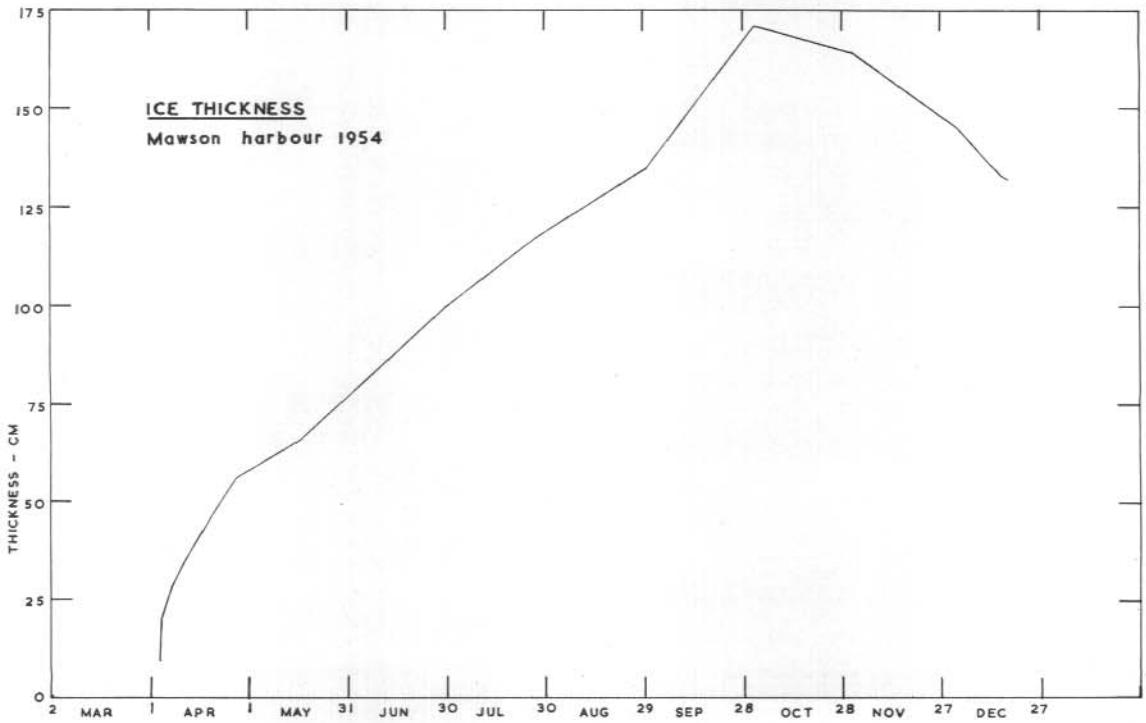

FIGURE 2

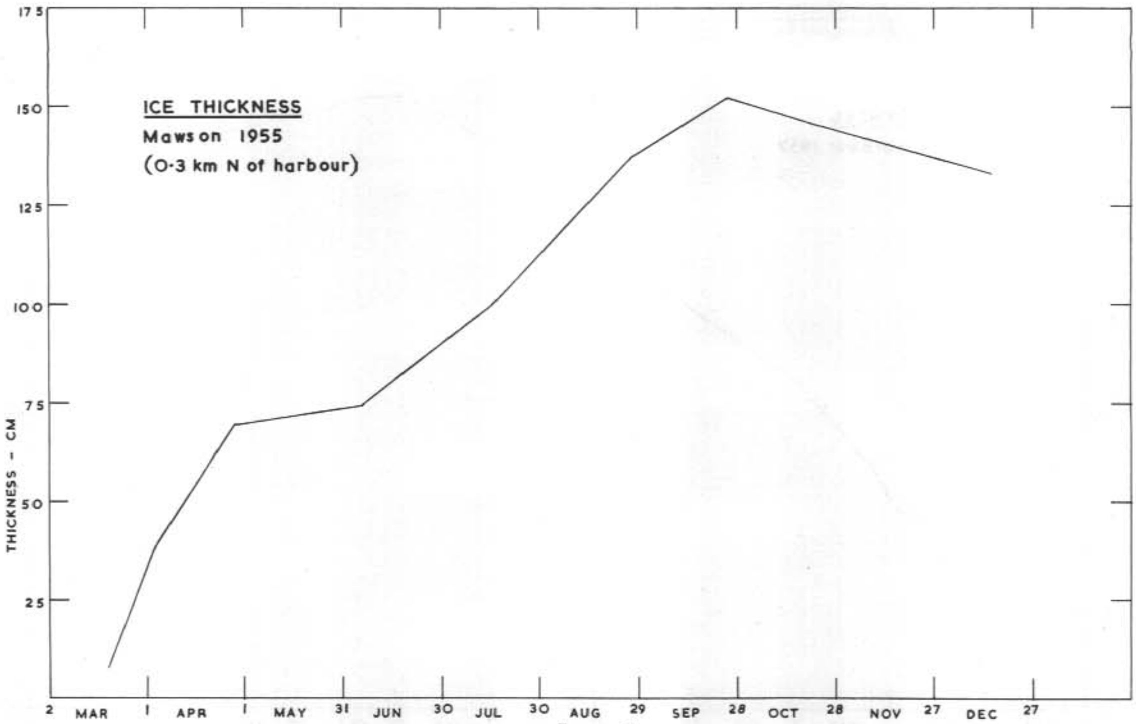

FIGURE 3

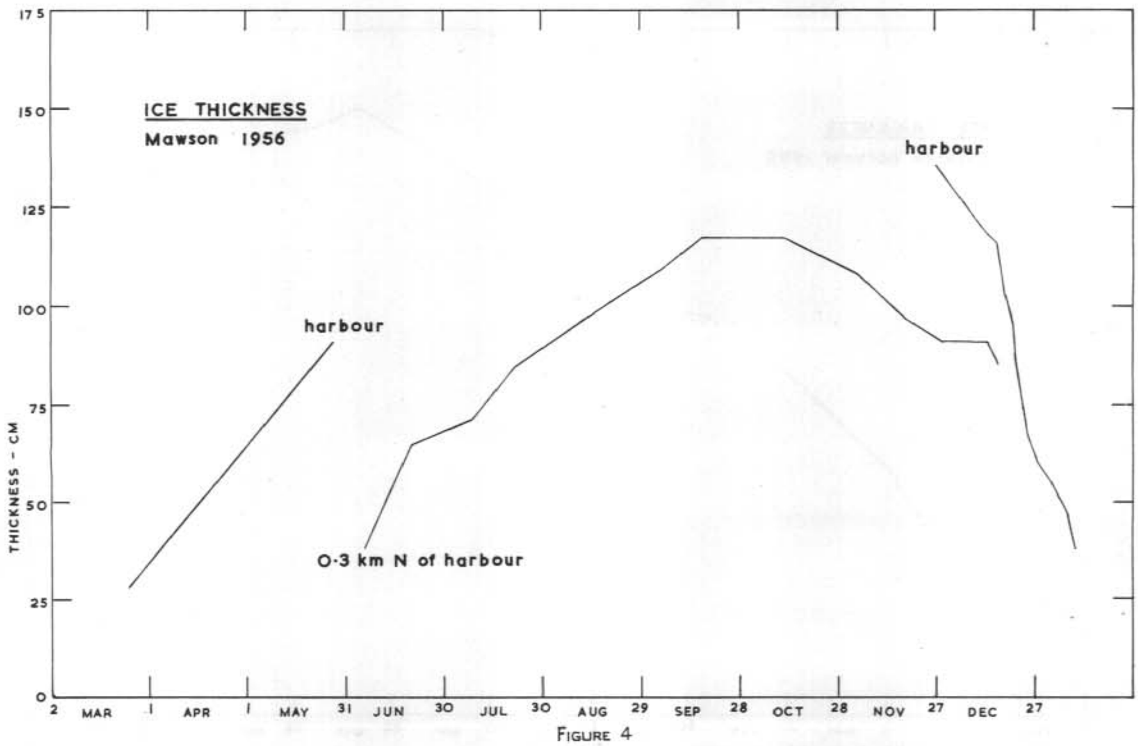

FIGURE 4

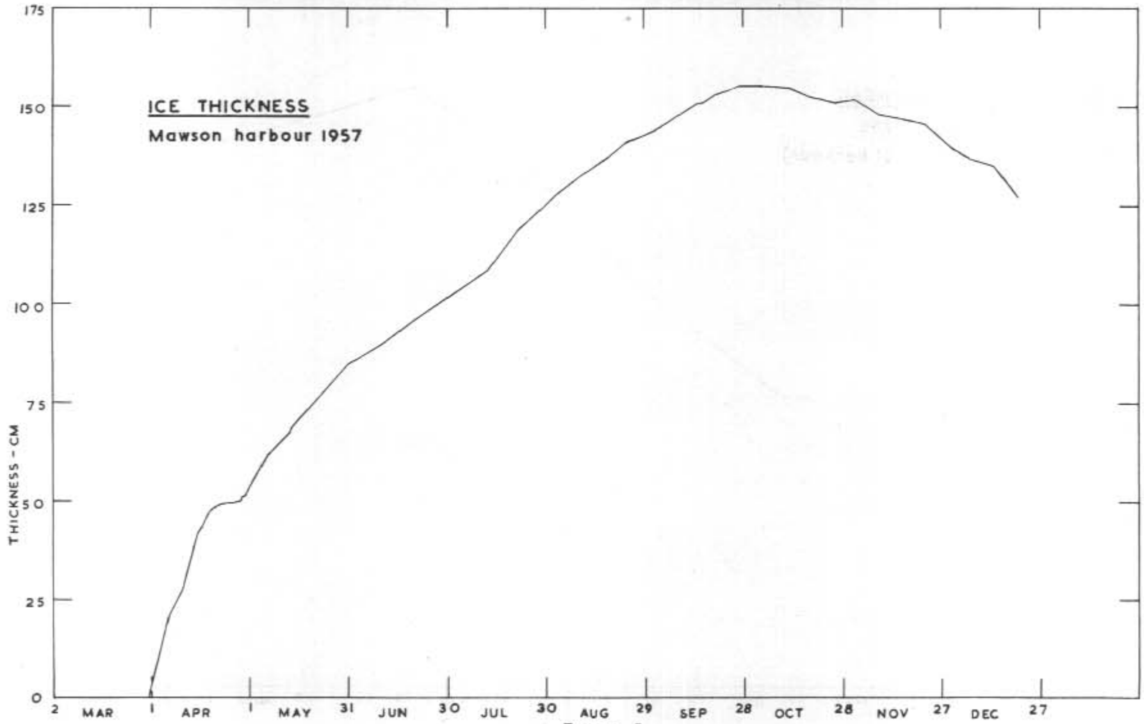

FIGURE 5

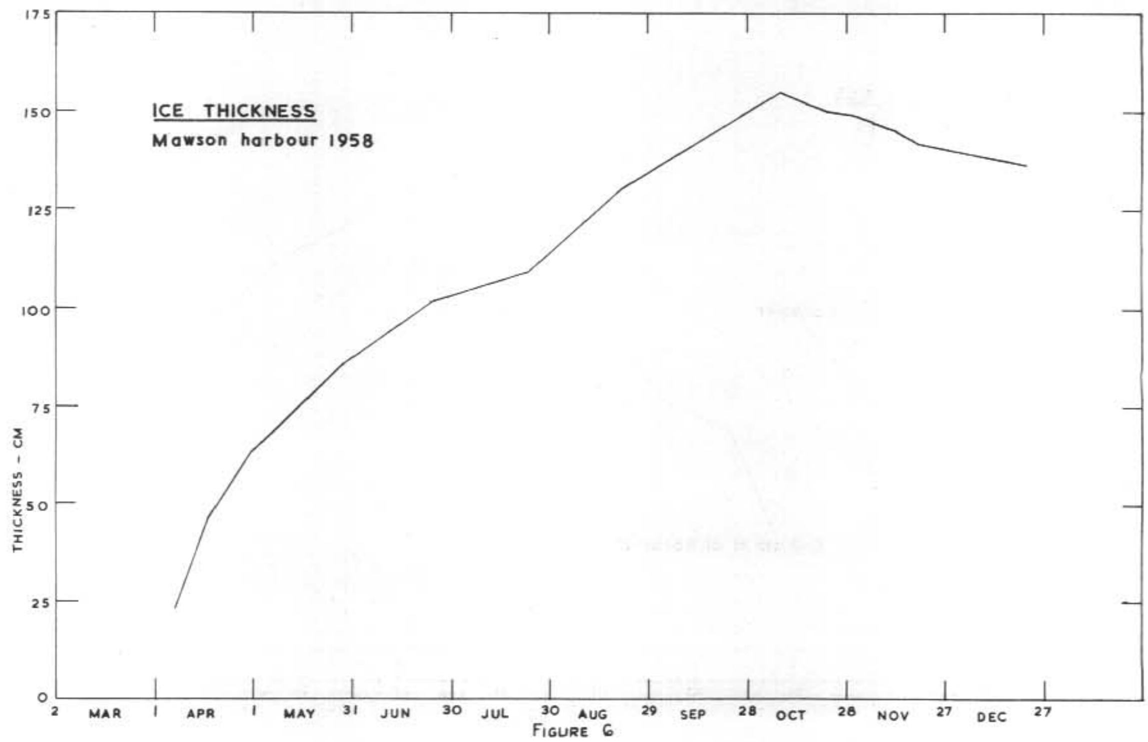

FIGURE 6

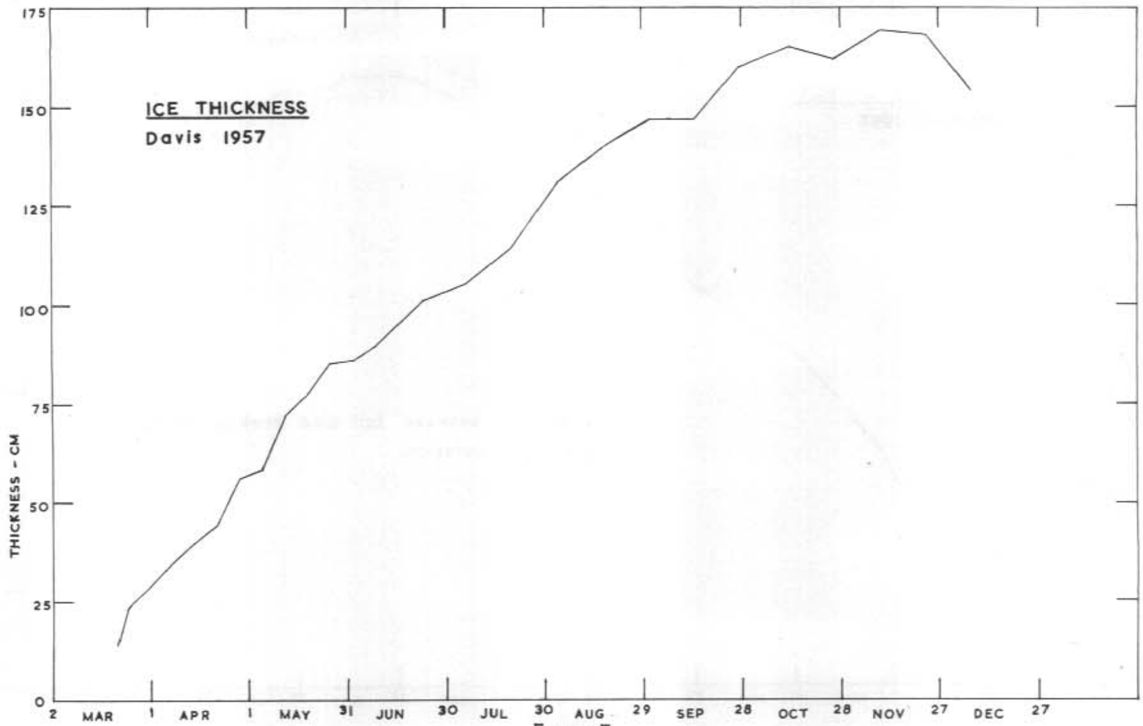

FIGURE 7

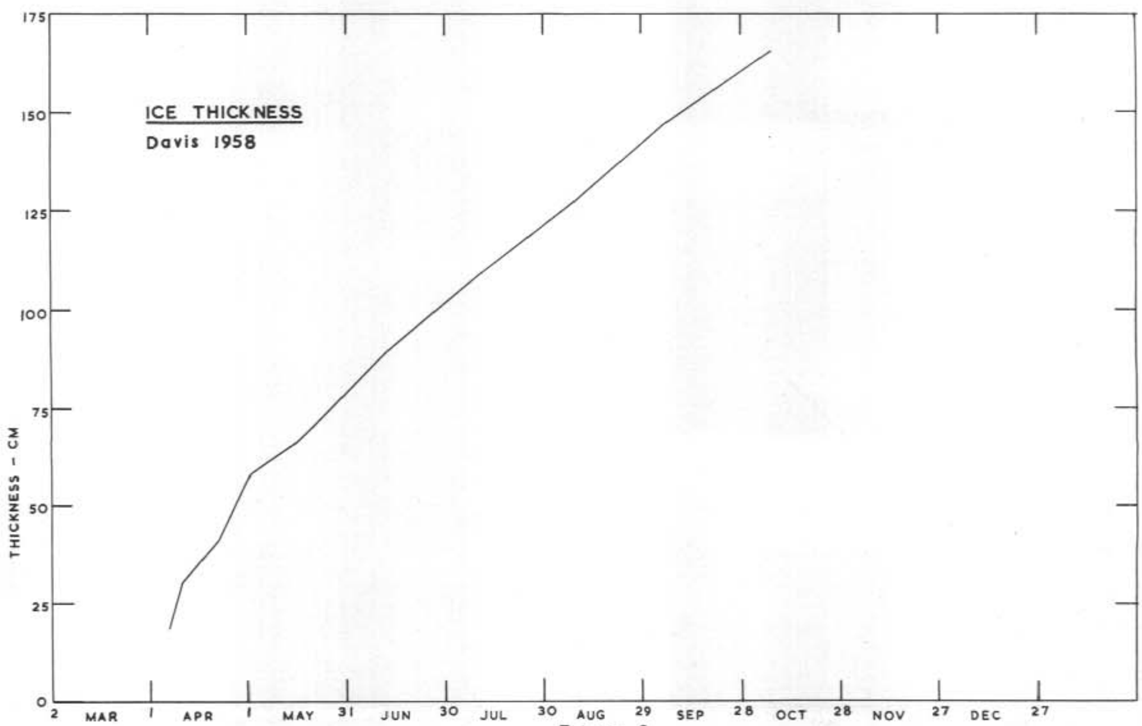

FIGURE 8

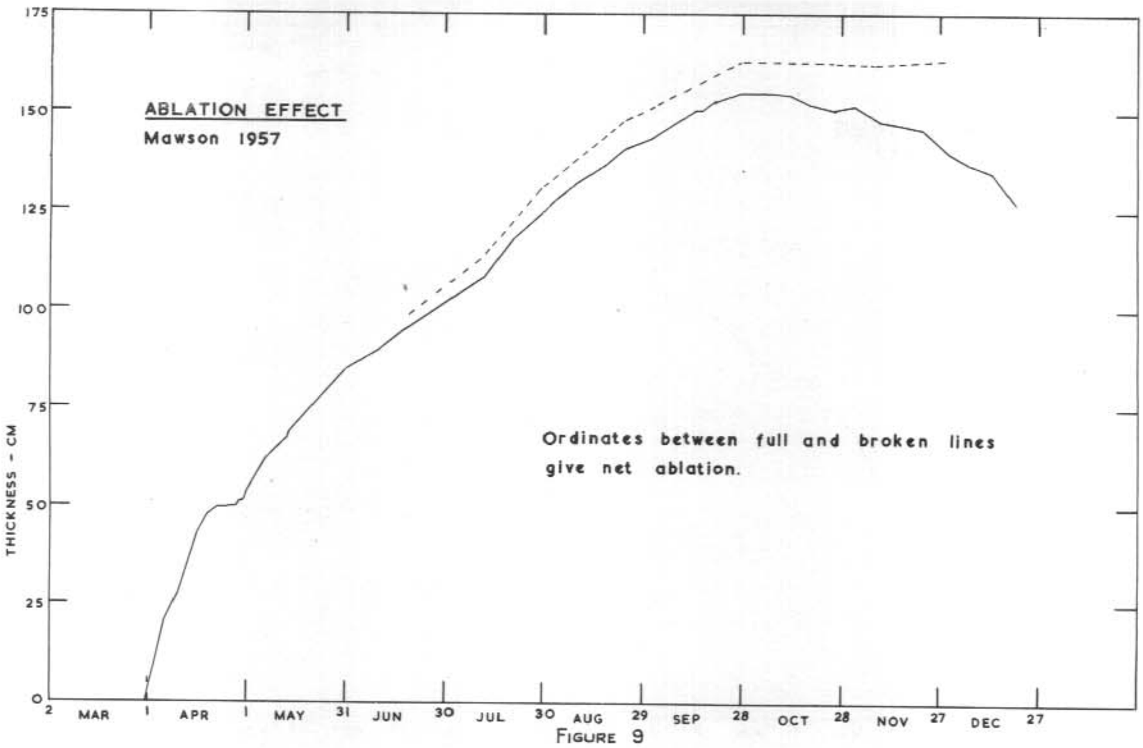
ABLATION EFFECT
Mawson 1957
Ordinates between full and broken lines give net ablation.
THICKNESS - CM
175
150
125
100
75
50
25
0
2 MAR 1 APR 1 MAY 31 JUN 30 JUL 30 AUG 29 SEP 28 OCT 28 NOV 27 DEC 27

FIGURE 9

APPENDIX 2.

Aircraft Reports

APPENDIX : AIRCRAFT REPORTS

1956.

Date	Route	Information
16-7-56	Reconnaissance 80 m. N. of Mawson.	Flight 80 miles north at 10,000 ft. no open water anywhere.
1-8-56	Mawson - Enderby Land	Open water from Cape Borley to a point about 10 miles east of Proclamation Island.
18-9-56	Mawson - Enderby Land	Open water from Magnet Bay to a point midway between Mt. Biscoe and Proclamation Island.
20-9-56	Mawson - Enderby Land	Open water from Magnet Bay to a point about 15 miles east of Mt. Biscoe.
25-9-56	Mawson - Amery Iceshelf	Patches of open water in Mackenzie Bay and between Cape Darnley and Scullin Monolith.
10-10-56	Mawson local	Large areas of open water about 40 miles due north of Mawson.
11-10-56	Mawson - Amundsen Bay	Open water from a point about 25 miles north of the mouth of Amundsen Bay to the coast at Mt. Biscoe, thence to coast at Magnet Bay, thence to a point about 30 miles north of the Oygarden Group.
12-10-56	Mawson - Prydz Bay	Large areas of open water in Prydz Bay and between Cape Darnley and Scullin Monolith.
24-11-56	Reconnaissance	Fast ice extending for 22 miles north of Mawson with heavy pack for approximately 200 miles beyond this.

1957.

Date	Route	Information
4-1-57	Reconnaissance	Fast ice and heavy pack extending for a total distance of 90 miles north of Mawson.
29-4-57	Mawson - King Edward Gulf	Open water in Stefansson Bay, pools off Law Promontory, otherwise continuous ice to Gulf. Previous year's ice had not broken out at K.E.G. depot.
1-5-57	Mawson - Davis.	No ice in Mackenzie Bay or Prydz Bay. Narrow belt of ice around Larsemenn and Vestfold Hills and associated islands.

Date	Route	Information
4-5-57	Mawson - Davis	Fast ice for 50 miles east of Mawson, then open water onwards (Scullin Monolith, Mackenzie and Prydz Bays) as far as Sorsdal Glacier. Belt 8 miles wide surrounding Vestfold Hills.
11-6-57	Mawson - Fold Island	Breakout beyond islands surrounding Mawson. Open water extending west almost to Stanton Group and east to Douglas Islands. Ice intact west of Oldham Island. Thicker than 18 inches in Stefansson Bay.
3-7-57	Mawson - Cape Bruce	Ice re-forming but still large pools around Mawson area. Mosaics of old floes set in new ice forming 5 miles north of Mawson and 4 miles east of Oldham Island.
5-7-57	Mawson - King Edward Gulf	Sea ice continuous except for area off Jelbart Glacier. Ice at Gulf more than one year old.
6-7-57	Mawson - Scullin Monolith	Big pool between Welch Island and Robinson Group and between 4 and 7 miles offshore. Open water 70 miles east of Mawson.
6-8-57	Mawson - Scullin Monolith.	Mawson ice now formed, but a shore polynya 1 to $1\frac{1}{2}$ miles wide extends eastwards to maximum visibility eastwards.
9-8-57	Mawson - Davis	Shore polynya one mile wide running from Scullin Monolith to Cape Darnley. Mackenzie and Prydz Bays have sludgy ice with open pools. Belt of sound fast ice 2 to 4 miles wide clinging to Larsemann and Vestfold Hills and the nearby islands, but only very narrow strip across tongue of Sorsdal Glacier. Fast ice surrounding Vestfolds cut back 4 miles since earlier observations. Tabular berg 12 miles long about 20 miles southwest of Rauer Group appeared to have moved a little way north two days later.
16-8-57	Mawson - Mackenzie Bay	Sludgy freeze with large pools in Mackenzie Bay. Very light freeze from 65° 30'E to Cape Darnley.
16-8-57	Ice reconnaissance to 66° 46'S, 62° 14'E.	From an altitude of 4,000 feet there were no signs of open water 60 miles out. The limits of the "berg belt" which lies north of Mawson were placed at 33 and 60 miles north of the base and it was estimated that the belt contained several thousand bergs, most of them grounded and of considerable age.

Date	Route	Information
23-8-57	Mawson - Mackenzie Bay	Strip of fast ice 5 to 8 miles wide along west side of Mackenzie Bay. Ice cover over rest of Bay less than $\frac{1}{8}$.
30-8-57	Ice reconnaissance to 65° 50'S, 61° 46'E.	Limit of fast ice proper 76 miles north of coast. Beyond this is 7/8 to 8/8 heavy rafted pack, consolidated by re-freezing in pools and leads. 130 miles out there were no signs of open water from 3,000 feet. 80 miles out there was a good snow cover and large dunes had been deposited by easterly winds. A landing was made on a small frozen pool and the surrounding ice was found to be rafted to a height of 6 feet. Thin freeze on pool 30 miles north of Byrd Head.
24-8-57 to 26-8-57	Mawson - Davis and local Davis flights.	Open lead one mile wide round tongue of Sorsdal Glacier and running south-west $\frac{1}{2}$ to 1 mile seaward of Rauer Group and Svenner Islands. An open lead describes an arc of 7 miles radius round the Vestfold Hills. Good fast ice inshore of lead and very thin ice over rest of Prydz Bay. Bay ice in Sandefjord Bay.
10.9.57	Mirny - Davis	No open water visible in Prydz Bay. Fast ice between Mirny and Gaussberg. Russians reported ice edge 250 nautical miles north of Mirny.
17-9-57	Mawson - Enderby Land	Continuous ice to King Edward Gulf and no open water. Visibility restricted, but ice appeared solid and continuous except for open area approximately 20 miles off Mt. Biscoe. Rafted ice at north end of Proclamation Island, smooth ice at south end. Good sound ice in Amundsen Bay.
20-9-57	Mawson - Amery Iceshelf	No signs of open water in Mackenzie Bay or Sandefjord Bay.
26-9-57	Mawson - Magnet Bay and Proclamation Island.	Ice unchanged in, and east of, Magnet Bay. Between Magnet Bay and Proclamation Island open water had appeared along a 10-mile stretch of coast. West of this area there was only a 5-mile wide strip of fast ice. A recent breakout had brought open water within $\frac{1}{4}$ mile of the north end of Proclamation Island.

Date	Route	Information
9-10-57	Mawson - Amundsen Bay	Only open water visible between Mawson and King Edward Gulf was the big pool 30 miles north of Byrd Head. No open water in Casey Bay or Amundsen Bay.
30-11-57	Mawson - Magnet Bay and Amundsen Bay	Gradual deterioration of the ice and two large leads, 3 miles apart, running from the pool north of Byrd Head to a point 10 miles north of Cape Boothby. Ice in Magnet Bay solid but open water visible to the west in the Proclamation Island area. Ice still solid in Amundsen Bay.
30-11-57	Mawson - Cape Bruce	Ice between Mawson and Innerskfera unchanged apart from wet appearance. West of Innerskfera 3 miles of dark ice with patches of open water up to 60 yards across and leads 10 to 25 feet wide. West of this area surface covered with slushy new snow and open tide cracks around bergs and islands.
17-12-57	Mawson - King Edward Gulf	Between Mawson and Gulf open water generally about 20 miles north of coastline, with maximum width of fast ice of 40 miles.
4-2-58	Sandefjord Bay area	Sea ice in Prydz Bay cleared completely.
15-2-58	Amundsen Bay area.	Continuous open water from Proclamation Island to Amundsen Bay. Sea ice broken out from mouths of Amundsen Bay and Casey Bay. Fast ice on west side of Amundsen Bay with floes over most other parts of bay. Fast ice intact inside Casey Bay.

A.N.A.R.E. REPORTS AND INTERIM REPORTS

Chronological Order of Publication

(When ordering, please quote publication number)

Pubn. No.	Date of Publication	Subject	Title	Author
1	Oct. 1950	Meteorology	Meteorology: Heard and Macquarie Islands, 1948 Part 1(a) Results.	W.J. Gibbs, A.V. Gotley & A.R. Martin
2	Oct. 1951	Meteorology	Meteorology: Heard and Macquarie Islands, 1948 Part 1(b) Analysed Charts.	W.J. Gibbs, A.V. Gotley & A.R. Martin
3	Oct. 1951	Zoology	Seal Marking at Heard Island, 1949. I.R.I.	R.G. Chittle-borough & E.H.M. Ealey
4	Mar. 1952	Physics of Upper Atmosphere	Hourly Measurements of Ionospheric Characteristics, Macquarie Island, 1950. I.R.2.	D.S. Cohen
5	Oct. 1952	Meteorology	Meteorology: Heard and Macquarie Islands, 1948 Part 1(c) Discussion.	W.J. Gibbs, A.V. Gotley & A.R. Martin
6	Oct. 1952	Zoology	The Fleas of Sea Birds in the Southern Ocean. The Ticks of Sea Birds	B. de Meillon F. Zumpt
7	Jan. 1953	Zoology	The Status of the Leopard Seal at Heard Island and Macquarie Island, 1948. I.R.3.	A.M. Gwynn
8	Jan. 1953	Zoology	Notes on the Fur Seals at Macquarie Island and Heard Island. I.R.4.	A.M. Gwynn
9	Jan. 1953	Aurorae	Observations of the Aurora Australis, Macquarie Island, May 1950 - April, 1951. I.R.5.	N.R. Parsons & K.B. Fenton
10	Jan. 1953	Physics of Upper Atmosphere	Hourly Measurements of Ionospheric Characteristics, Macquarie Island, 1951. I.R.6.	Z.R. Jeffrey
11	Mar. 1953	Botany	The Mosses of Macquarie Island and Heard Island	H.T. Clifford
12	May. 1953	Geography	Heard Island. I.R.7.	P.G. Law & T. Burstall
13	July. 1953	Meteorology	Meteorology: Heard and Macquarie Islands, 1949.	Comm. Met. Bureau

Pubn. No.	Date of Publication	Subject	Title	Author
14	July. 1953	Meteorology	Meteorology: Heard and Macquarie Islands, 1950.	Comm. Met. Bureau
15	July. 1953	Meteorology	Meteorology: Heard and Macquarie Islands, 1951.	Comm. Met. Bureau
16	July. 1953	Zoology	The Egg-laying and Incubation Periods of Rockhopper, Macaroni and Gentoo Penguins.	A.M. Gwynn
17	Aug. 1953	Terrestrial Magnetism	Magnetic observations at Heard, Kerguelen and Macquarie Islands, 1947-51.	F. Jacka
18	Mar. 1955	Zoology	Penguin Marking at Heard Island, 1951 and 1953.	M.C. Downes & A.M. Gwynn
19	May. 1955	Botany	The Flora, Vegetation and Soils of Macquarie Island.	B.W. Taylor
20	Aug. 1955	Meteorology	Meteorology: Heard and Macquarie Islands, 1952.	Comm. Met. Bureau
21	Aug. 1955	Meteorology	Meteorology: Heard and Macquarie Islands, 1953.	Comm. Met. Bureau.
22	Nov. 1955	Zoology	A New Genus and Species of Hyadesid Mite - Algophagus antarcticus - from Heard Island.	A. Margaret Hughes
23	Nov. 1955	Aurorae	Instruments and Methods for Auroral Observation. I.R. 11.	F. Jacka & J. Ballantyne
24	Dec. 1955	Physics of Upper Atmosphere	Hourly Measurements of Ionospheric Characteristics, Macquarie Island 1954. I.R. 12.	T.F. Firmstone
25	Jan. 1956	Physics of Upper Atmosphere	Hourly Measurements of Ionospheric Characteristics, Macquarie Island, 1952. I.R. 9.	G. Major
26	Jan. 1956	Physics of Upper Atmosphere	Hourly Measurements of Ionospheric Characteristics, Macquarie Island, 1953. I.R. 10.	A.S. Little
27	Aug. 1956	Physics of Upper Atmosphere	Hourly Measurements of Ionospheric Characteristics, Macquarie Island, 1955. I.R. 13.	D.R.L. Callow
28	Sep. 1956	Terrestrial Magnetism	Magnetic Observations at Heard Island, 1952.	L.N. Ingall
29	Sep. 1956	Geography	Macquarie Island. I.R. 14.	P.G. Law & T. Burstall

Pubn. No.	Date of Publication	Subject	Title	Author
30	Sep. 1956	Zoology	Plankton, Hydrology and Marine Fouling at Heard Island. I.R.15.	E.H.M. Ealey & R.G. Chittle-borough.
31	Sep. 1956	Terrestrial Magnetism	Magnetic Observations at Macquarie Island, 1952.	R.M. McGregor
32	Feb. 1957	Zoology	The Seasonal Reproductive Cycle of the Female Elephant Seal - Mirounga leonina, Linn. - at Heard Island.	L.F. Gibbney
33	Feb. 1957	Zoology	Some Jellyfish from Macquarie Island and Heard Island.	P.L. Kramp
34	Mar. 1957	Terrestrial Magnetism	Magnetic Observations at Heard Island, 1953.	J.A. Brooks
35	Mar. 1957	Zoology	The Leopard Seal at Heard Island, 1951-54. I.R.16.	K.G. Brown
36	Mar. 1957	Cosmic Rays	The Design and Operation of ANARE Cosmic Ray Recorder "C". I.R.17.	N.R. Parsons
37	June. 1957	Terrestrial Magnetism	Magnetic Observations at Macquarie Island, 1953.	P.B. Tenni & J.A. Brooks
38	June. 1957	Meteorology	Meteorology: Mawson, Heard and Macquarie Islands, 1954.	Comm. Met. Bureau
39	Aug. 1957	Geology	The Trace Element of Some Soils and Rock from Macquarie Island, South Pacific Ocean.	D.J. Swaine
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42	Mar. 1958	Terrestrial Magnetism	Magnetic Observations at Heard Island, 1954.	K.B. Lodwick
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48	June. 1959	Terrestrial Magnetism	Magnetic Observations at Mawson, 1955.	W.H. Oldham
49	Sep. 1959	Geology	A Contribution to the Geology and Glaciology of the Western Part of Australian Antarctic Territory.	P.W. Crohn
50	Sep. 1959	Meteorology	Meteorology: Mawson and Macquarie Island, 1956.	Comm. Met. Bureau.
51	Nov. 1959	Zoology	The Birds of Heard Island.	M.C. Downes, E.H.M. Ealey, A.M. Gwynn & P.S. Young
52	June, 1960	Terrestrial Magnetism	Magnetic Observations at Mawson, 1956.	P.M. McGregor.
53	Nov. 1960	Terrestrial Magnetism	Field Magnetic Observations in Antarctica.	J.B. Pinn
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