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ICE CONDITIONS IN THE EASTERN BERING SEA FROM NOAA AND LANDSAT IMAGERY: WINTER CONDITIONS 1974, 1976, 1977, 1979

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CONTENTS

FIGURES

TABLES

Ice Conditions in the Eastern Bering Sea from NOAA and LANDSAT Imagery: Winter Conditions 1974, 1976, 1977, 1979*

by

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Abstract

LANDSAT and NOAA satellite images from the University of Alaska LANDSAT Library have been used to make maps of ice conditions in the eastern Bering Sea. The analyses included daily charts of the ice, polynya locations, floe trajectories, and comparisons between data taken from the two sources. A Zoom Transfer Scope (ZTS) was used to transfer the data from an image to a map base for late winter conditions in 1974, 1976, 1977, and 1979.

1. Introduction

The base map used in this study was taken from the JNC-16 Aeronautical Chart (NOAA) for the Bering Sea region. This chart conforms well with both LANDSAT and NOAA imagery. The LANDSAT library at the University of Alaska routinely files only those images which have 10 percent or less cloud cover, so the imagery used in this study is for areas where relatively cloud-free conditions existed. The LANDSAT images used in this study are limited to those which were available in

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print at the library. Some additional data were mapped which had more than 10 percent cloud cover; while other images were missing from the files and were not mapped. These omissions and additions do not significantly impact the data set. A list of all imagery used (and their dates) is presented in Appendix I.

NOAA images were selected on the basis of LANDSAT availability to provide concomitant coverage in cloud-free conditions. Periods with no LANDSAT data were also checked and imagery was chosen for other cloud-free times. Some cloud-free NOAA imagery was rejected due to the extreme distortion of the study area, if it was located in the margins of the imagery, or because poor imagery reproduction made analysis difficult. Corrections to the NOAA data were made on ice features where land was visible. Some distortion still remains so interpretations of these data are made on the basis of relative position and shape rather than absolute geographical location.

The study area was limited to that shown in the base map (Figure 1). The LANDSAT imagery rarely extends further than the southernmost portions of this map due to the cloudy conditions which often prevail at the ice edge. The floe motion was studied from the Bering Strait along the eastern margins near the Seward Peninsula (in Norton Sound) and east of St. Lawrence Island. The floe studies for 1974 were prepared on a different base map (Figure 2). Muench and Ahlnäs (1976) made an exhaustive study on floe motion in the Bering Sea using NOAA imagery for 1974. The 1974 LANDSAT imagery on these charts shows conditions in Norton Sound for that period and is intended to augment their work. These maps are treated separately in the present study.

2. Daily Charts

Daily charts showing conditions interpreted from NOAA and LANDSAT have been prepared for the following periods:

NOAA	LANDSAT
6-14 February 1976 (6) 22-27 February 1976 (5)	22-28 February 1976 (6)
9-21 March 1976 (9) 27,29 March 1976 (2)	13-16 March 1976 (4)
25-31 March 1977 (5) 13-17 April 1977 (5)	25-31 March 1977 (5) 13-16 April 1977 (4)
17-20 February 1979 (3) 23-28 February 1979 (6)	16-21 February 1979 (6) 25,28 February 1979 (2)

The NOAA and LANDSAT data were mapped separately, without cross referencing position of details of one to the other so that comparisons could be made of the separate interpretations. Previous NOAA imagery was used in order to facilitate location of features with the ZTS. In both cases, floes were identified from previous imagery to maintain continuity in tracking.

Annotations were made on the imagery about the "whiteness" of the ice type in each image. Thicker ice is whiter in a visual image due to snow cover and the fact that it rides higher out of the water; in an infrared (IR) image it is whiter because it is colder. The degree of whiteness is relative to each image only. The apparent location of these ice areas does carry over from day to day, but the absolute grey level is different from image to image. No corrections have been applied. The delineation of these areas is subjective and is plotted with a

broken line. The heavy dark line represents fast ice--ice that is attached to the shore. The terms used to describe the ice, i.e. grey, grey-white, are those used by the World Meteorology Organization (WMO) to describe ice thicknesses (WMO, 1970). These thickness distributions are implicit and are not intended to be used as absolute guidelines to ice thicknesses in the regions studied. Areas that show no detail were cloud-covered or extended beyond the imagery coverage.

The 41 NOAA charts are presented in Appendix II; the 27 LANDSAT charts are in Appendix III. All subsequent comparisons of these charts were made on the same base map.

3. Polynya Locations

The WMO definition of a polynya is "any nonlinear-shaped opening enclosed in the ice...(which) may contain brash ice and/or be covered with new ice, nilas or young ice" (WMO, 1970). The boundary shown in this study is between grey/grey-white and white ice. Most imagery showed a continuous change in grey tone from very dark to grey/grey-white with a pronounced change at the boundary of white ice. In some cases a very dark area of new ice/open water could be seen as the flow polynya near the fast ice edge. The outline of this area has been plotted with a finer line using the same symbols. Fast ice is shown with a heavy line. Changes seen in the fast ice boundary are plotted with the daily symbol in a heavy line. In order to retain readability, only three days' data are included on each map. The charts showing the polynya locations are in Appendix IV.

Existing literature shows that polynyas in the eastern Bering Sea form to the leeward side of east-west trending coasts under a dominant wind regime from the north-northeast (Muench and Ahlnäs, 1976; McNutt, 1980; Shapiro et al., 1980). These conditions exist for the charts from 6-14, 22-27 February 1976; 14-19 March 1976; 25-26, 29-31 March 1977; 13-17 April 1977. During 9-12 March 1976 the polynyas were open along northern coasts. This condition had reversed itself by 14-16 March 1976. Analyses of the winds for this period have been initiated using the METLIB package at the Pacific Marine Environmental Laboratory (Overland et al., 1980). Indications are that a low-pressure system caused a southerly wind and that this was replaced by north-northeast winds as the storm passed (Pease, personal communication). From 17-19 February

1979, the polynya south of Point Clarence was open, but loose ice was also present north of St. Lawrence Island. Charts for 23-28 February 1979 show the polynya areas opening to the west of the coastlines, indicating an easterly wind. This was a relatively light ice year (Niebauer, 1980), and ice growth took place rapidly. An analysis of the wind field has been initiated.

4. Floe Trajectories

Charts made from floe studies of NOAA and LANDSAT imagery are shown in Appendix V. Each chart is accompanied by a table estimating floe speeds and distance traveled. Floes on the NOAA imagery are numbered; those on LANDSAT are identified by letter. Floes on LANDSAT imagery also identified on NOAA retain their number identification. The initial location of the floe is a circle; subsequent locations are triangles which indicate the apparent direction of movement. If little or no significant movement occurred, the symbol is bracketed by parentheses.

The floe trajectories are interesting compared to polynya locations for the same period. Floe motion shows a response similar to the change in polynya location. This is most evident in the March 1976 charts. Floes move north when the polynyas are open along northern coastlines, and then move south when polynyas open along southern coasts. Floe motion in March 1977 and February 1976 show a southward movement of ice. February 1979 shows a motion to the north-northwest, similar to polynya locations. Individual floes on the NOAA imagery were tracked for 2 to 7 days. These days are not always continuous, so the actual period of time can be longer. LANDSAT coverage is for 2 and occassionally 3 days, all continuous.

The tables accompanying the floe trajectory charts in Appendix V give an approximate floe speed as measured from the mapped locations. The speeds are lowest in areas such as Norton Sound where the ice is bounded on three sides. The speeds are highest in areas where polynyas develop rapidly, e.g., south of Nome-Point Hope, or where the areal extent of the ice field increases downwind and ice divergence occurs,

e.g., east of St. Lawrence Island. Comparisons of floe speeds and discrepancies in locations and direction of travel are covered in section 6.

5. Comparisons between NOAA and LANDSAT Imagery

NOAA imagery provides information on a greater number of floes over a longer period of time than LANDSAT. However, the floe direction is affected by the corrections applied by the zoom transfer scope. This may account for the zig-zag floe motion seen in the trajectories for April 1977 north of Nunivak Island. The figures in Appendix VI show plots of the locations of floes and polynyas on LANDSAT and NOAA imagery. The floe trajectories from LANDSAT to NOAA compare well, except for April 1977. Here, the floes west of Seward Peninsula move south in LANDSAT and north in NOAA imagery. Daily plots of NOAA and LANDSAT data are shown on pages 155-157. The floe locations for 13 April and 14 April 1977 are very close, but in 15 April 1977 the discrepancy is large. There were many more floes present in the imagery than those mapped. Misidentification of floes from LANDSAT to NOAA and from image to image may account for the errors, along with distortion correction errors. In the other cases in Appendix V, floes in the same areas and the same floes tracked on NOAA and LANDSAT data have similar speeds and show a strong correlation in floe direction.

The NOAA polynya maps in Appendix IV are useful in examining the ice processes and conditions for forecasting purposes. A study is currently underway to relate the response time of the change in polynya location for March 1976 to the wind conditions for that period. The polynya locations compare well in Appendix VI, especially in shape and extent. The actual location seems to be shifted due to corrections applied to NOAA imagery, however, because the larger area presented

makes changes in grey scale more apparent. Differences such as those on 15 April 1977 may be due to a different interpretation of the relative grey scale. When only one LANDSAT image is available, polynya extent is difficult to determine.

A two-day event is presented in Appendix VI for 29-30 March 1977 where ice has broken free from the pack surrounding St. Lawrence Island and is moving south-southwest away from the island. The rotation and disintegration of these floes is easy to see on LANDSAT imagery. The location of the leads and the rapid change in position and rotation of the floes gives insight to the shear processes which occur under conditions of rapid divergence.

6. LANDSAT Charts for 1974

Muench and Ahlnäs (1976) made a comprehensive study of floe locations in the Bering Sea using 1974 NOAA satellite data. They found that the dominant ice motion was to the south-southwest under a north-northeast wind regime, and that this created regions of ice divergence to the south of east-west trending coasts. No LANDSAT data were used in this study. Appendix VII shows daily charts and floe trajectory charts for 1974 LANDSAT data.

Muench and Ahlnäs showed that there was a southward motion in floe movement until April when the ice edge was ill-defined and the ice cover began to retreat. LANDSAT floe studies for 1974 show a southward floe motion in February and March and a reduced southward floe motion in April. April also shows an increased northerward floe motion in northern Norton Sound and, by May, a northward floe motion toward Bering Strait. A westward motion also appears in the March and April data in the Norton Sound area. This suggests an easterly wind. This motion is also found in the February and March 1976 trajectories.

Another comparison is found in the location of the ice edge in Norton Sound. As the ice in the main pack is retreating and individual floes begin to move northward toward Bering Strait, the retreat in Norton Sound begins in the eastern area and proceeds toward the southwestern portion of the sound. The ice is pulled away from the northern shore beginning on the easternmost side, and is blown to the west-southwest leaving open water behind. This also suggests a strong local easterly component to the wind in Norton Sound.

7. Conclusions

Subject to cloud cover, both NOAA and LANDSAT imagery provide useful information for preparing daily ice charts. The size, shape, and relative locations of polynyas and ice thickness estimations can be provided by NOAA imagery. The general motion and speed of floes can be estimated but should not be used for absolute geographic location unless rigorous methods of geometric correction are applied. Accuracy will still be subjective because of the difficulties in identifying individual floes and in carrying a grey-scale interpretation from image to image when no absolute calibrations have been applied. Use of LANDSAT imagery is limited by its orbit, which provides floe coverage for a two- to three-day period and then does not repeat again for several days. The NOAA orbit is not designed for use in the Bering Sea, and often the image area is distorted. The needed geometric corrections provide good information on floe speed and the shape of ice features when done on a ZTS. Even with these problems, both types of imagery are useful for preparing small-scale ice charts for the Bering Sea.

The floe trajectories and ice conditions found in this study agree with hypotheses on Bering Sea ice processes (Muench and Ahlnäs, 1976, McNutt, 1980; Shapiro et al., 1980). The winter ice in the Bering Sea is formed in the leeward sides of east-west trending coasts and is advected downwind under a dominant north-northeast wind. Ice travels fastest in areas of divergence where there is an open boundary downwind and travels more slowly where it is contained, e.g., east of St. Lawrence Island vs. Norton Sound. When a storm passes through causing a wind shift to the south-southwest, the polynyas will open to the north of

east-west trending coasts. The time required for this change in March 1976 was three days. In general, floes travel to the south-southwest under fully developed winter conditions and begin to migrate northward as the ice cover begins to retreat. The ice retreat and floe motions in Norton Sound suggest a strong easterly component to the local wind there.

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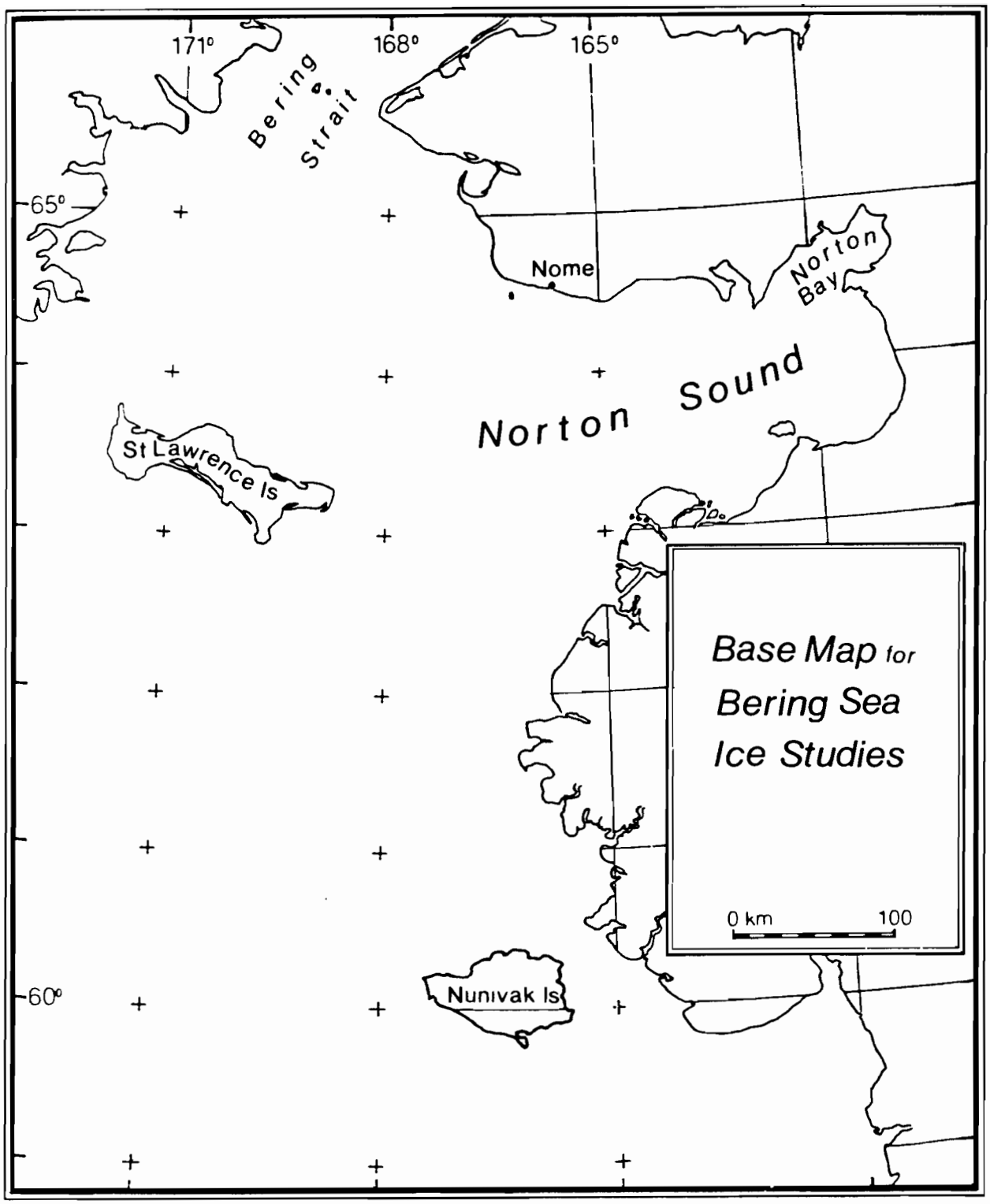


Figure 1. Base map used for study area.

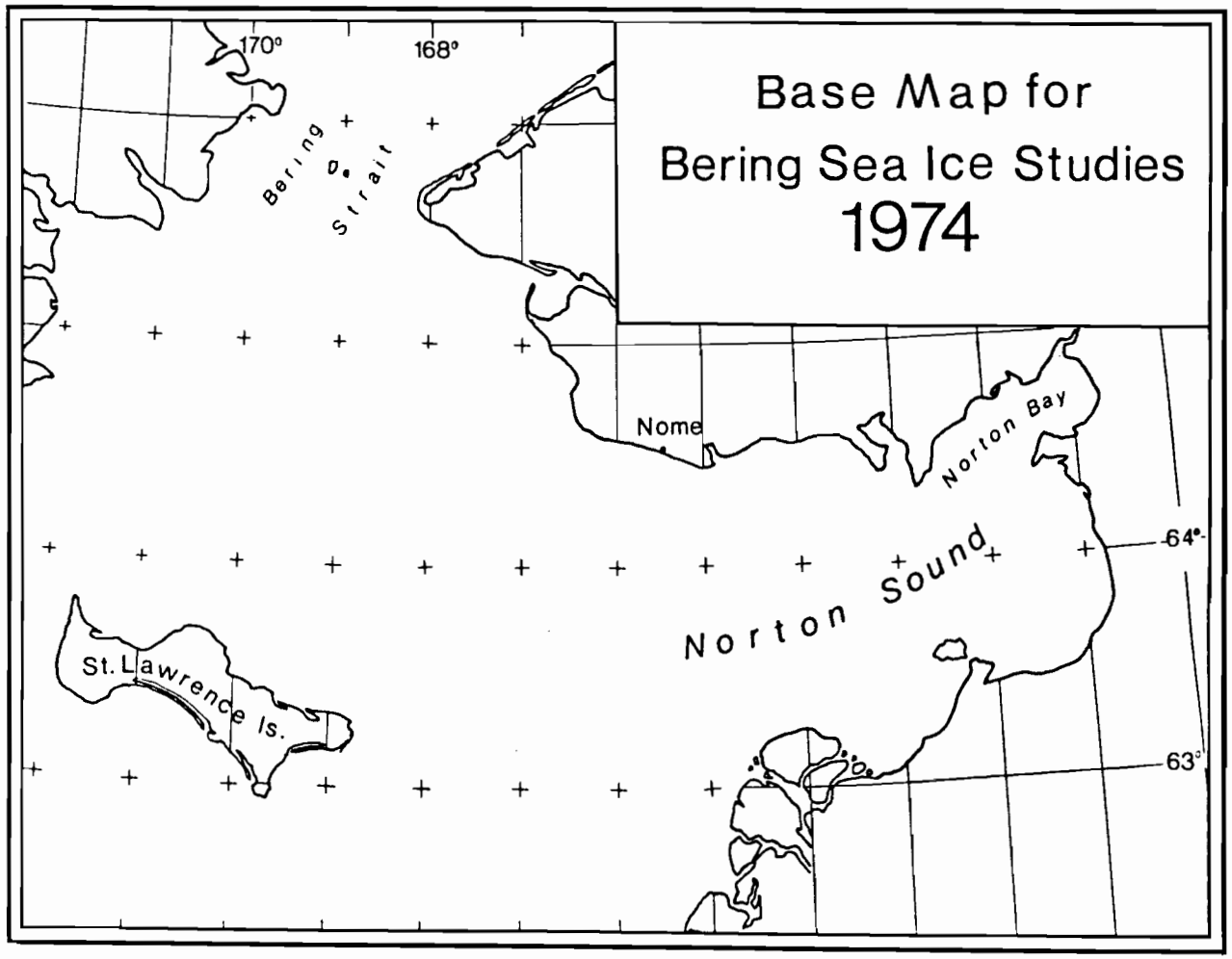


Figure 2. Base map used for 1974 LANDSAT study.

Table 1

NOAA Floe Trajectories for February 1976

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
1	22	--	--	--
	23	24.9	11.3	12.6
2	23	--	--	--
	25	47.9	37.7	21.8*
	26	23.9	9.4	10.9
	27	24.9	11.3	12.6
3	23	--	--	--
	25	47.9	37.7	21.8*
	26	23.9	7.5	8.7
	27	24.9	11.3	12.6
4	23	--	--	--
	25	47.9	39.5	22.9*
	26	23.9	13.1	15.3
5	25	--	--	--
	26	23.9	3.7	4.4
6	25	--	--	--
	26	23.9	7.5	8.7
	27	24.9	7.5	8.7

*Averaged over more than one day interval.

Table 2

NOAA Floe Trajectories for March 1976

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
1.	9	--	--	--
	10	23.0	20.0	24.1
	13	72.8	13.1	5.0*
	14	23.0	32.0	38.7
	16	47.9	47.1	27.3
	17	24.9	29.0	32.4
2	9	--	--	--
	10	23.0	20.7	25.0
	13	72.8	7.5	2.8*
	14	23.0	39.6	47.8
	16	47.9	66.0	38.2
	17	24.9	38.8	55.9
3	10	--	--	--
	14	95.2	22.6	6.6*
	17	73.0	58.4	22.2*
4	15	--	--	--
	16	23.0	11.3	13.7
	17	24.9	11.3	12.6
	18	23.0	16.7	20.5
	21	72.8	19.6	7.5*
	27	143.8	15.1	2.9*
	29	47.9	10.2	5.9*
5	15	--	--	--
	16	23.0	9.4	11.4
	17	24.9	8.3	9.1
	18	23.0	7.5	9.1
	21	42.8	15.1	5.8*
	27	143.8	15.1	2.9*
	29	47.9	7.5	4.4I
6	14	--	--	--
	15	24.9	39.6	44.2
	16	23.0	41.5	50.0
	17	24.9	8.3	9.2

Table 2 (continued)

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
7	14	--	--	--
	15	24.9	39.6	44.2
	16	23.0	20.7	25.0
	17	24.9	54.7	60.9
8	14	--	--	--
	15	24.9	40.7	45.4
	16	23.0	40.3	48.7
	17	24.9	44.5	49.6
9	15	--	--	--
	16	23.0	25.2	30.5
	17	24.9	22.6	25.2
	18	23.0	41.5	50.0
10	16	--	--	--
	17	24.9	30.2	33.6
	18	23.0	15.8	19.1
11	16	--	--	--
	17	24.9	15.8	19.1
12	16	--	--	--
	17	24.9	15.1	16.8
13	16	--	--	--
	17	24.9	22.6	25.2
	18	23.0	41.5	50.0
	21	72.8	47.9	18.3*
14	16	--	--	--
	17	24.9	30.2	33.6
	18	23.0	35.8	43.2
	21	72.8	45.2	17.2*
15	16	--	--	--
	17	24.9	28.3	31.5
	18	23.0	37.7	45.5
	21	72.8	40.3	15.4*

Table 2 (continued)

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
16	27	--	--	--
	29	47.9	18.6	10.9*
17	27	--	--	--
	29	47.9	24.5	14.2*
18	27	--	--	--
	29	47.9	13.2	7.6*

*Averaged over more than 1 day interval.

Table 3

LANDSAT Floe Trajectories for February 1976

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
A	22	--	--	--
	23	24.1	9.4	10.9
B	23	--	--	--
	25	48.2	15.1	8.7
C	25	--	--	--
	26	24.1	3.8	4.3
D	25	--	--	--
	26	24.1	4.5	5.2
E	25	--	--	--
	26	24.1	5.7	6.5
F	25	--	--	--
	26	24.1	3.0	3.5
G	25	--	--	--
	26	24.1	3.0	3.5
H	25	--	--	--
	26	24.1	15.1	17.4
	27	24.1	7.5	8.7
J	27	--	--	--
	28	24.1	7.5	8.7
K	27	--	--	--
	28	24.1	11.3	13.0
L	27	--	--	--
	28	24.1	17.0	19.6
M	27	--	--	--
	28	24.1	26.4	30.4

Table 3 (continued)

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
N	24	--	--	--
	28	24.1	9.4	10.9
O	27	--	--	--
	28	24.1	24.5	28.2
P	27	--	--	--
	28	24.1	18.6	21.7
Q	27	--	--	--
	28	24.1	24.5	28.2

Table 4

LANDSAT Floe Trajectories for March 1976

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
A	13	--	--	--
	14	24.1	7.5	8.7
B	13	--	--	--
	14	24.1	5.7	6.5
C	14	--	--	--
	15	24.1	38.8	44.7
D	14	--	--	--
	15	24.1	35.1	40.4
F	14	--	--	--
	15	24.1	10.9	12.6
G	14	--	--	--
	15	24.1	13.2	15.2
H	14	--	--	--
	15	24.1	11.3	13.0
K	14	--	--	--
	15	24.1	13.2	15.2
L	14	--	--	--
	15	24.1	9.4	10.8
M	14	--	--	--
	15	24.1	17.0	19.6
	16	24.1	15.1	17.4
N	14	--	--	--
	15	24.1	22.6	26.1
P	15	--	--	--
	16	24.1	52.8	60.8
Q	15	--	--	--
	16	24.1	52.8	60.8
R	15	--	--	--
	16	24.1	50.8	58.7

Table 4 (continued)

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
S	15	--	--	--
	16	24.1	49.0	56.5
T	15	--	--	--
	16	24.1	47.1	54.3
7	14	--	--	--
	15	24.1	39.6	45.6
8	14	--	--	--
	15	24.1	42.6	49.1

Table 5

NOAA Floe Trajectories for March 1977

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
1	25	--	--	--
	26	23.3	6.8	8.0
2	25	--	--	--
	26	23.3	12.4	14.8
3	25	--	--	--
	26	23.3	16.2	19.3
4	25	--	--	--
	26	23.3	20.0	23.8
5	25	--	--	--
	26	23.3	17.7	21.1
6	25	--	--	--
	26	23.3	22.6	27.0
7	25	--	--	--
	26	23.3	20.7	24.7
8	25	--	--	--
	26	23.3	20.7	24.7
9	25	--	--	--
	26	23.3	18.9	22.5
10	25	--	--	--
	26	23.3	20.7	24.7
11	25	--	--	--
	26	23.3	19.6	23.4
12	25	--	--	--
	26	23.3	0	0
13	25	--	--	--
	26	23.3	8.7	10.3
14	25	--	--	--
	26	23.3	4.9	5.8

Table 5 (continued)

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
15	25	--	--	--
	26	23.3	9.4	11.2
16	25	--	--	--
	26	23.3	18.9	22.5
17	25	--	--	--
	26	23.3	18.9	22.5
18	25	--	--	--
	26	23.3	20.7	24.7
	29	71.3	11.3	4.4*
	30	25.2	9.4	10.4
	31	23.3	7.5	9.0
19	25	--	--	--
	26	23.3	22.6	27.0
	29	71.3	17.0	6.6*
	30	25.2	5.6	6.2
	31	23.3	15.1	18.0
20	25	--	--	--
	26	23.3	23.8	28.3
21	25	--	--	--
	26	23.3	17.0	20.2
22	25	--	--	--
	26	23.3	20.7	24.7
23	25	--	--	--
	26	23.3	13.2	15.7
24	25	--	--	--
	26	23.3	13.2	15.7
25	25	--	--	--
	26	23.3	11.3	13.5
	29	71.3	22.6	8.8*
	30	25.2	12.8	14.1
	31	23.3	0	0

Table 5 (continued)

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
26	25	--	--	--
	26	23.3	9.4	11.2
27	25	--	--	--
	26	23.3	12.4	14.8
28	25	--	--	--
	26	23.3	15.1	18.0
29	25	--	--	--
	26	23.3	15.8	18.9
30	25	--	--	--
	26	23.3	15.1	18.0
31	25	--	--	--
	26	23.3	17.0	20.2
32	25	--	--	--
	26	23.3	11.3	13.5
	29	71.3	25.3	9.8*
	30	25.2	11.3	13.5
	31	23.3	18.6	22.5
33	25	--	--	--
	26	23.3	11.3	13.5
	29	71.3	18.6	7.3*
34	25	--	--	--
	26	23.3	14.7	17.5
35	25	--	--	--
	26	23.3	17.0	20.2
36	25	--	--	--
	26	23.3	17.0	21.1
37	25	--	--	--
	26	23.3	18.6	22.5
38	25	--	--	--
	26	23.3	17.0	20.2
39	25	--	--	--
	26	23.3	17.0	20.2

Table 5 (continued)

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
40	25	--	--	--
	26	23.3	18.6	22.5
41	29	--	--	--
	30	25.2	18.6	20.8
	31	23.3	28.3	33.7
42	29	--	--	--
	30	25.2	15.1	16.6
	31	23.3	26.4	31.5
43	29	--	--	--
	30	25.2	11.3	12.5
	31	23.3	16.6	19.8
44	29	--	--	--
	30	25.2	22.6	25.0
	31	23.3	8.3	9.9
45	29	--	--	--
	30	25.2	20.7	22.6
	31	23.3	7.5	9.0
46	29	--	--	--
	30	25.2	27.9	30.8
	31	23.3	4.5	5.4
47	29	--	--	--
	30	25.2	18.6	20.8
	31	23.3	5.7	6.7
48	29	--	--	--
	30	25.2	18.1	19.9
	31	23.3	6.8	8.0

*Averaged over more than one day interval.

Table 6

NOAA Floe Trajectories for April 1977

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
1	13	--	--	--
	14	23.3	11.3	13.5
	15	25.2	11.3	12.5
	16	23.3	15.1	18.0
	17	23.3	9.4	11.2
2	13	--	--	--
	14	23.3	11.3	13.5
	15	25.2	11.3	12.5
	16	23.3	13.6	16.1
	17	23.3	14.3	17.1
3	13	--	--	--
	14	23.3	14.7	17.5
	15	25.2	13.2	14.5
4	13	--	--	--
	14	23.3	15.1	18.0
5	13	--	--	--
	14	23.3	13.2	15.7
	15	25.2	7.5	8.3
	16	23.3	7.5	9.0
8	13	--	--	--
	14	23.3	11.3	13.5
	15	25.2	7.2	7.9
	16	23.3	10.9	13.0
9	13	--	--	--
	14	23.3	12.1	14.4
	15	25.2	8.3	9.1
	16	23.3	9.0	10.8
10	13	--	--	--
	14	23.3	7.5	9.0
	15	25.2	5.6	6.2
	16	23.3	6.0	7.2
	17	23.3	18.1	21.6

Table 6 (continued)

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
11	13	--	--	--
	14	23.3	9.0	10.8
	15	25.2	0	0
	16	23.3	7.5	9.0
	17	23.3	15.1	17.8
12	13	--	--	--
	14	23.3	5.3	6.3
	15	25.2	0	0
	16	23.3	9.8	11.7
	17	23.3	15.8	18.9
13	13	--	--	--
	14	23.3	13.2	15.7
14	13	--	--	--
	14	23.3	5.7	6.7
	15	25.2	0	0
	16	23.3	13.6	16.2
15	13	--	--	--
	14	23.3	6.4	7.6
	15	25.2	4.5	5.0
	16	23.3	17.0	20.2
16	13	--	--	--
	14	23.3	5.3	6.3
17	13	--	--	--
	14	23.3	3.8	4.5
	15	25.2	3.0	3.3
18	13	--	--	--
	14	23.3	0	0
	15	25.2	6.4	7.1
19	13	--	--	--
	14	23.3	5.7	6.7
	15	25.2	3.8	4.2
	16	23.3	7.2	8.5

Table 6 (continued)

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
20	13	--	--	--
	14	23.3	0	0
	15	25.2	6.8	7.5
	16	23.3	13.2	15.7
21	13	--	--	--
	14	23.3	3.4	4.0
	15	25.2	2.3	2.5
	16	23.3	6.0	7.2
22	13	--	--	--
	14	23.3	3.8	4.5
	15	25.2	3.4	3.7
	16	23.3	6.0	7.2
23	13	--	--	--
	14	23.3	7.5	9.0
	15	25.2	7.9	8.7
	16	23.3	13.9	16.6
	17	23.3	13.2	15.7
24	13	--	--	--
	14	23.3	5.7	6.7
	15	25.2	5.7	6.2
25	13	--	--	--
	14	23.3	15.1	18.0
	15	25.2	10.9	12.1
26	13	--	--	--
	14	23.3	6.0	7.2
	15	25.2	18.9	20.8
	16	23.3	6.8	8.0
27	13	--	--	--
	14	23.3	9.4	11.2
	15	25.2	18.1	19.9
	16	23.3	9.0	10.8

Table 6 (continued)

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
28	13	--	--	--
	14	23.3	6.8	8.1
	15	25.2	15.1	16.6
	16	23.3	8.7	10.3
	17	23.3	15.1	18.0
29	13	--	--	--
	14	23.3	7.9	9.4
	15	25.2	13.9	15.4
30	13	--	--	--
	14	23.3	8.7	10.3
31	13	--	--	--
	14	23.3	7.2	8.5
32	13	--	--	--
	14	23.3	6.0	7.2
	15	25.2	10.6	11.6
33	13	--	--	--
	14	23.3	6.8	8.1
	15	25.2	9.4	10.4
34	13	--	--	--
	14	23.3	6.0	7.2
	15	25.2	11.3	12.5
	17	47.3	15.1	8.6*
35	13	--	--	--
	14	23.3	7.5	9.0
	15	25.2	13.2	14.5
36	13	--	--	--
	14	23.3	9.8	11.7
37	13	--	--	--
	14	23.3	11.3	13.5
38	13	--	--	--
	14	23.3	9.4	11.2

Table 6 (continued)

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
39	13	--	--	--
	14	23.3	12.4	14.8
40	15	--	--	--
	16	23.3	9.8	11.7
	17	23.3	15.8	18.9
41	15	--	--	--
	16	23.3	7.2	8.0
42	15	--	--	--
	16	23.3	4.9	5.8
43	15	--	--	--
	16	23.3	9.4	11.2
	17	23.3	14.3	17.1
44	15	--	--	--
	16	23.3	13.2	15.7
	17	23.3	17.0	20.2
45	15	--	--	--
	16	23.3	7.5	9.0
46	15	--	--	--
	16	23.3	8.3	9.9

*Averaged over more than one day interval.

Table 7

LANDSAT Floe Trajectories for March 1977

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
A	25	--	--	--
	26	24.1	7.5	8.7
C	25	--	--	--
	26	24.1	0	0
D	25	--	--	--
	26	24.1	0	0
E	25	--	--	--
	26	24.1	0	0
F	25	--	--	--
	26	24.1	3.8	4.3
G	25	--	--	--
	26	24.1	3.0	3.5
H	25	--	--	--
	26	24.1	0	0
I	25	--	--	--
	26	24.1	3.0	3.5
J	25	--	--	--
	26	24.1	0	0
K	25	--	--	--
	26	24.1	3.4	3.9
L	25	--	--	--
	26	24.1	2.6	3.9
M	25	--	--	--
	26	24.1	1.9	2.8
N	25	--	--	--
	26	24.1	2.6	3.0
O	25	--	--	--
	26	24.1	3.8	4.3

Table 7 (continued)

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
P	25	--	--	--
	26	24.1	3.8	4.3
Q	25	--	--	--
	26	24.1	3.8	4.3
R	25	--	--	--
	26	24.1	3.8	4.3
S	25	--	--	--
	26	24.1	0	0
U	29	--	--	--
	30	24.1	22.6	26.1
V	29	--	--	--
	30	24.1	29.8	34.3
W	29	--	--	--
	30	24.1	18.1	20.9
X	29	--	--	--
	30	24.1	26.8	30.9
Y	29	--	--	--
	30	24.1	26.4	30.4
Z	29	--	--	--
	30	24.1	28.3	32.6
AA	30	--	--	--
	31	24.1	18.9	21.7
AB	30	--	--	--
	31	24.1	15.1	17.4
AC	30	24.1	15.8	18.3

Table 8

LANDSAT Floe Trajectories for April 1977

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
A	13	--	--	--
	14	24.1	0	0
	15	24.1	9.0	10.4
B	13	--	--	--
	14	24.1	0	0
	15	24.1	8.7	10.0
C	13	--	--	--
	14	24.1	2.6	3.0
D	13	--	--	--
	14	24.1	0	0
E	13	--	--	--
	14	24.1	0	0
F	13	--	--	--
	14	24.1	9.8	11.3
G	13	--	--	--
	14	24.1	10.6	12.2
H	13	--	--	--
	14	24.1	9.4	10.9
I	13	--	--	--
	14	24.1	15.1	17.4
J	13	--	--	--
	14	24.1	18.9	21.7
K	13	--	--	--
	14	24.1	20.7	23.9
L	13	--	--	--
	14	24.1	20.4	23.5
M	15	--	--	--
	16	24.1	15.8	18.3
N	16	--	--	--
	17	24.1	7.5	8.7

Table 8 (continued)

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
3	15	--	--	--
	16	24.1	6.4	7.4
13	14	--	--	--
	15	24.1	7.5	8.7
14	14	--	--	--
	15	24.1	12.8	14.8
16	13	--	--	--
	14	24.1	0	0
	15	24.1	3.8	4.3
17	13	--	--	--
	14	24.1	0	0
18	13	--	--	--
	14	24.1	3.8	4.3
19	13	--	--	--
	14	24.1	3.8	4.3
21	13	--	--	--
	14	24.1	4.5	5.2
23	13	--	--	--
	14	24.1	6.8	7.8
40	15	--	--	--
	16	24.1	7.5	6.9
43	15	--	--	--
	16	24.1	9.4	10.9
46	15	--	--	--
	16	24.1	15.1	17.4

Table 9

NOAA Floe Trajectories for February 1979

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
1	17	--	--	--
	18	23.3	17.0	20.2
	20	48.5	32.0	18.4*
	21	24.9	41.5	46.3
	24	72.1	13.6	5.2*
2	20	--	--	--
	21	24.9	43.4	48.4
	24	72.1	15.1	5.8*
3	21	--	--	--
	24	72.1	12.4	4.8*
4	21	--	--	--
	24	72.1	13.2	5.1*
5	21	--	--	--
	24	72.1	15.1	5.8*

*Averaged over more than one day interval.

Table 10

LANDSAT Floe Trajectories for February 1979

Floe No.	Date	Time (hrs)	Dist. (km)	Speed (cms^{-1})
A	19	--	--	--
	20	24.1	11.3	13.0
B	19	--	--	--
	20	24.1	12.4	14.3
C	19	--	--	--
	20	24.1	11.3	13.0
D	19	--	--	--
	20	24.1	9.0	10.4
E	19	--	--	--
	20	24.1	21.5	24.8
F	19	--	--	--
	20	24.1	24.1	27.8
G	19	--	--	--
	20	24.1	25.6	29.5
I	19	--	--	--
	20	24.1	22.6	26.1

Appendix I

Listing of NOAA and LANDSAT Imagery

A listing of all NOAA and LANDSAT imagery used in this study is contained in Appendix I. The tables list the imagery by month and year, image type, and (with LANDSAT) by path and row number.

March 1976

Date	Image Type	Number	Path-row	Time
9 Mar 76	NOAA	6013	-	21:59:08
10 Mar 76	NOAA	6025	-	21:00:39
13 Mar 76	NOAA	6063	-	21:49:31
	LANDSAT	2416	86-15	21:38:10
14 Mar 76	NOAA	6075	-	20:50:45
	LANDSAT	2417	87-15	21:44:00
15 Mar 76	NOAA	6088	-	21:45:43
	LANDSAT	2418	88-15	21:49:40
			88-16	21:50:00
16 Mar 76	NOAA	6100	-	20:46:10
	LANDSAT	2419	89-14	21:55:00
			89-15	21:55:20
17 Mar 76	NOAA	6113	-	21:40:02
18 Mar 76	NOAA	6125	-	20:41:05
21 Mar 76	NOAA	6163	-	21:30:21
27 Mar 76	NOAA	6238	-	21:15:50
29 Mar 76	NOAA	6263	-	21:10:49

February 1976

Date	Image type	Number	Path-row	Time
6 Feb 76	NOAA	5612	-	21:24:31
7 Feb 76	NOAA	5624	-	20:25:09
8 Feb 76	NOAA	5637	-	21:19:08
9 Feb 76	NOAA	5649	-	20:20:11
10 Feb 76	NOAA	5662	-	21:14:20
12 Feb 76	NOAA	5687	-	21:09:29
14 Feb 76	NOAA	5712	-	21:04:48
22 Feb 76	NOAA	5812	-	20:45:13
	LANDSAT	2396	84-15	21:27:20
23 Feb 76	NOAA	5825	-	21:39:21
	LANDSAT	2397	85-15	21:33:00
			85-16	21:33:30
			85-17	21:33:50
25 Feb 76	NOAA	5850	-	21:34:16
	LANDSAT	2399	87-15	21:44:30
26 Feb 76	NOAA	5862	-	20:35:19
	LANDSAT	2400	88-14	21:49:50
			88-15	21:50:10
			88-16	21:50:40
27 Feb 76	NOAA	5875	-	21:29:32
	LANDSAT	2401	89-14	21:55:30
			89-15	21:55:50
28 Feb 76	LANDSAT	2402	90-14	22:01:10

1974

February

Date	Image type	Number	Path-row	Time
8 Feb 74	LANDSAT	1565	87-15	21:55:00
		1565	87-16	21:55:20
9 Feb 74	LANDSAT	1566	88-15	22:00:40
		1566	88-16	22:01:10
10 Feb 74	LANDSAT	1567	89-14	22:06:00
		1567	89-15	22:06:20
		1567	89-16	22:06:50
11 Feb 74	LANDSAT	1568	90-16	22:12:30
27 Feb 74	LANDSAT	1584	89-16	22:00:50

March

14 Mar 74	LANDSAT	1599	85-15	21:43:00
		1599	85-16	21:43:20
15 Mar 74	LANDSAT	1600	86-15	21:48:40
		1600	86-16	21:49:10
16 Mar 74	LANDSAT	1601	87-15	21:54:20
			87-16	21:54:50

April

2 Apr 74	LANDSAT	1618	86-16	21:48:20
		1618	86-17	21:48:50
3 Apr 74	LANDSAT	1619	87-15	21:54:00
		1619	87-16	21:54:30
7 Apr 74	LANDSAT	1623	91-15	22:16:50
		1623	91-16	22:17:20
8 Apr 74	LANDSAT	1624	92-14	22:22:10
		1624	92-15	22:22:40
21 Apr 74	LANDSAT	1637	87-15	21:53:40

May

Date	Image type	Number	Path-row	Time
8 May 74	LANDSAT	1654	86-15	21:47:30
26 May 74	LANDSAT	1672	86-15	21:47:70
30 May 74	LANDSAT	1676	90-14	22:09:20
31 May 74	LANDSAT	1677	91-14	22:15:00

March 1977

25 Mar 77	NOAA	2961	-	21:59:21
	LANDSAT	2793	85-15	21:19:50
			85-16	21:20:10
			85-17	21:20:40
			85-18	21:21:00
26 Mar 77	NOAA	2973	-	21:17:36
	LANDSAT	2794	86-15	21:25:30
			86-16	21:26:00
			86-17	21:26:20
			86-18	21:26:50
29 Mar 77	NOAA	3010	-	21:01:36
	LANDSAT	2797	89-16	21:43:00
			89-17	21:43:20
30 mar 77	NOAA	3023	-	22:12:37
	LANDSAT	2798	90-14	21:47:50
			90-15	21:48:20
31 Mar 77	NOAA	3035	-	21:31:32
	LANDSAT	2789	91-15	21:54:00

April 1977

Date	Image type	Number	Path-row	Time
13 Apr 77	NOAA	3196	-	21:39:36
	LANDSAT	2812	86-15	21:24:40
		2812	86-16	21:25:00
		2812	86-17	21:25:30
		2812	86-18	21:25:50
14 Apr 77	NOAA	3208	-	20:56:36
	LANDSAT	2813	87-15	21:30:20
		2813	87-16	21:30:40
		2813	87-17	21:31:10
15 Apr 77	NOAA	3221	-	22:06:36
	LANDSAT	2814	88-15	21:36:00
16 Apr 77	NOAA	3233	-	21:24:35
	LANDSAT	2815	89-14	21:41:10
			89-15	21:41:40
17 Apr 77	NOAA	3245	-	20:41:35
	LANDSAT	2816	90-14	21:46:50

February 1979

Date	Image type	Number	Path-row	Time
16 Feb 79	LANDSAT	30348	85/15	21:37:10
			85/16	21:37:40
			85/17	21:38:00
			85/18	21:38:30
17 Feb 79	NOAA	11551	-	21:27:20
	LANDSAT	30349	86-15	21:42:50
		30349	86-16	21:43:40
		30349	86-17	21:44:10
18 Feb 79	NOAA	11563	-	20:43:38
	LANDSAT	30350	87-16	21:49:00
19 Feb 79	LANDSAT	30351	88-14	21:54:00
		30351	88-15	21:54:20
20 Feb 79	NOAA	11588	-	21:13:36
	LANDSAT	30352	89-14	21:59:40
		30352	89-15	22:00:10
21 Feb 79	LANDSAT	30353	90-14	22:05:30
23 Feb 79	NOAA	11625	-	20:58:36
24 Feb 79	NOAA	11638	-	22:09:22
25 Feb 79	NOAA	11650	-	21:23:59
		11650	-	21:29:34
	LANDSAT	21495	85-15	21:25:10
		21495	85-16	21:25:40
26 Feb 79	NOAA	11662	-	20:40:55
27 Feb 79	NOAA	11675	-	21:51:42
		11675	-	21:57:17
28 Feb 79	NOAA	11687	-	21:14:20
		11687	-	21:08:45
	LANDSAT	21498	88-15	21:42:30

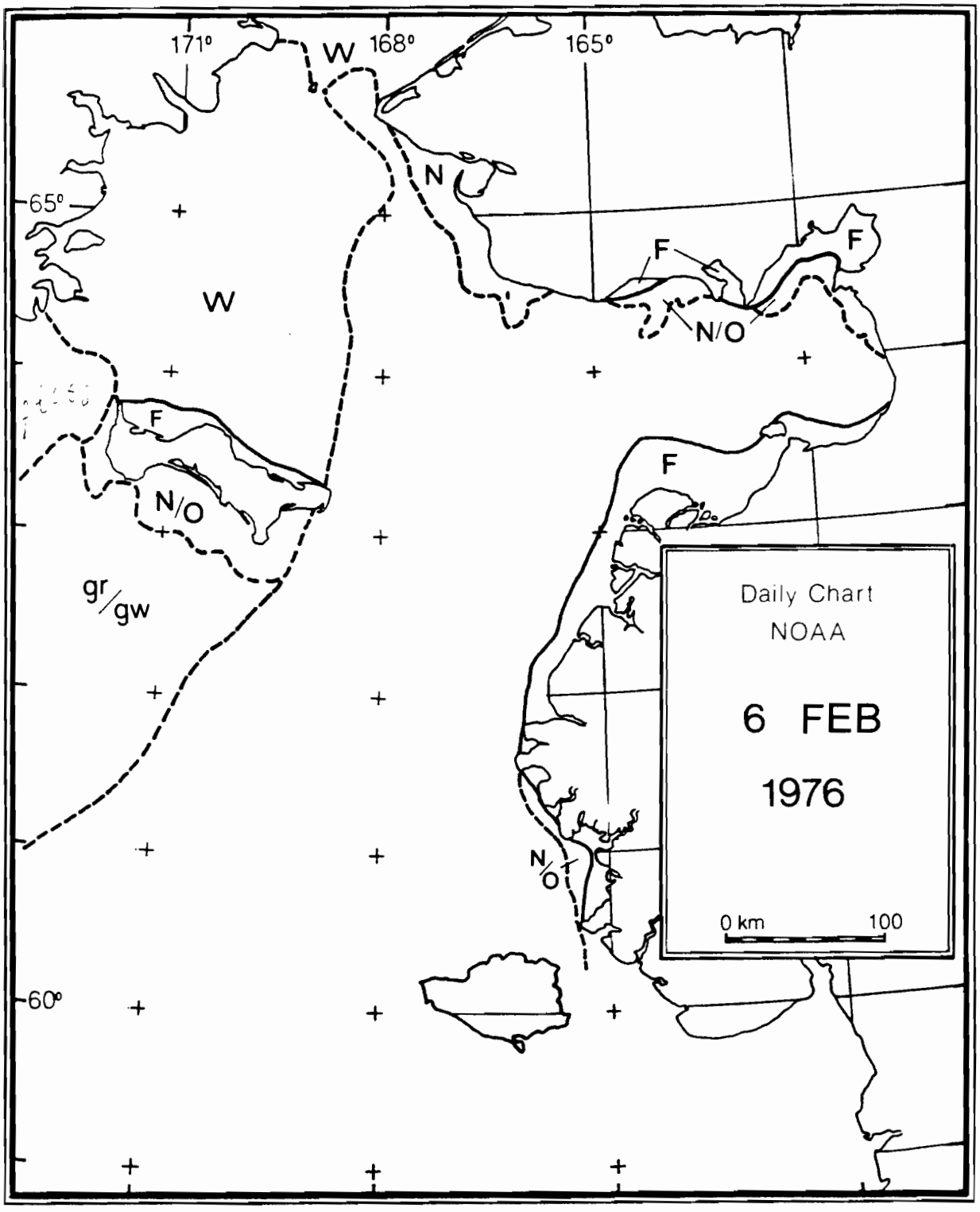
Appendix II

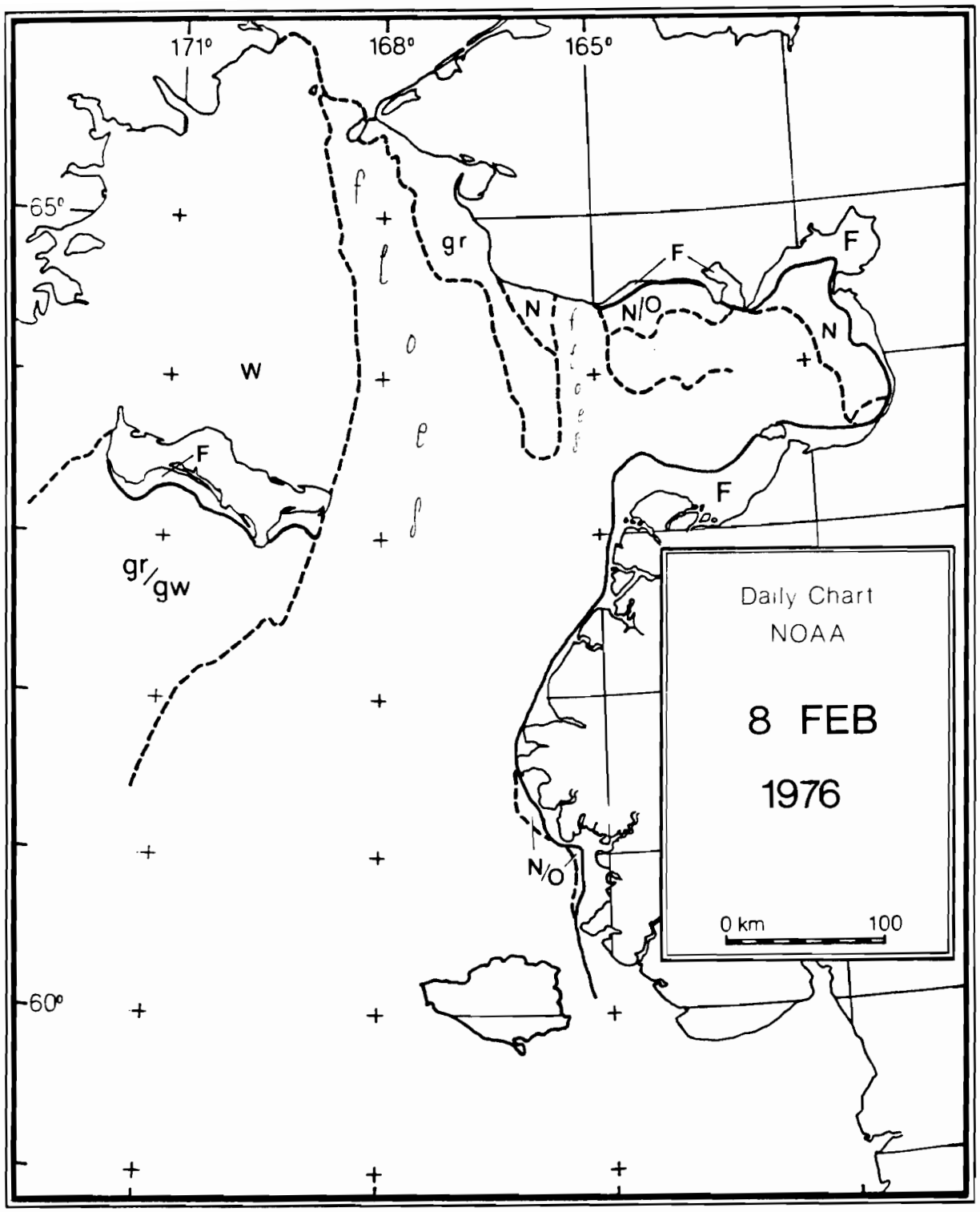
NOAA--Daily Charts of Ice Conditions

The NOAA imagery listed in Appendix I provided the daily ice data which has been transferred to the base map shown in Figure 1. The legend presented on the following page explains the line symbols and the ice-type abbreviations used. All ice definitions refer to WMO classifications (1970), but show a grey scale distinction in ice color on each image, not actual ice type or thickness.

LEGEND

▬▬	land-fast ice
- - -	border of change from one ice color to another
——	lead
0	open water
N	new ice
gr	grey ice
gw	grey-white ice
W	white ice
◯	ice floe


171°
W
168°
165°
65°
N
W
F
F
N/O
F
F
N/O
gr/gw
Daily Chart
NOAA
6 FEB
1976
N/O
0 km
100
60°


171°
168°
165°
65°
60°
W
gr
N
N/O
F
gr/gw
Daily Chart
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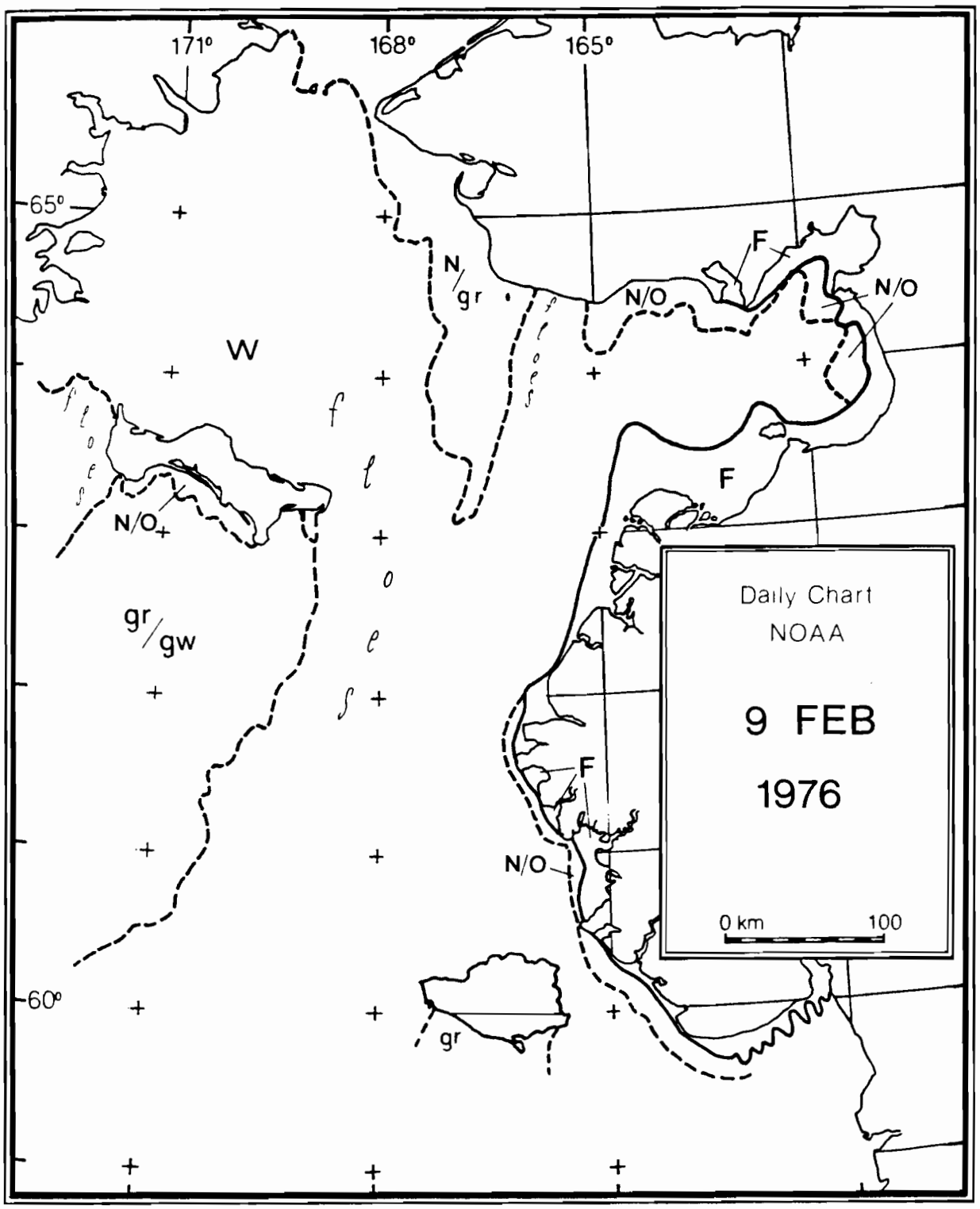
8 FEB
1976
0 km
100


171°
168°
165°
65°
60°
W
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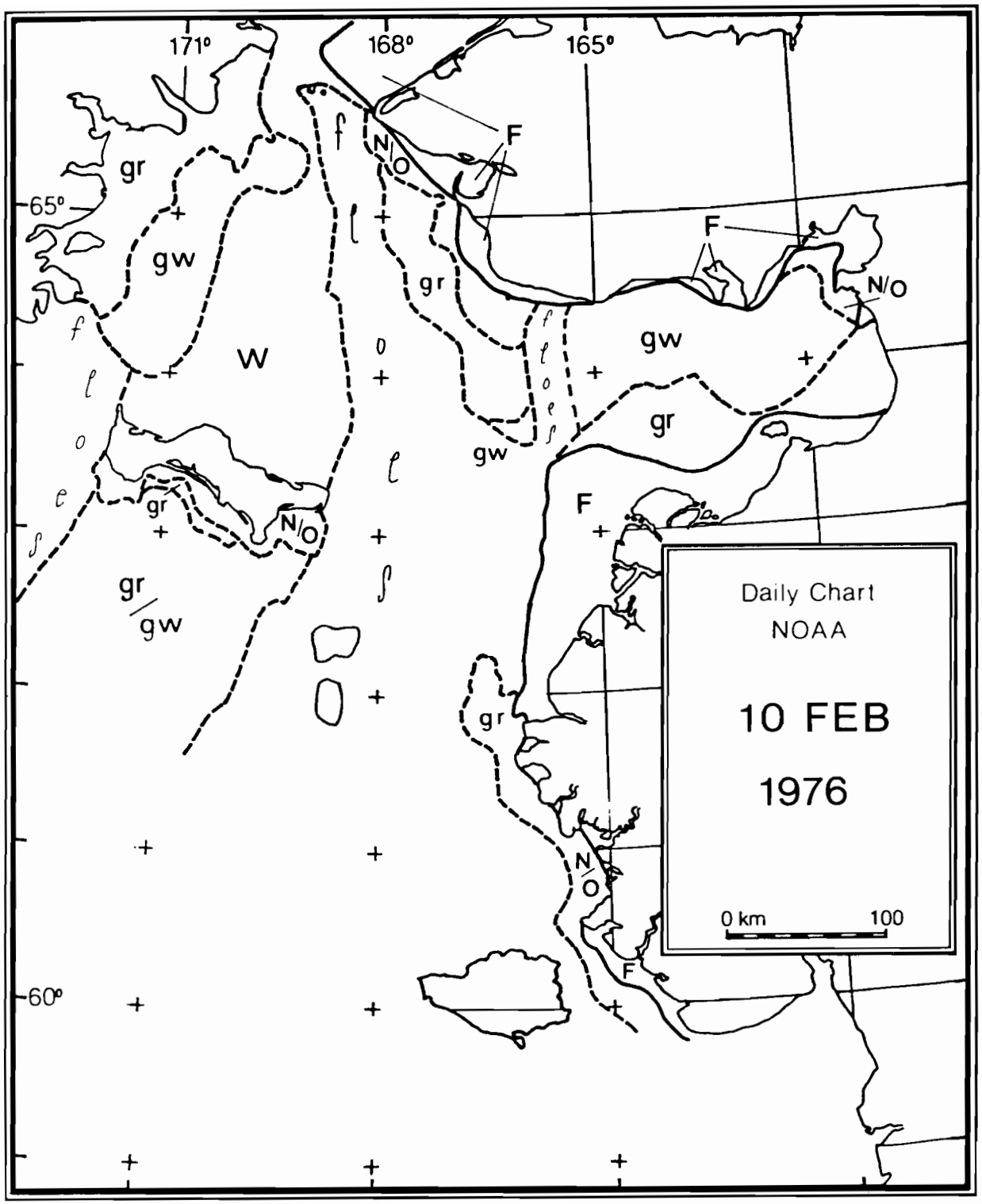
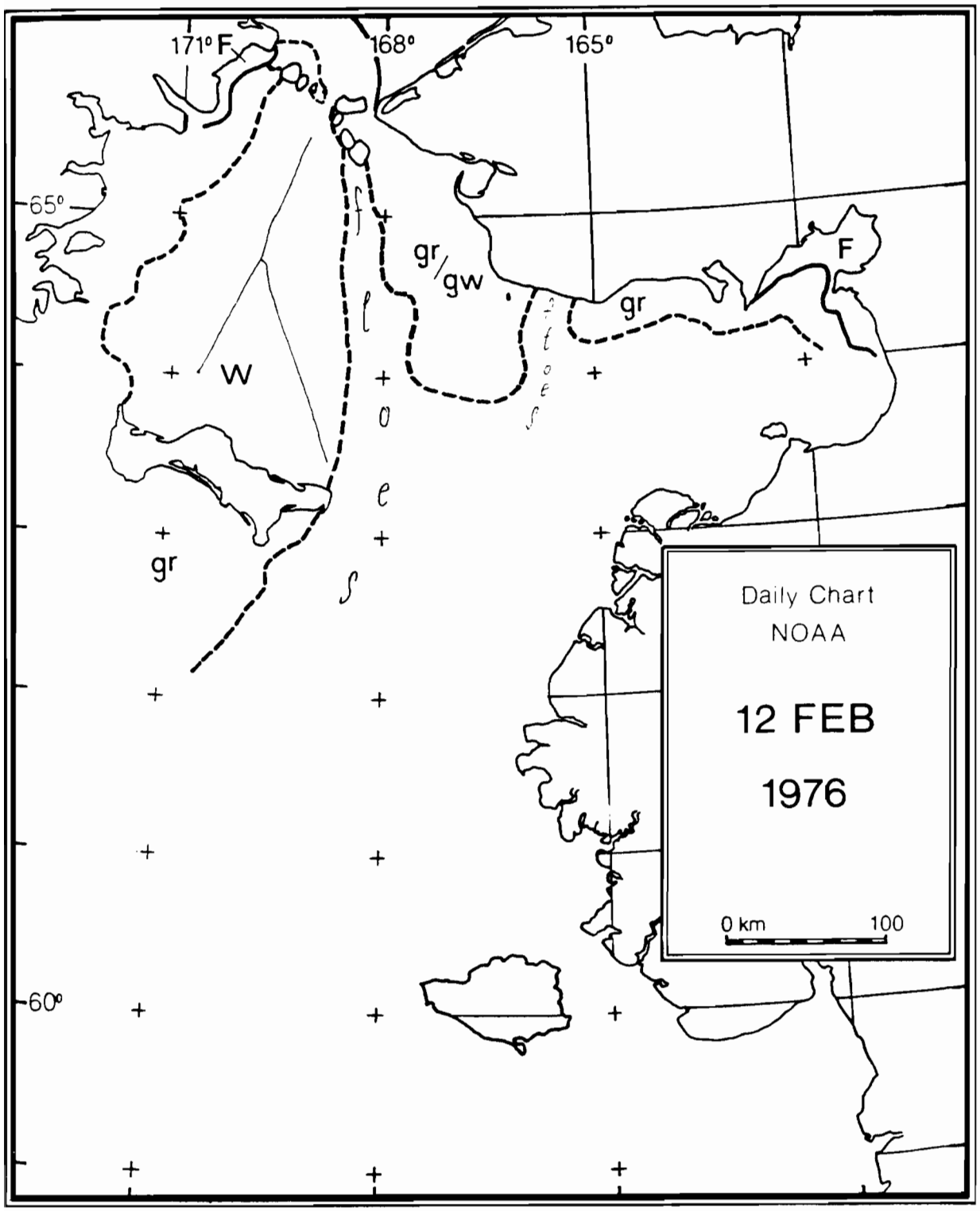
N/O
F
N/O
F
N/O
gr/gw
F
N/O
gr
Daily Chart
NOAA
9 FEB
1976
0 km
100


171°
168°
165°
65°
60°
gr
gw
W
f
l
o
e
s
N/O
F
Daily Chart
NOAA
10 FEB
1976
0 km
100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65°
60°
W
gr
gr/gw
gr
F
Daily Chart
NOAA
12 FEB
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0 km
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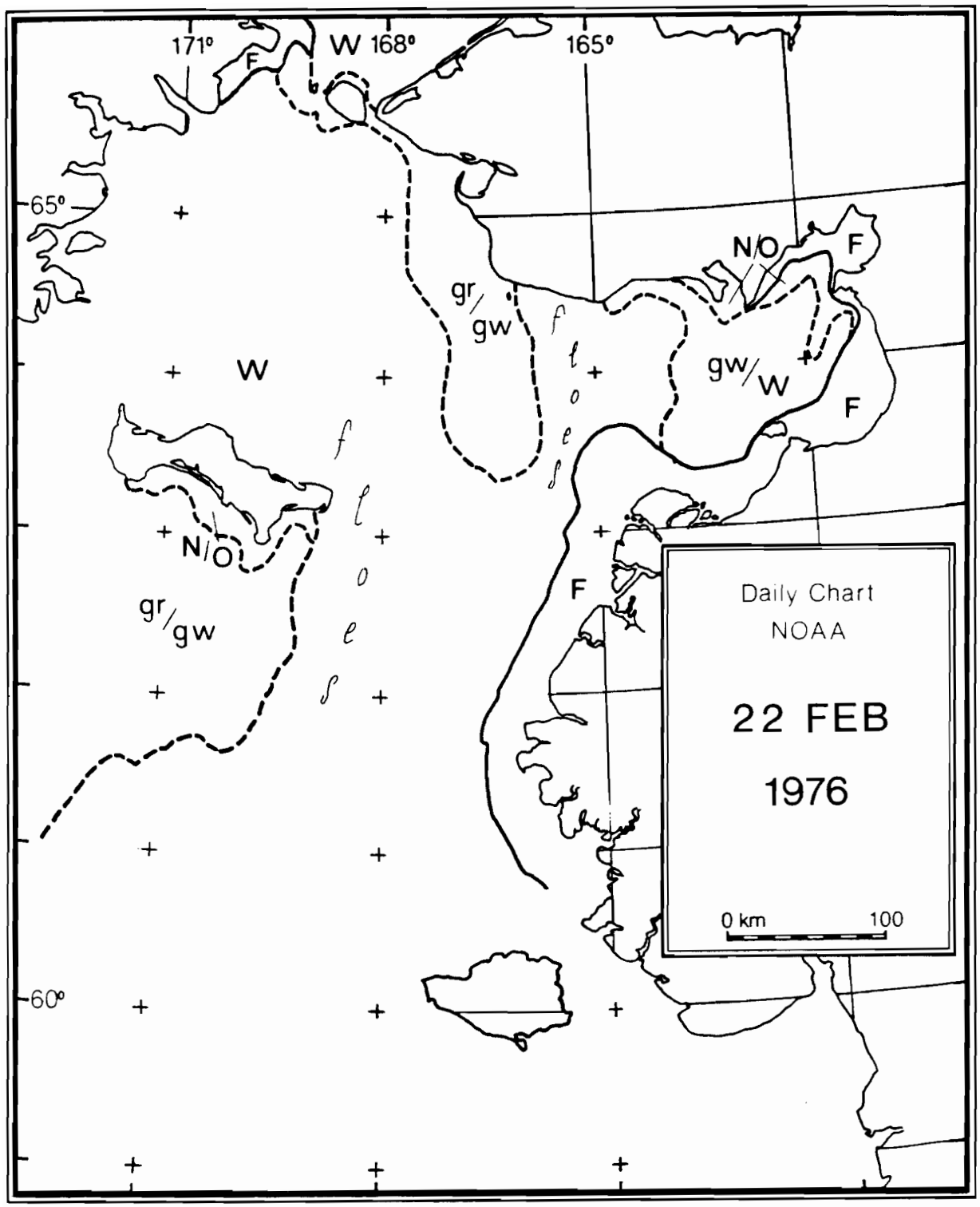
171°
W 168°
165°
65°
60°
F
W
N/O
gr/gw
W
gw/W
F
F
N/O
gr/gw
floes
floes
Daily Chart
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22 FEB
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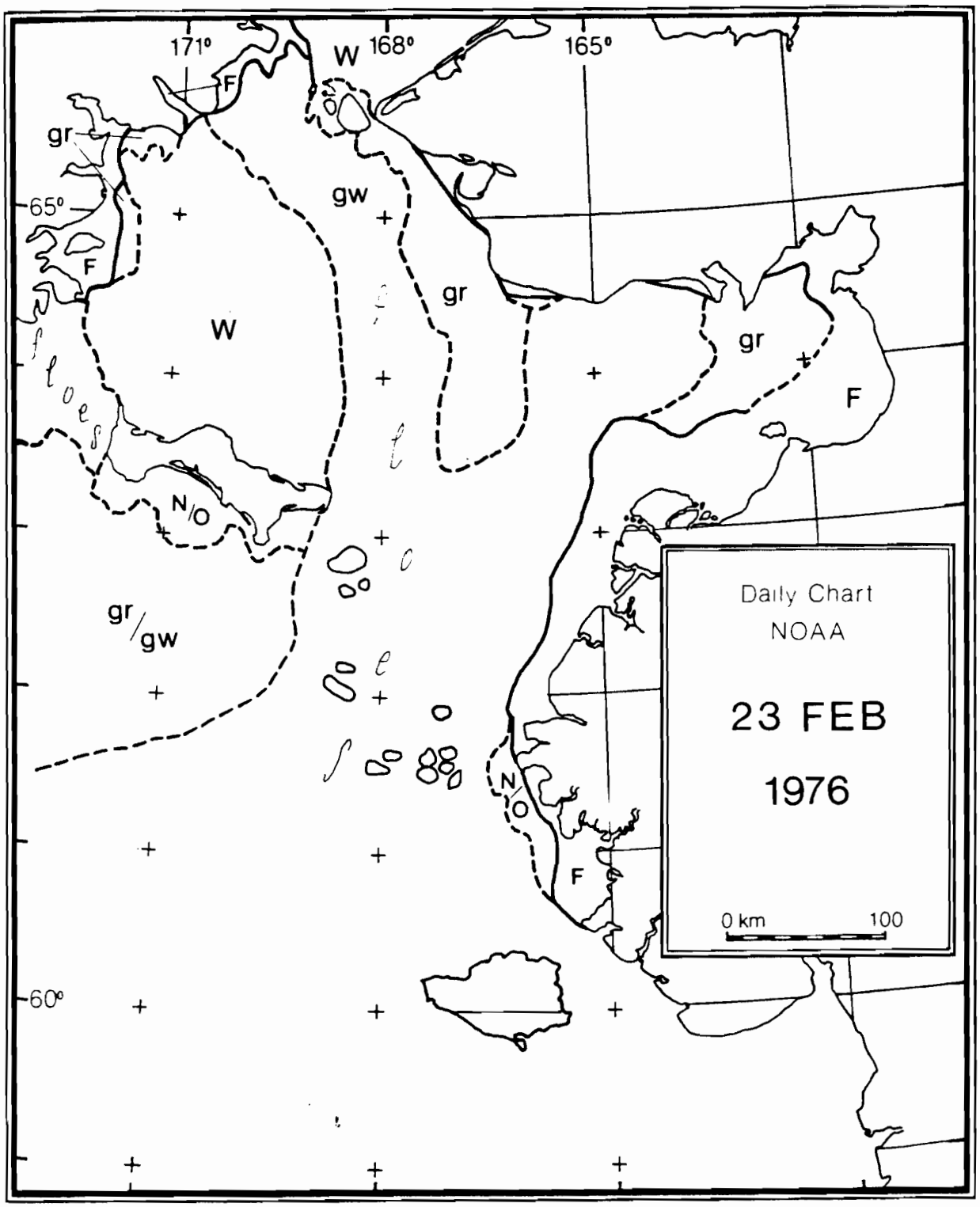
0 km
100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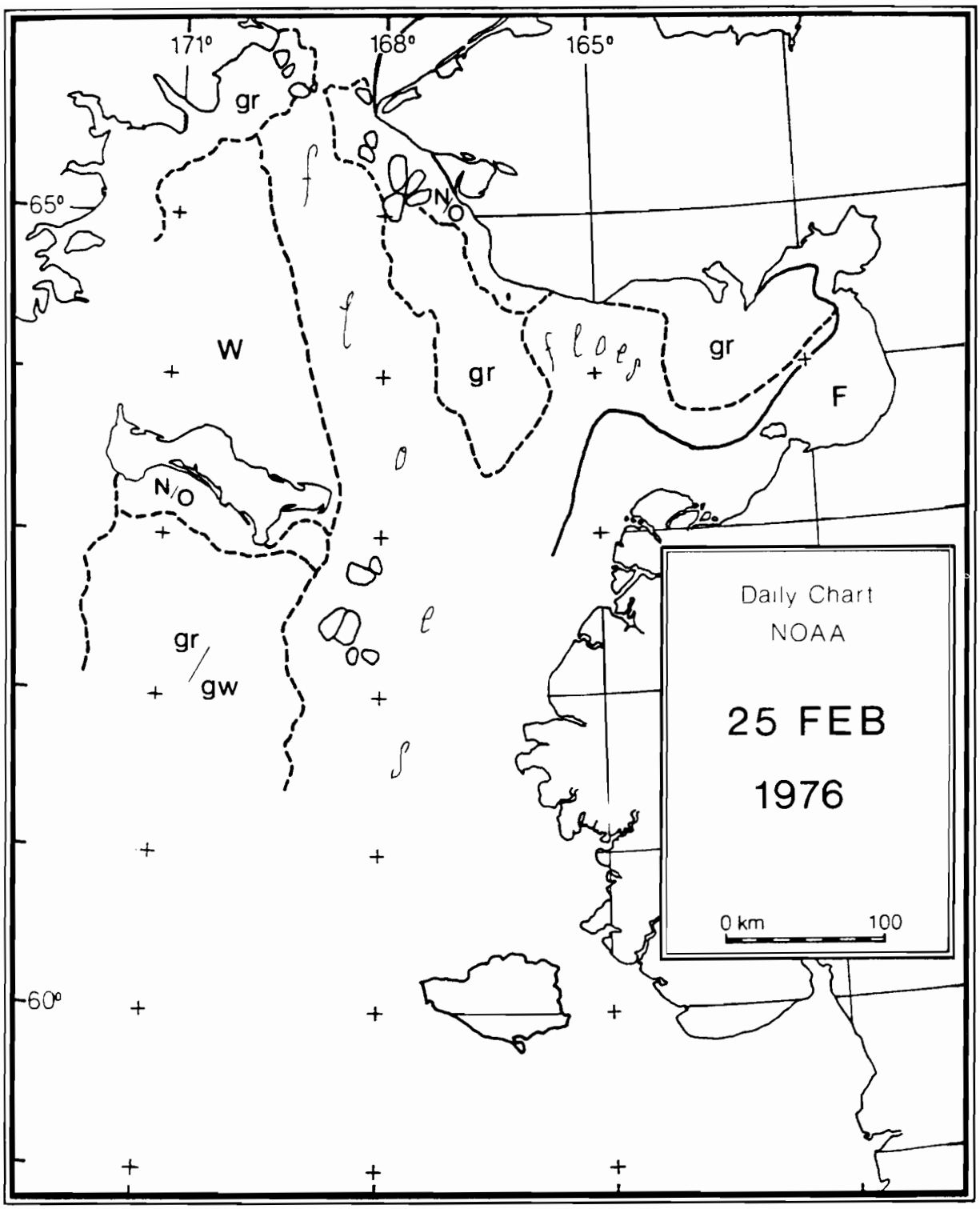
W
168°
165°
F
gr
65°
gw
F
W
gr
gr
F
floes
N/O
gr/gw
N/O
F
60°
Daily Chart
NOAA
23 FEB
1976
0 km
100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168°
165°
65°
60°
gr
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W
gr
floes
gr
F
N/O
gr/gw
Daily Chart
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25 FEB
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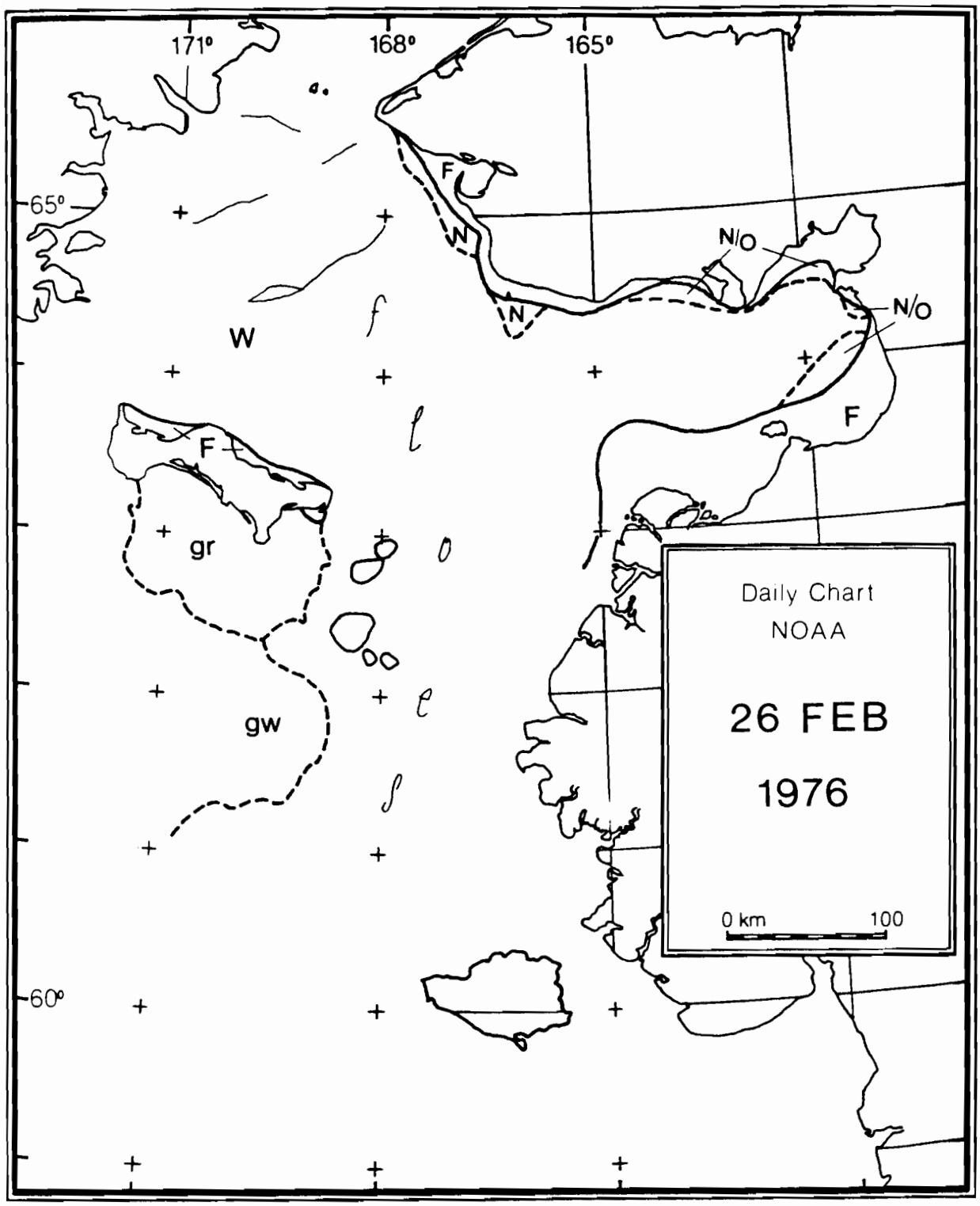
0 km
100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168°
165°
65°
60°
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N/O
N/O
W
F
F
gr
gw
Daily Chart
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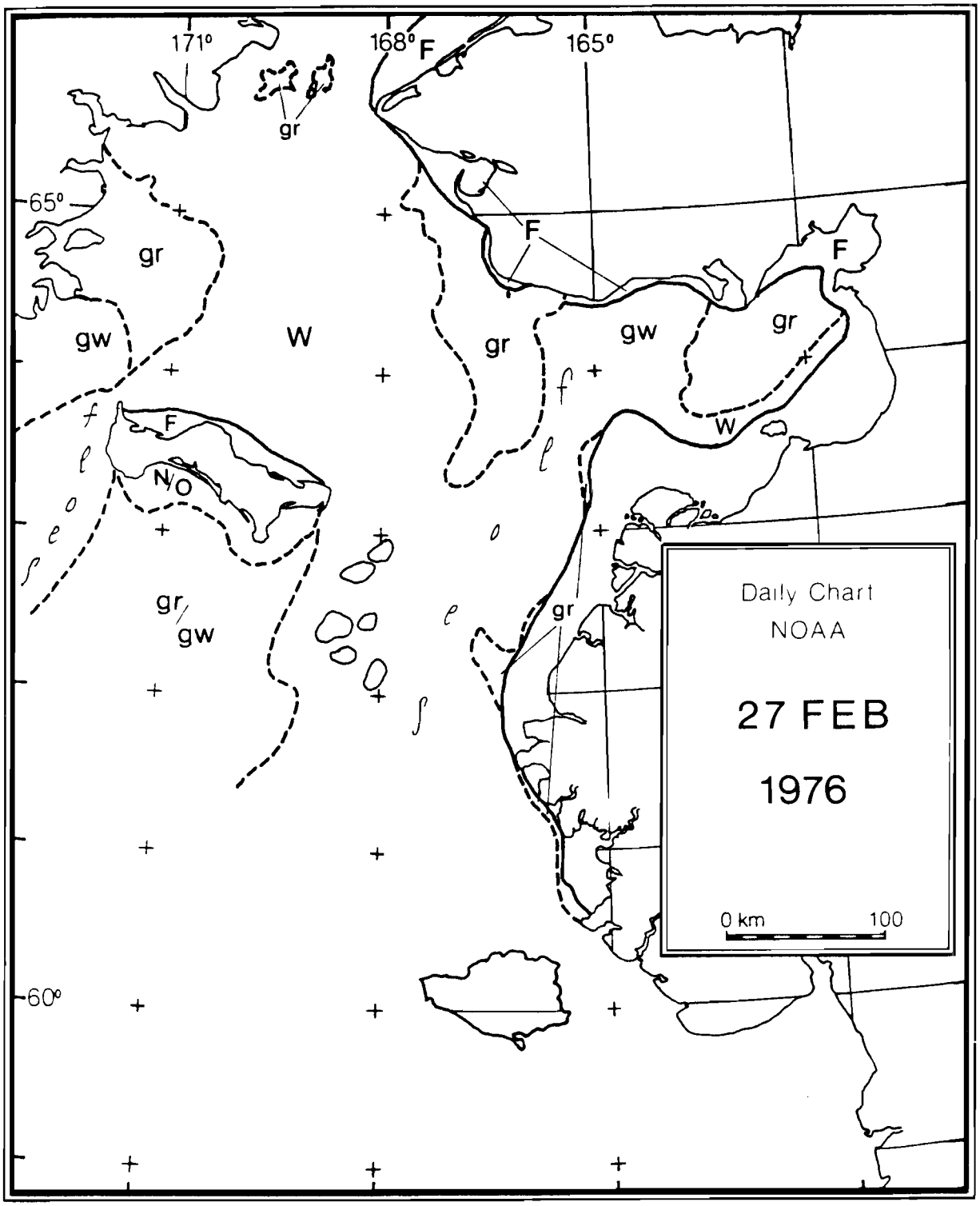
26 FEB
1976
0 km
100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168°
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165°
gr
65°
gr
gw
W
gr
gw
gr
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W
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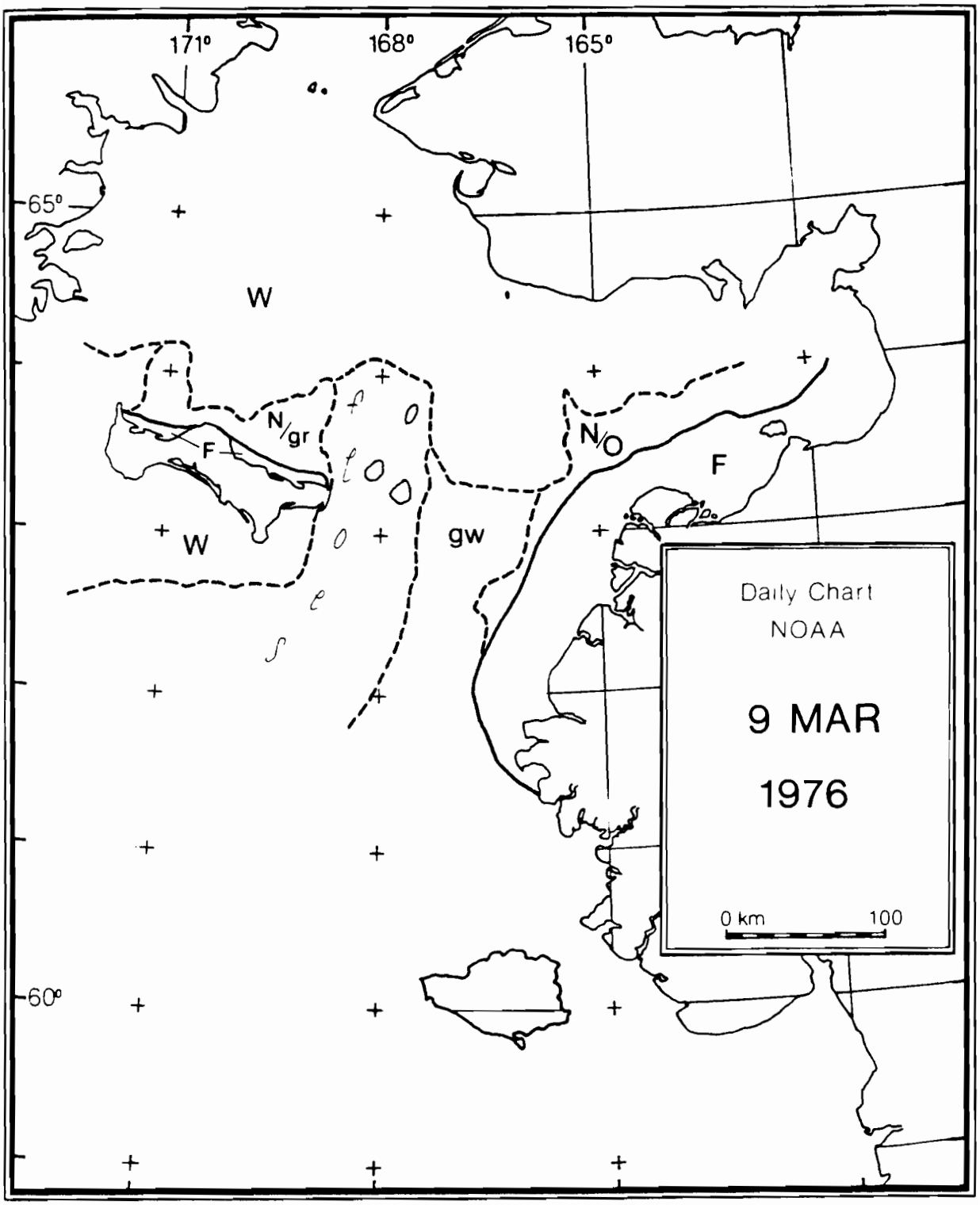
gr/
gw
gr
Daily Chart
NOAA
27 FEB
1976
0 km
100
60°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168°
165°
65°
60°
W
W
N/gr
F
N/O
F
gw
Daily Chart
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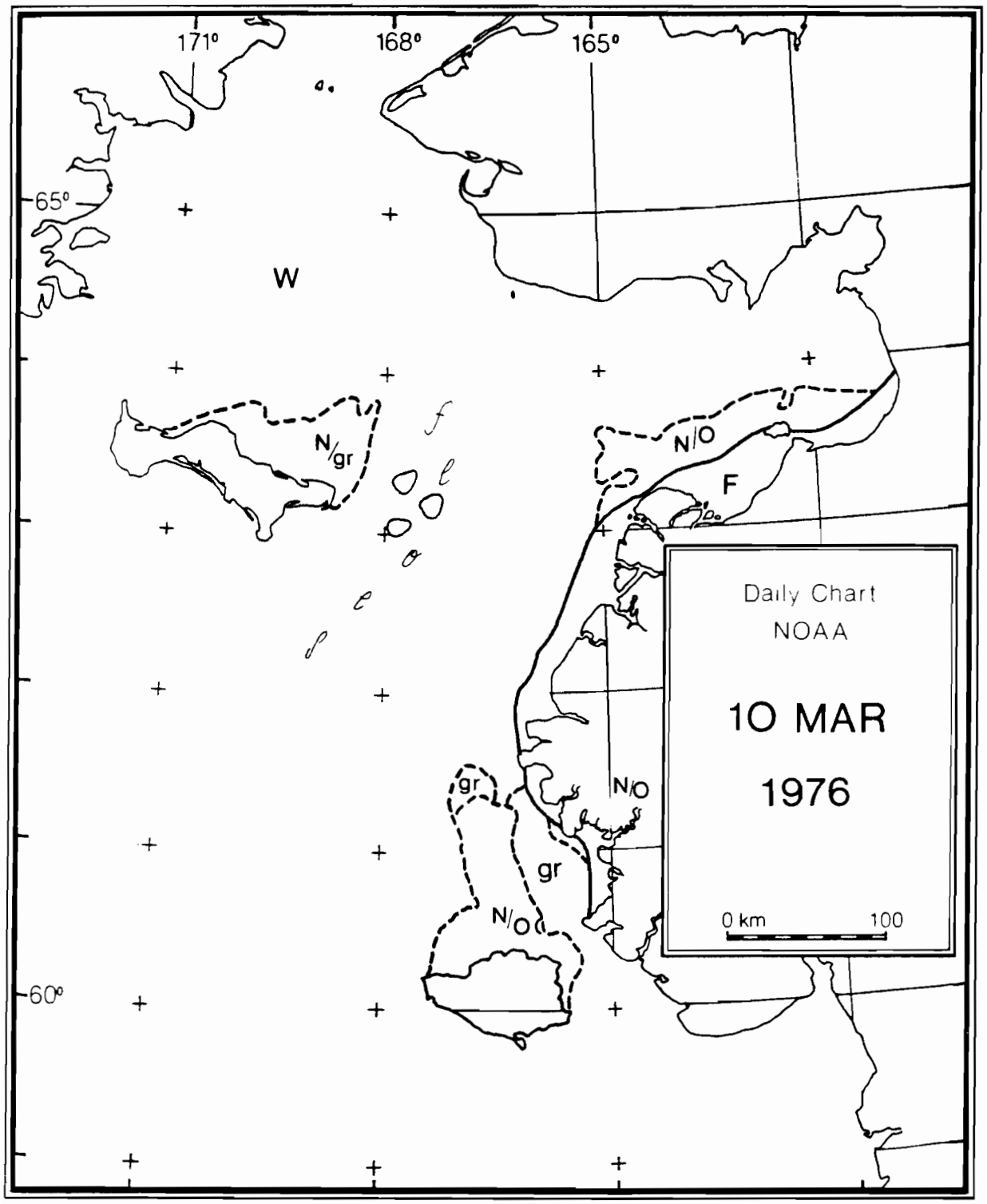
9 MAR
1976
0 km
100


171°
168°
165°
65°
60°
W
N/gr
N/O
F
gr
N/O
gr
N/O
Daily Chart
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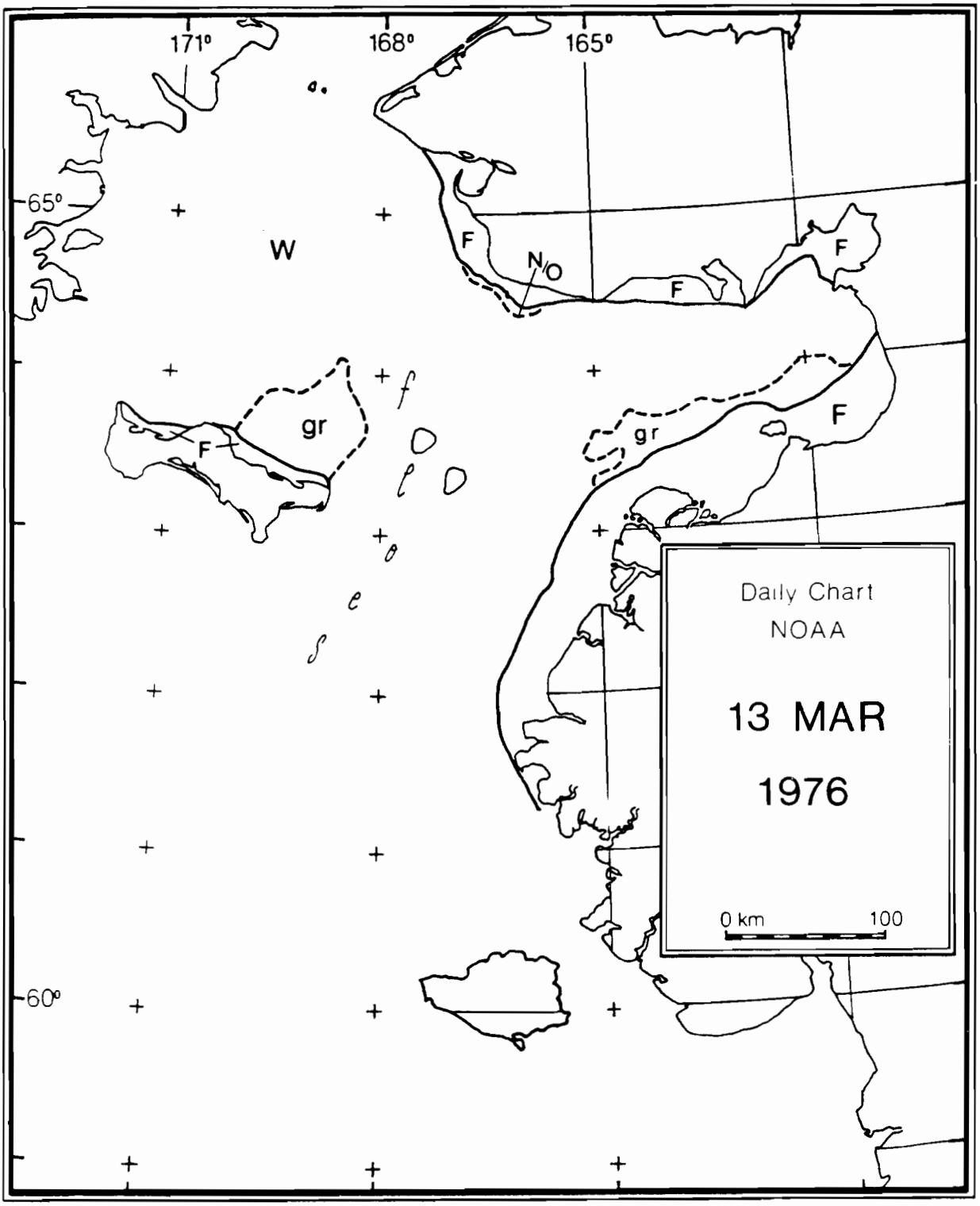
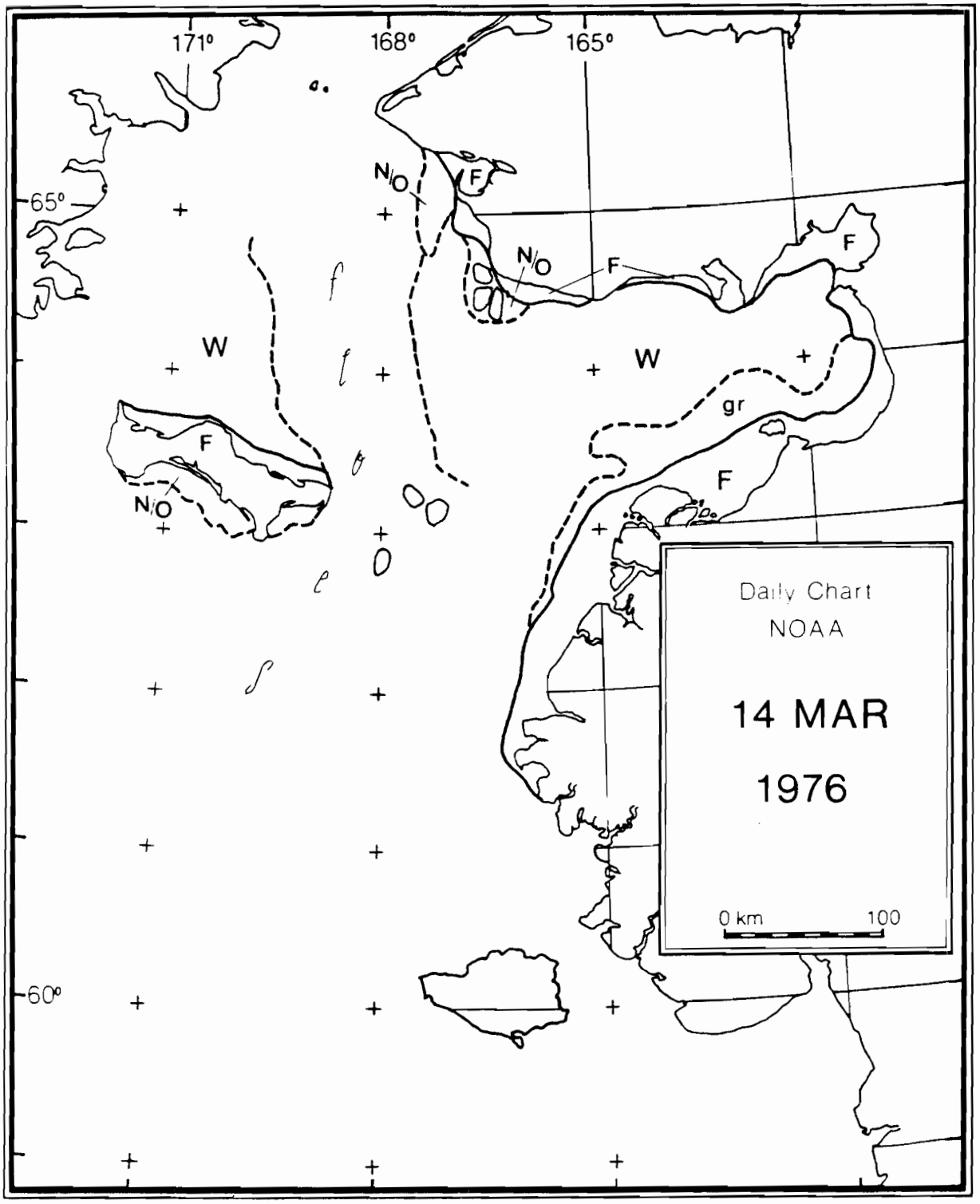
10 MAR
1976
0 km
100


171°
168°
165°
65°
60°
W
F
N/O
F
F
gr
F
gr
F
Daily Chart
NOAA
13 MAR
1976
0 km
100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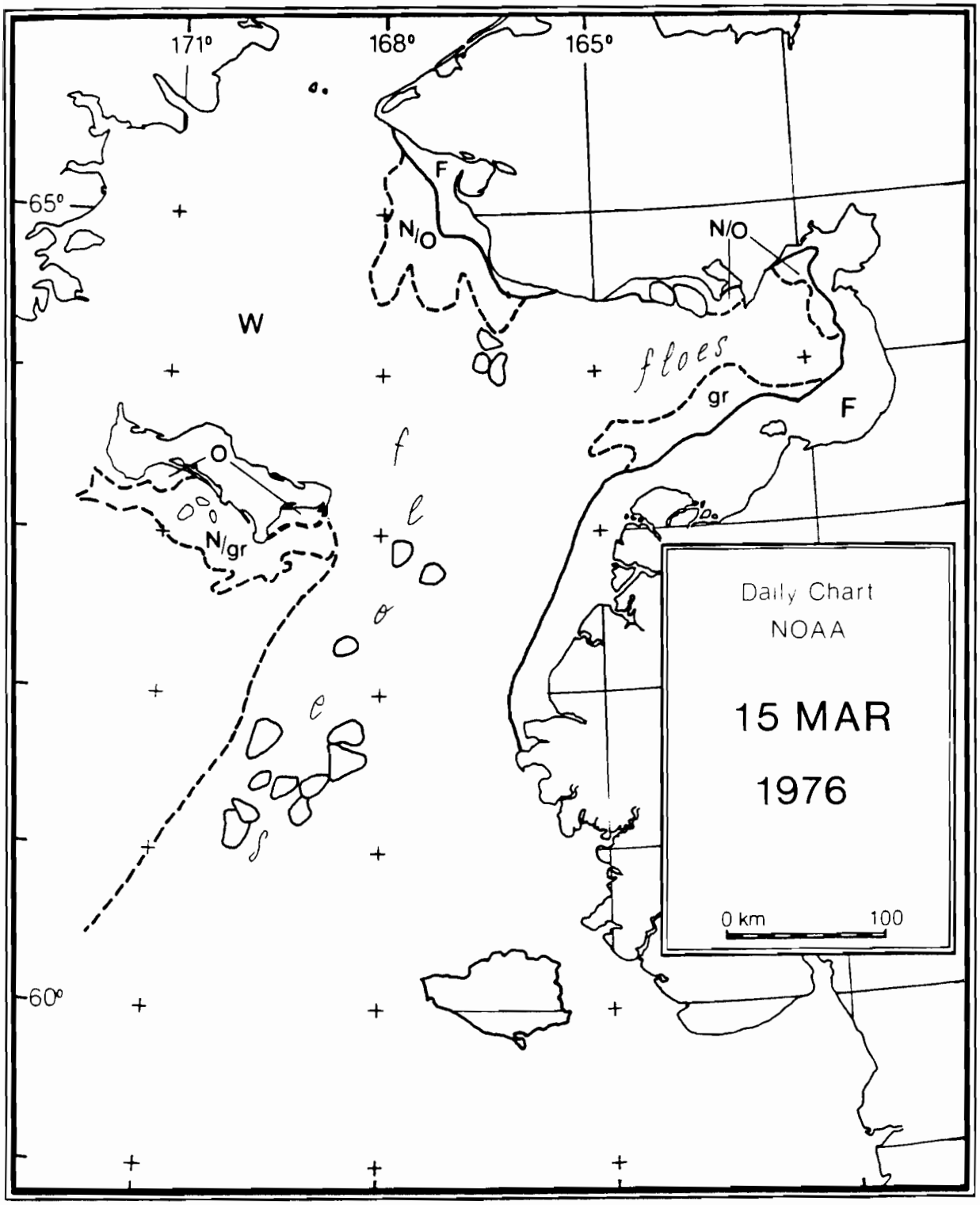
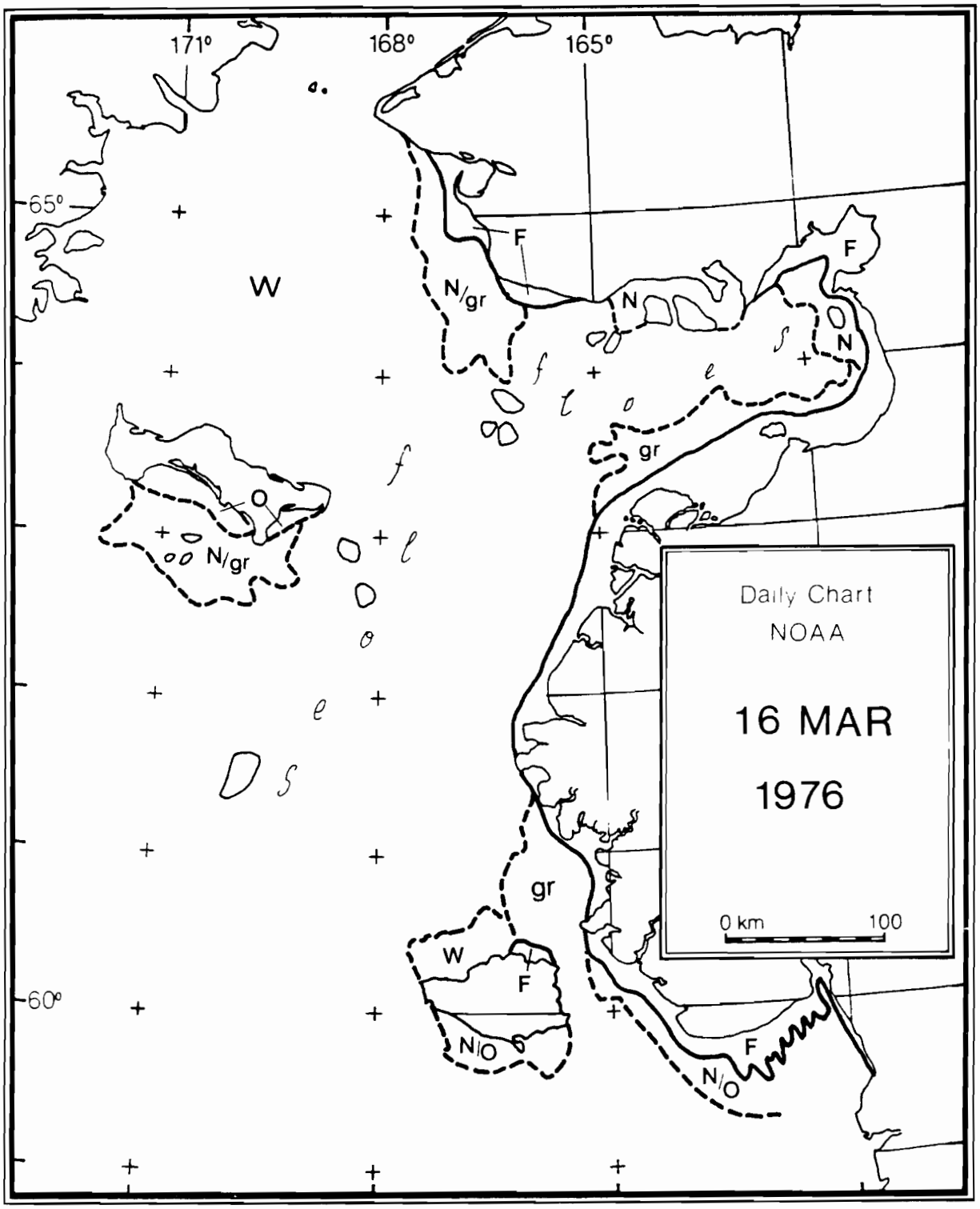
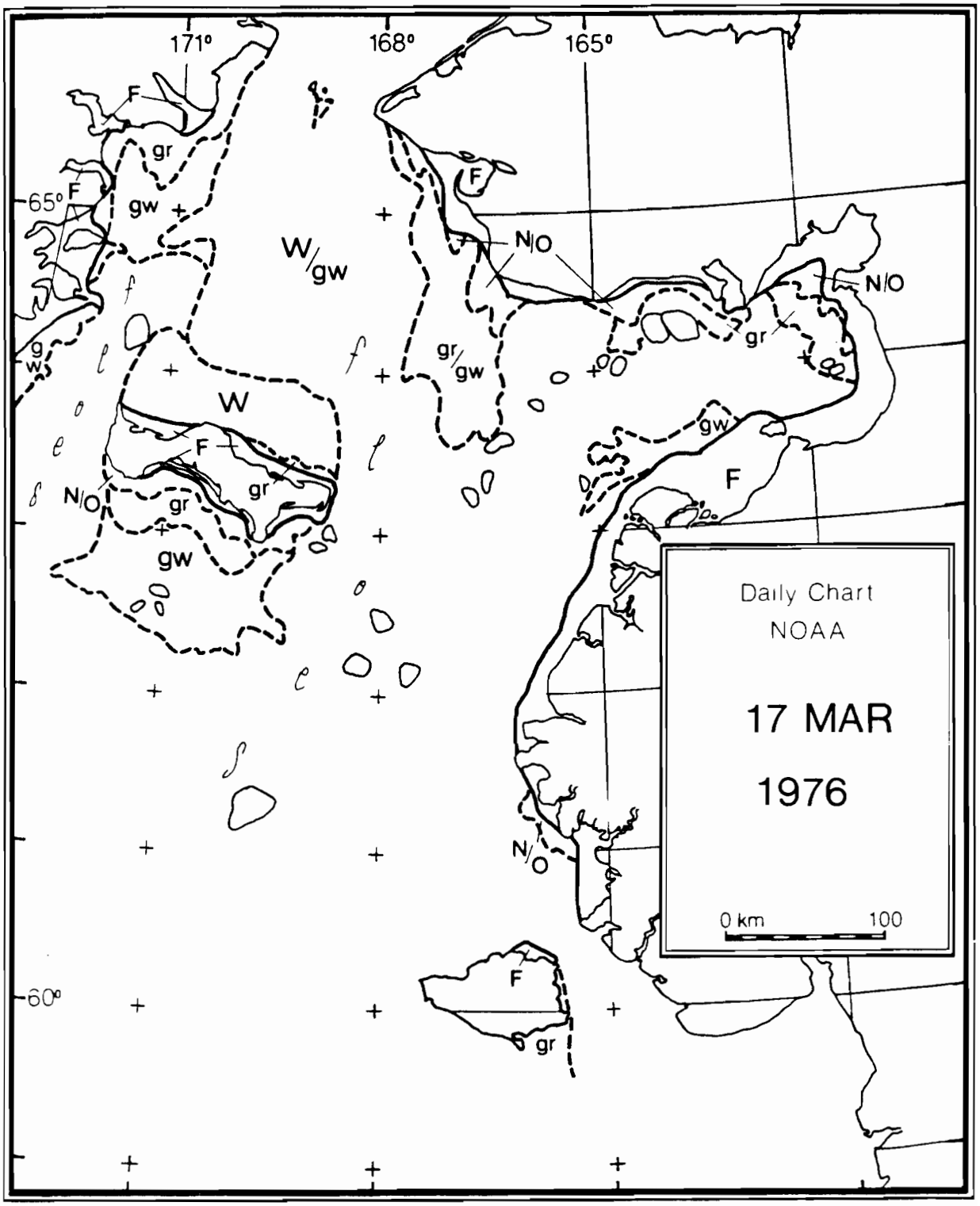
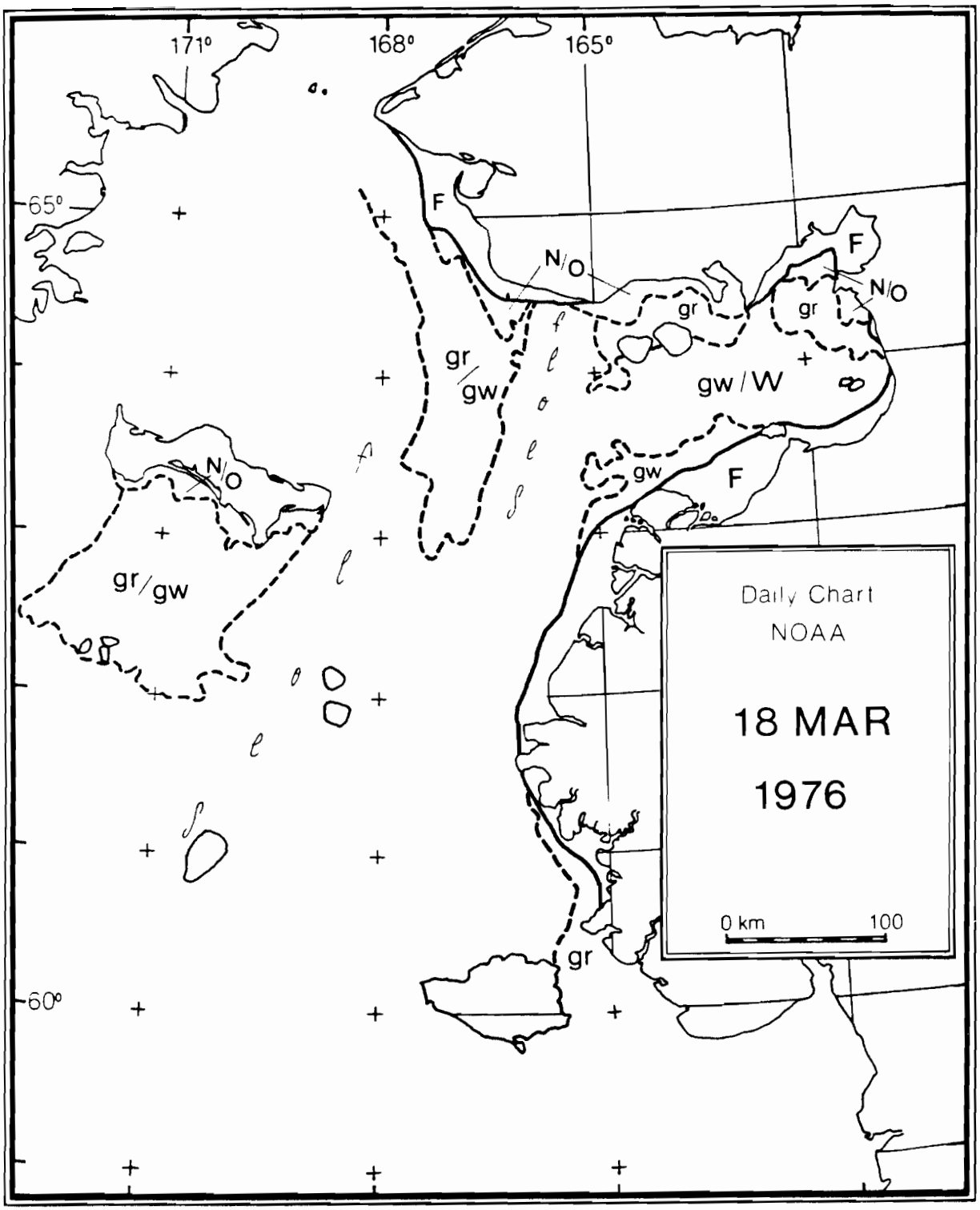
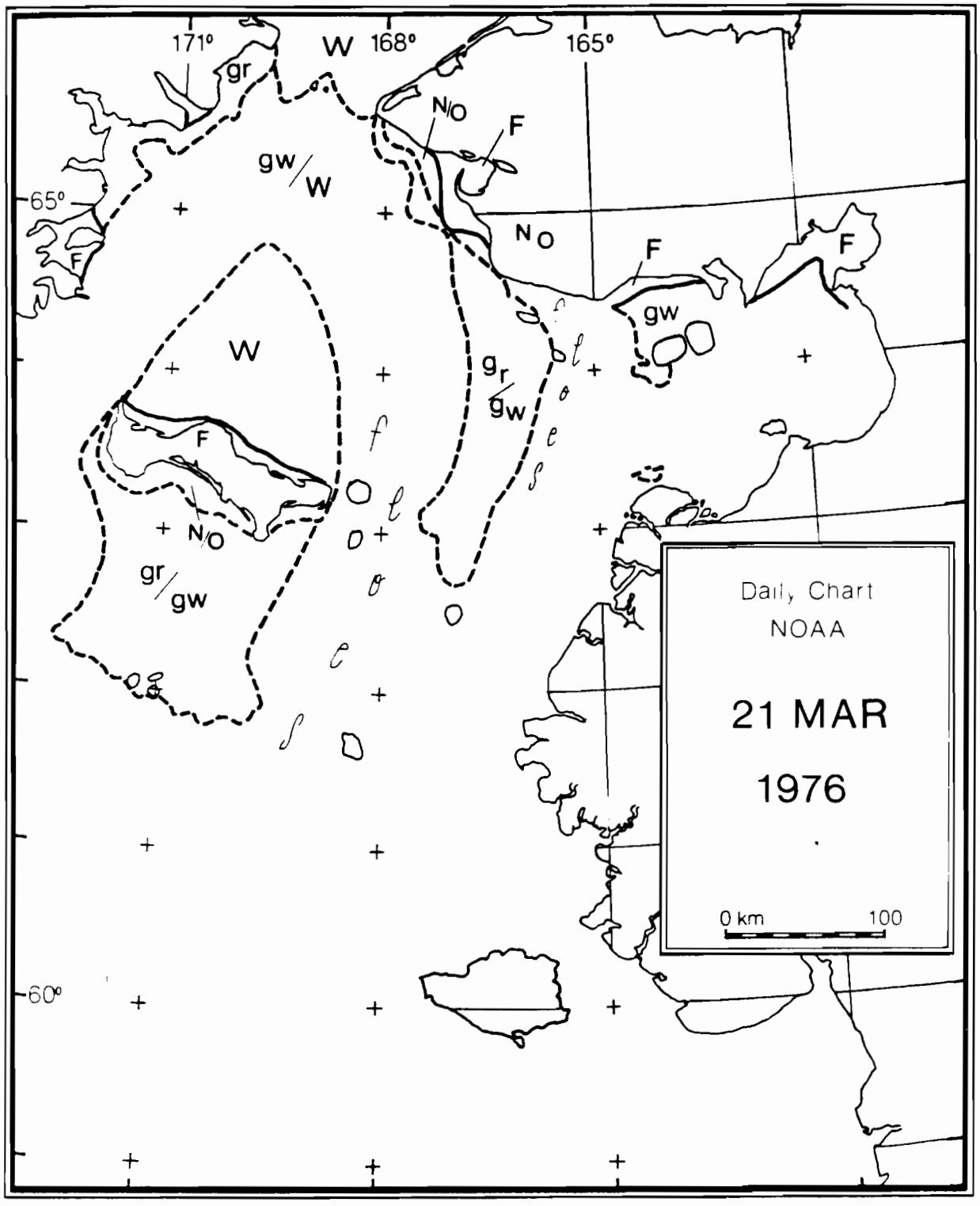
168°
165°
65°
60°
N/O
F
W
gr
Daily Chart
NOAA
14 MAR
1976
0 km
100

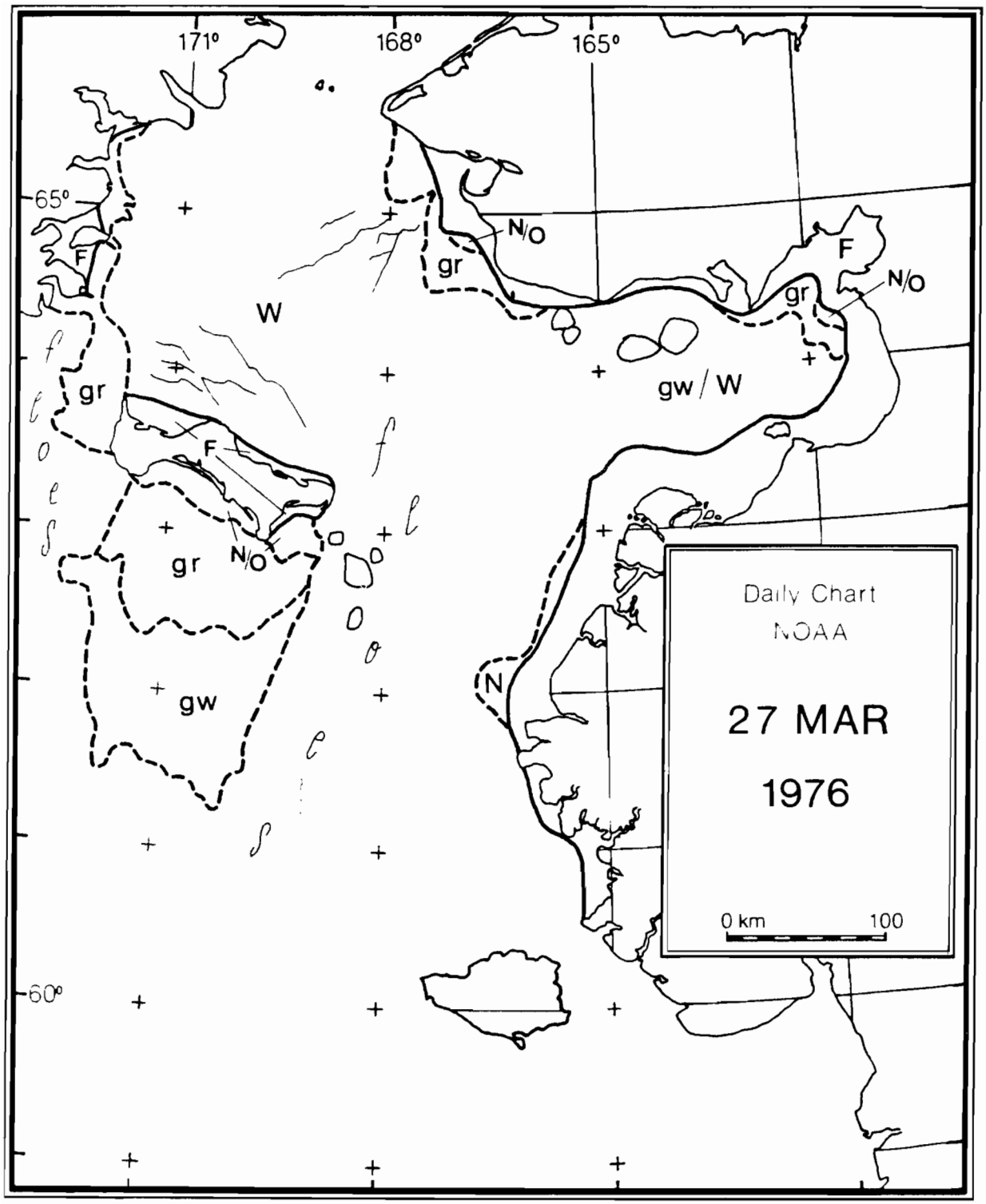

171°
168°
165°
65°
60°
F
N/O
N/O
W
floes
gr
F
O
N/gr
Daily Chart
NOAA
15 MAR
1976
0 km
100

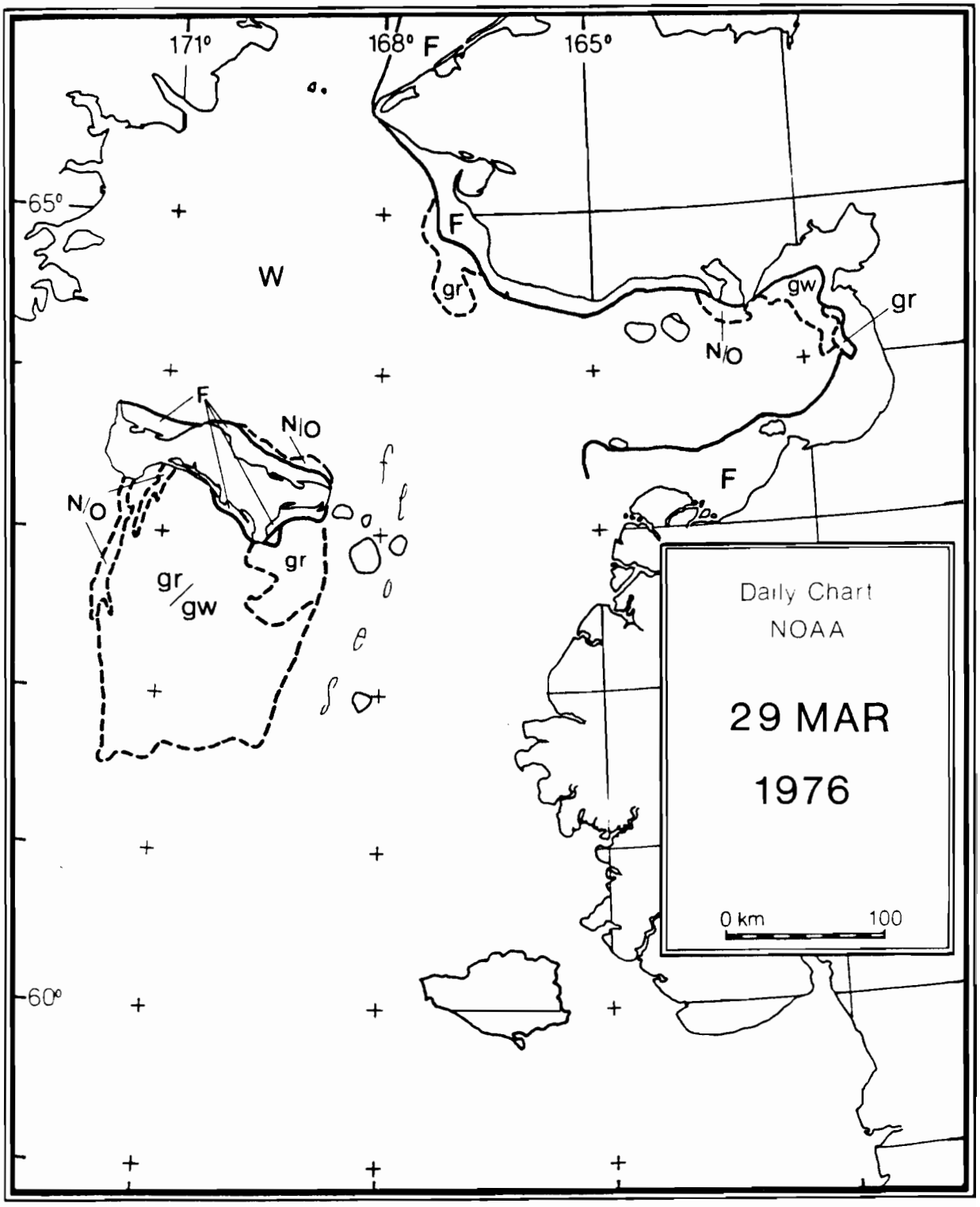

171°
168°
165°
65°
60°
W
F
N/gr
N
F
N
gr
O
N/gr
gr
W
F
N/O
F
N/O
Daily Chart
NOAA
16 MAR
1976
0 km
100

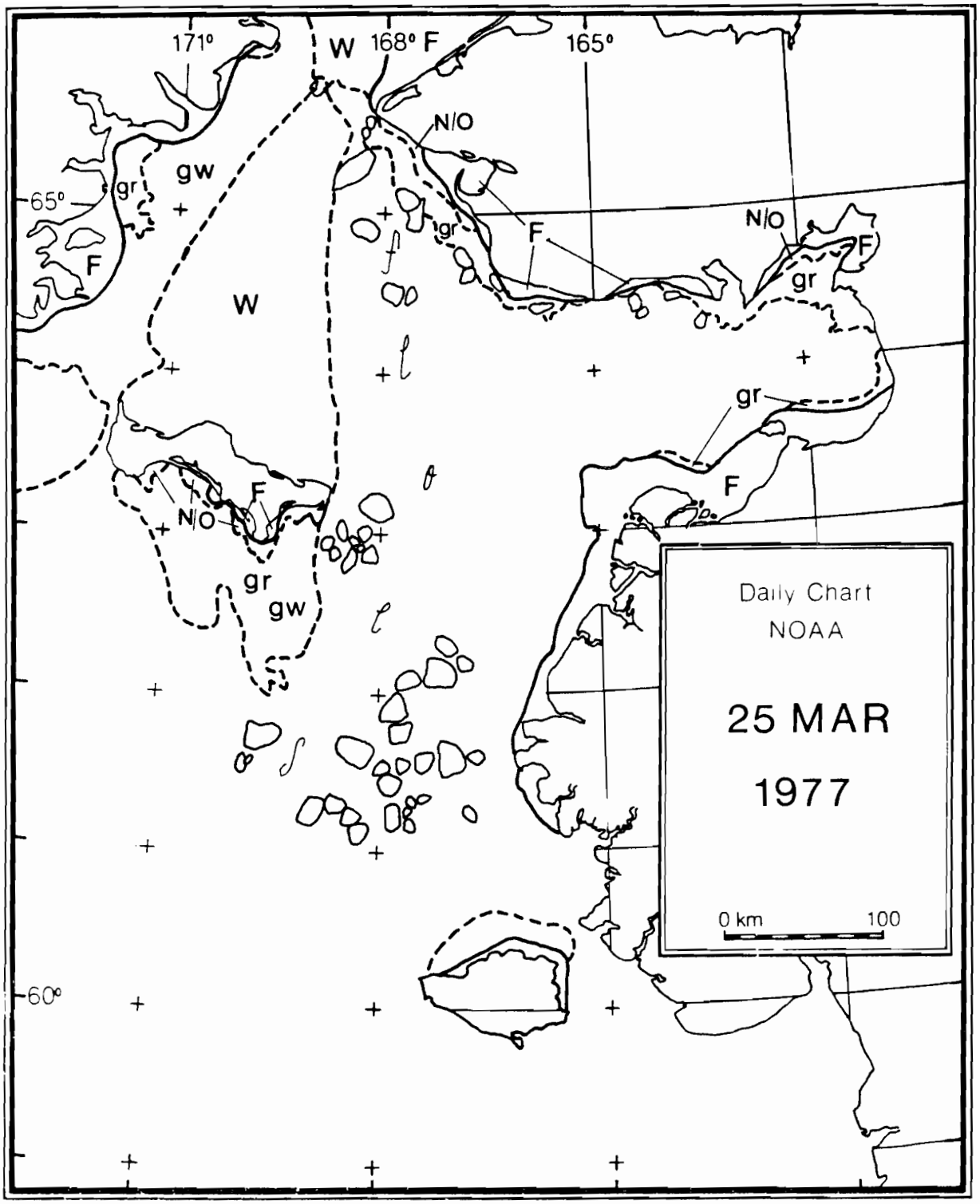

171°
168°
165°
65°
60°
F
gr
gw
W/gw
W
gr/gw
N/O
Daily Chart
NOAA
17 MAR
1976
0 km
100

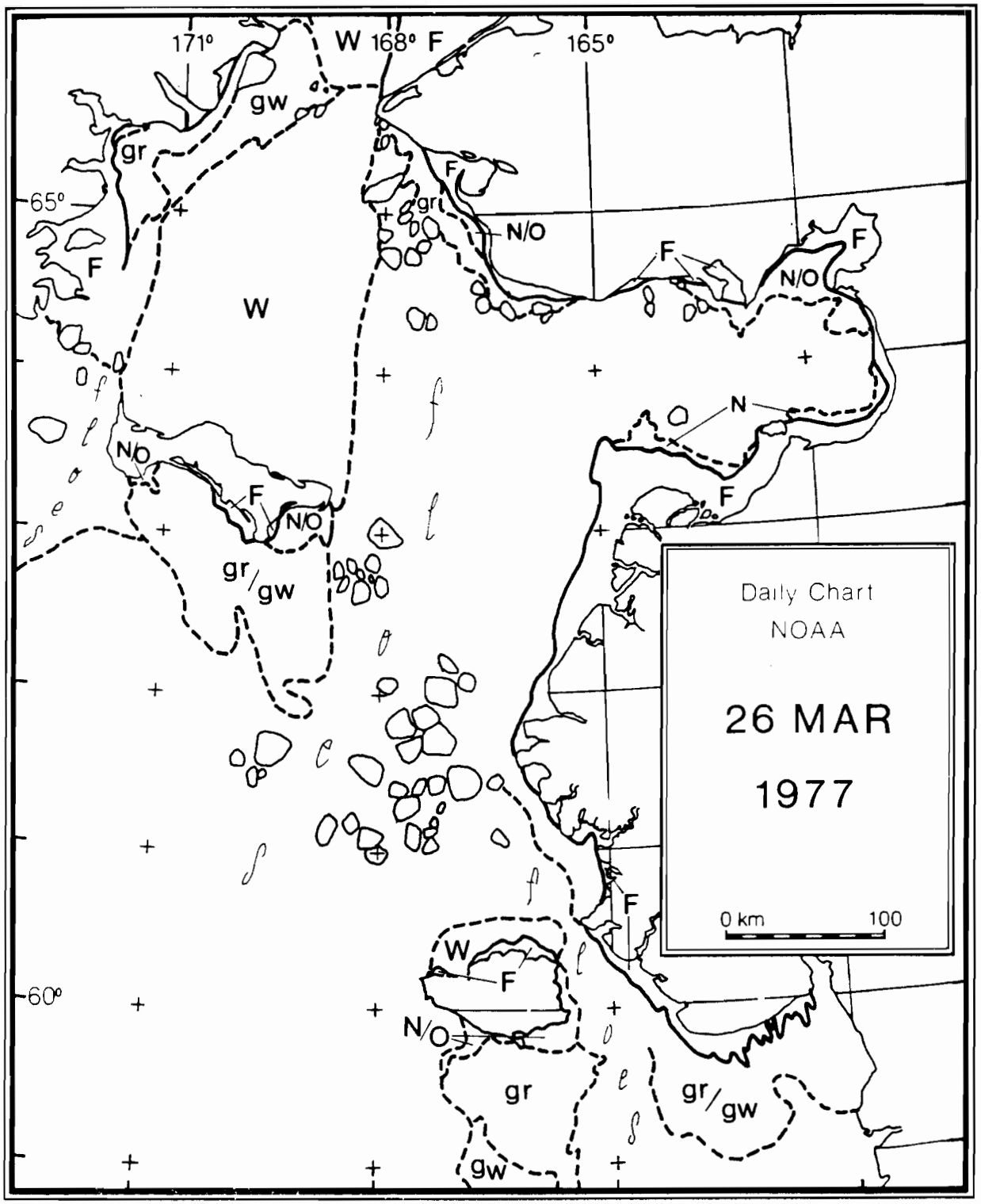

171°
168°
165°
65°
60°
F
N/O
gr
gw/W
gw
gr/gw
Daily Chart
NOAA
18 MAR
1976
0 km
100

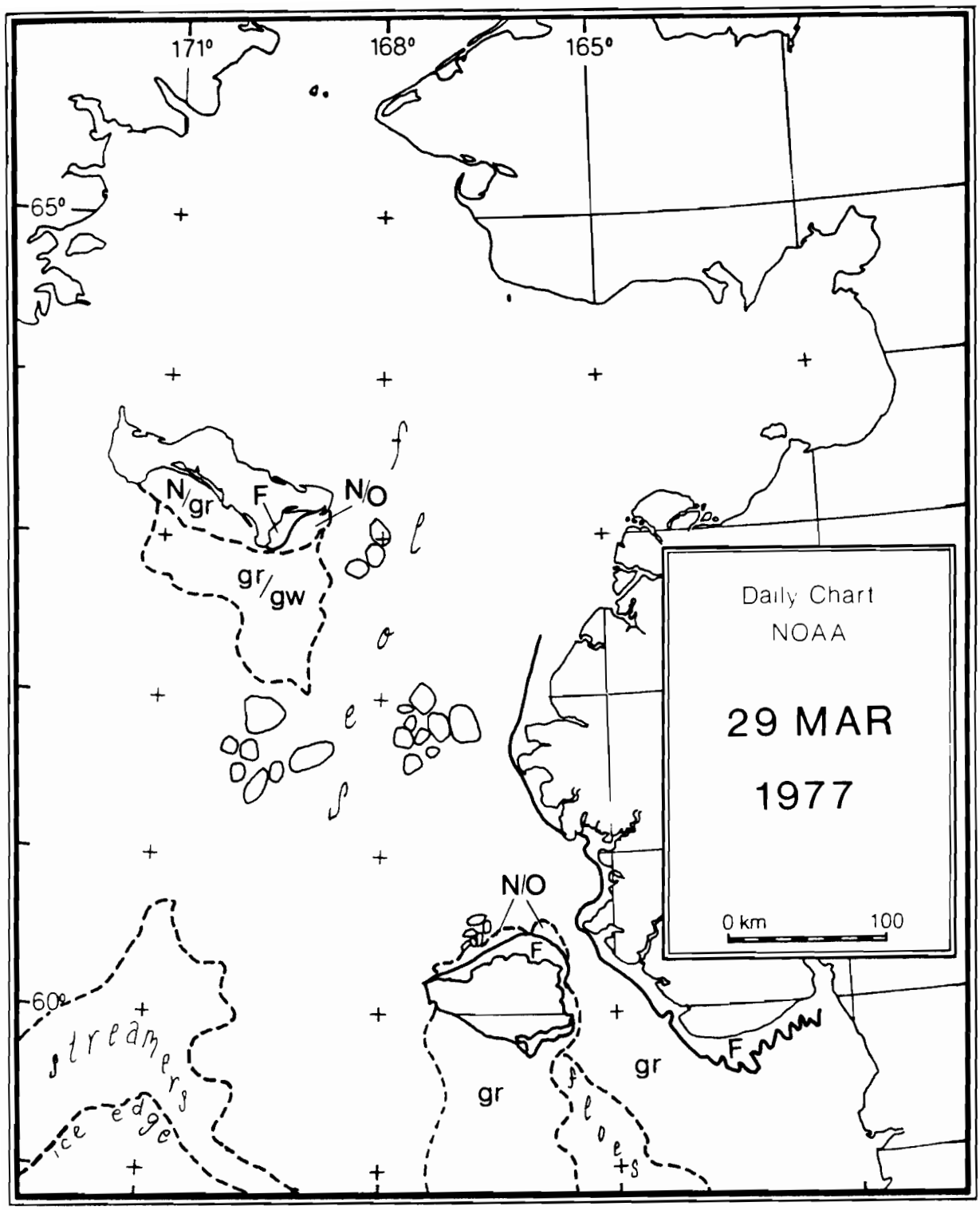

171°
W
168°
165°
gr
N/O
F
gw/W
65°
F
N O
F
F
gw
W
gr/gw
F
N/O
gr/gw
60°
Daily Chart
NOAA
21 MAR
1976
0 km
100

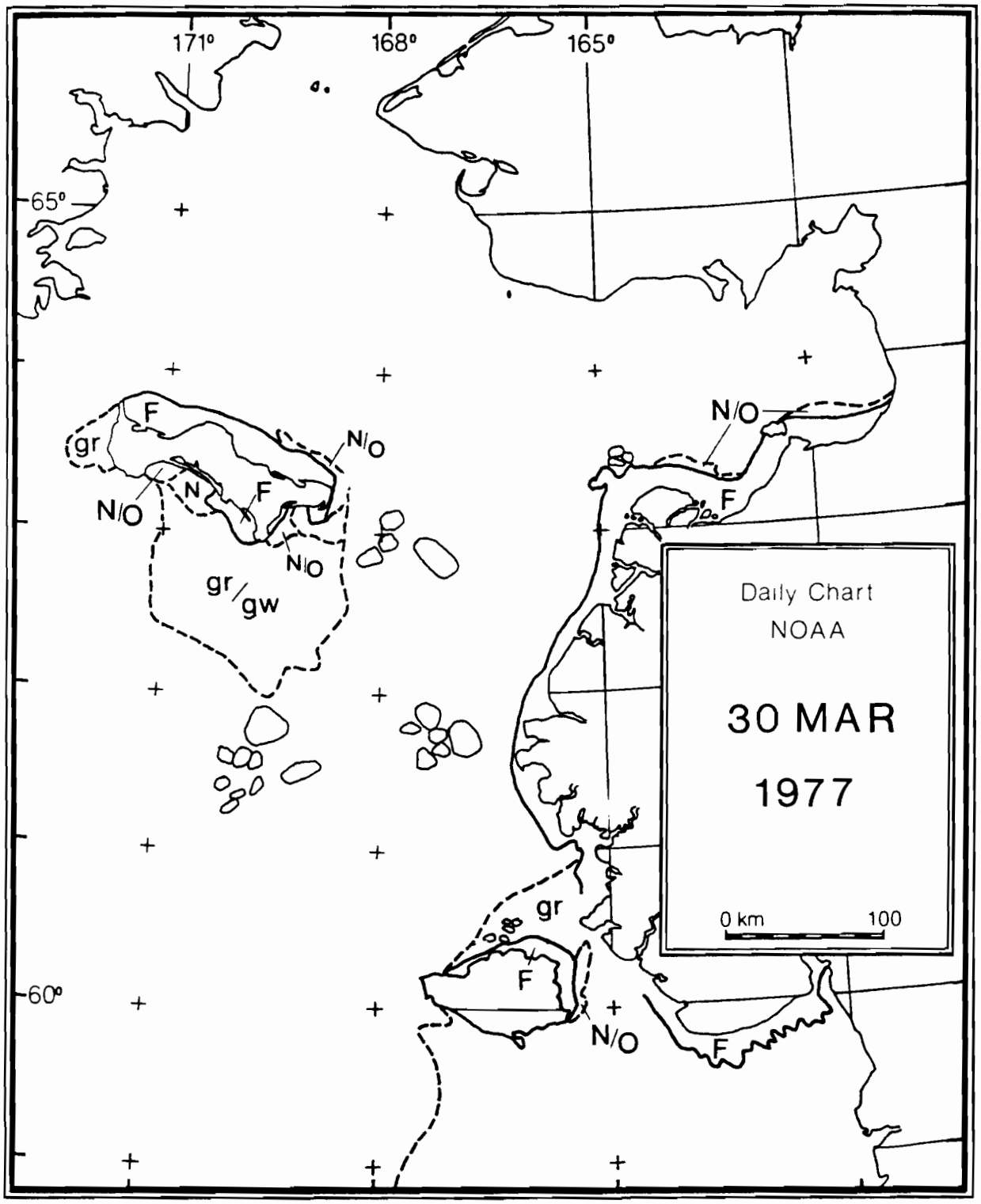

171°
168°
165°
65°
60°
F
N/O
gr
W
gw / W
gw
N
Daily Chart
NOAA
27 MAR
1976
0 km
100

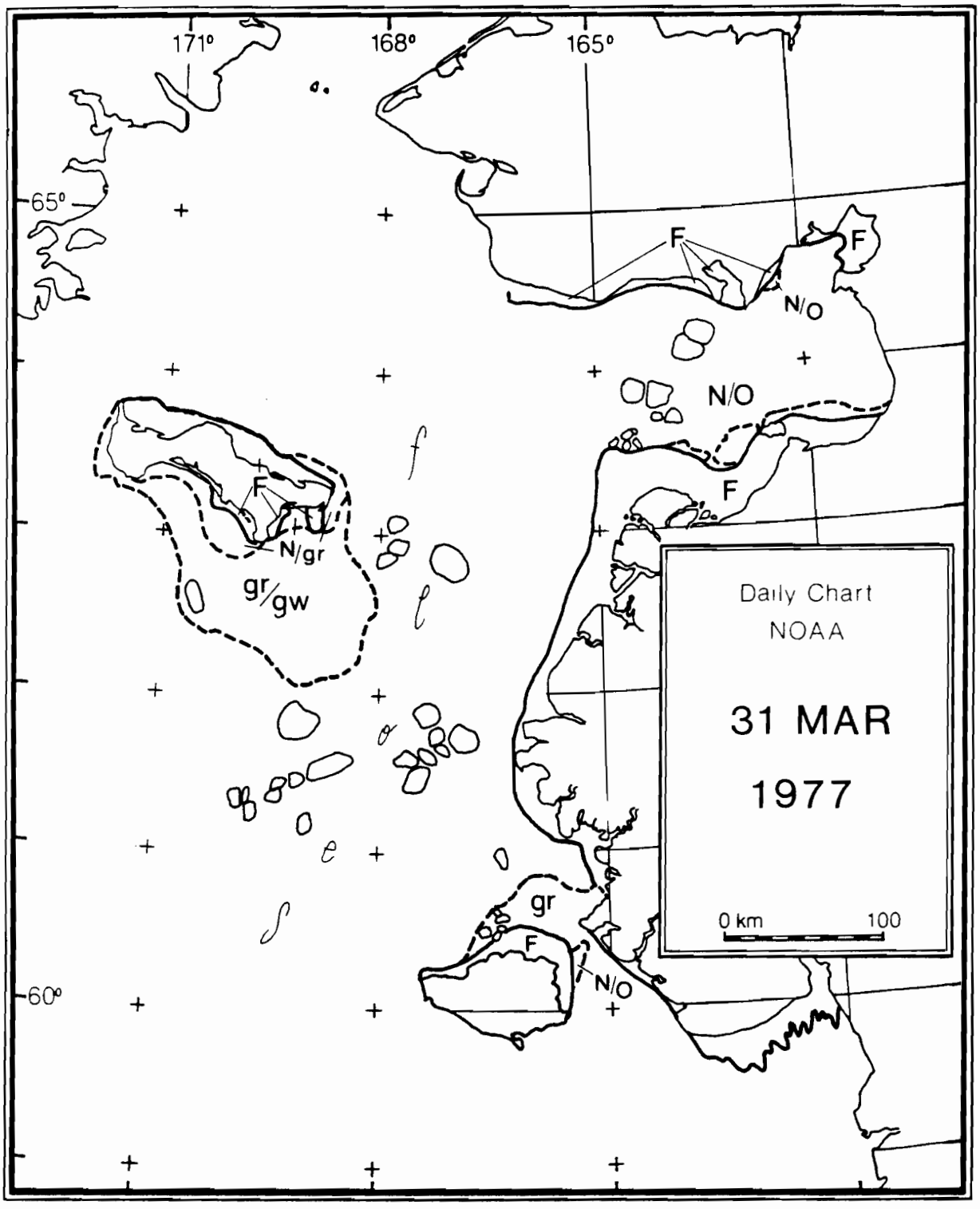

171°
168°
165°
65°
60°
W
F
F
gr
gw
gr
N/O
F
N/O
N/O
gr
gr/gw
F
Daily Chart
NOAA
29 MAR
1976
0 km
100

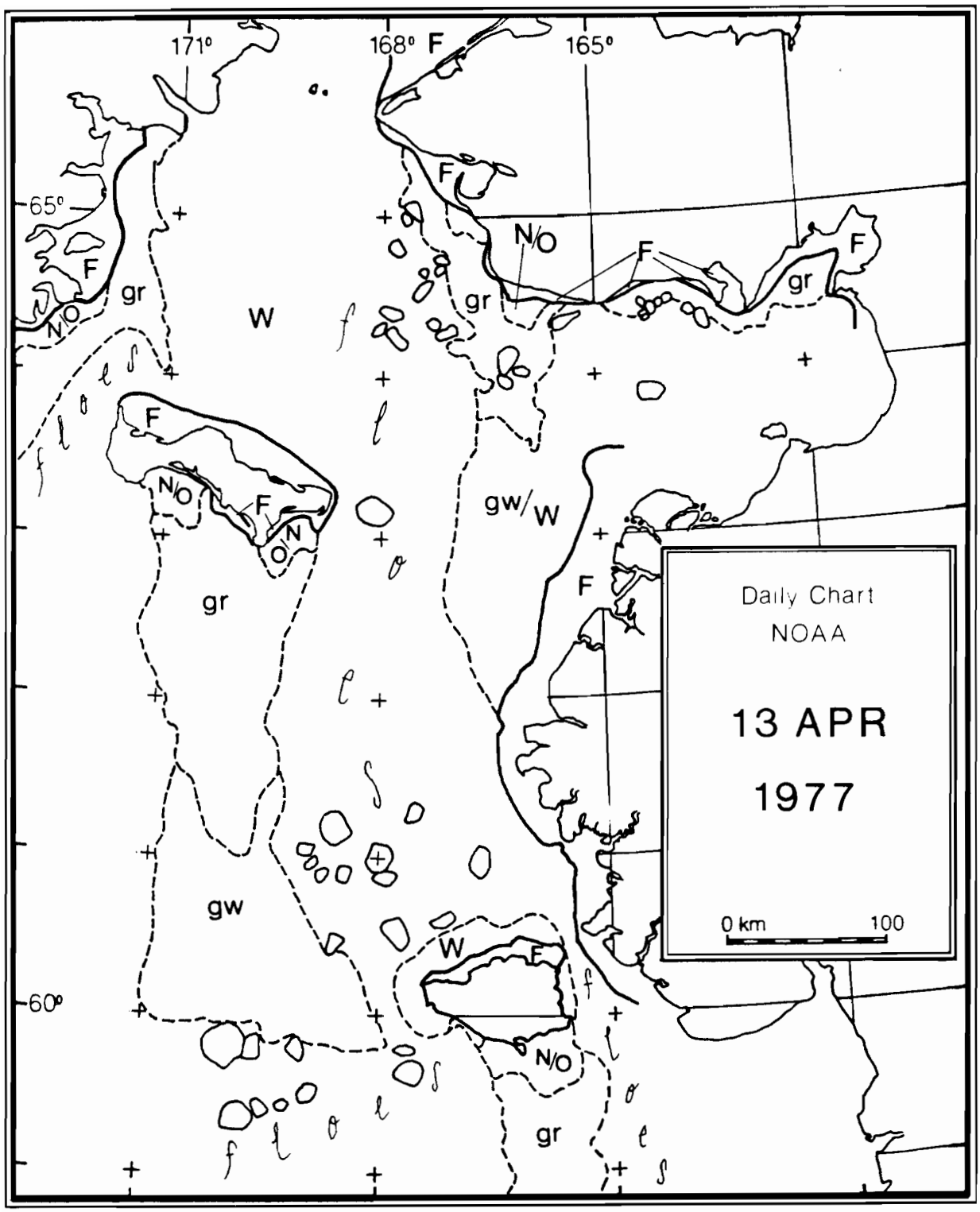

171°
W
168° F
165°
N/O
gw
gr
65°
F
W
gr
F
N/O
F
gr
gr
F
N/O
F
gr
gw
Daily Chart
NOAA
25 MAR
1977
0 km
100
60°

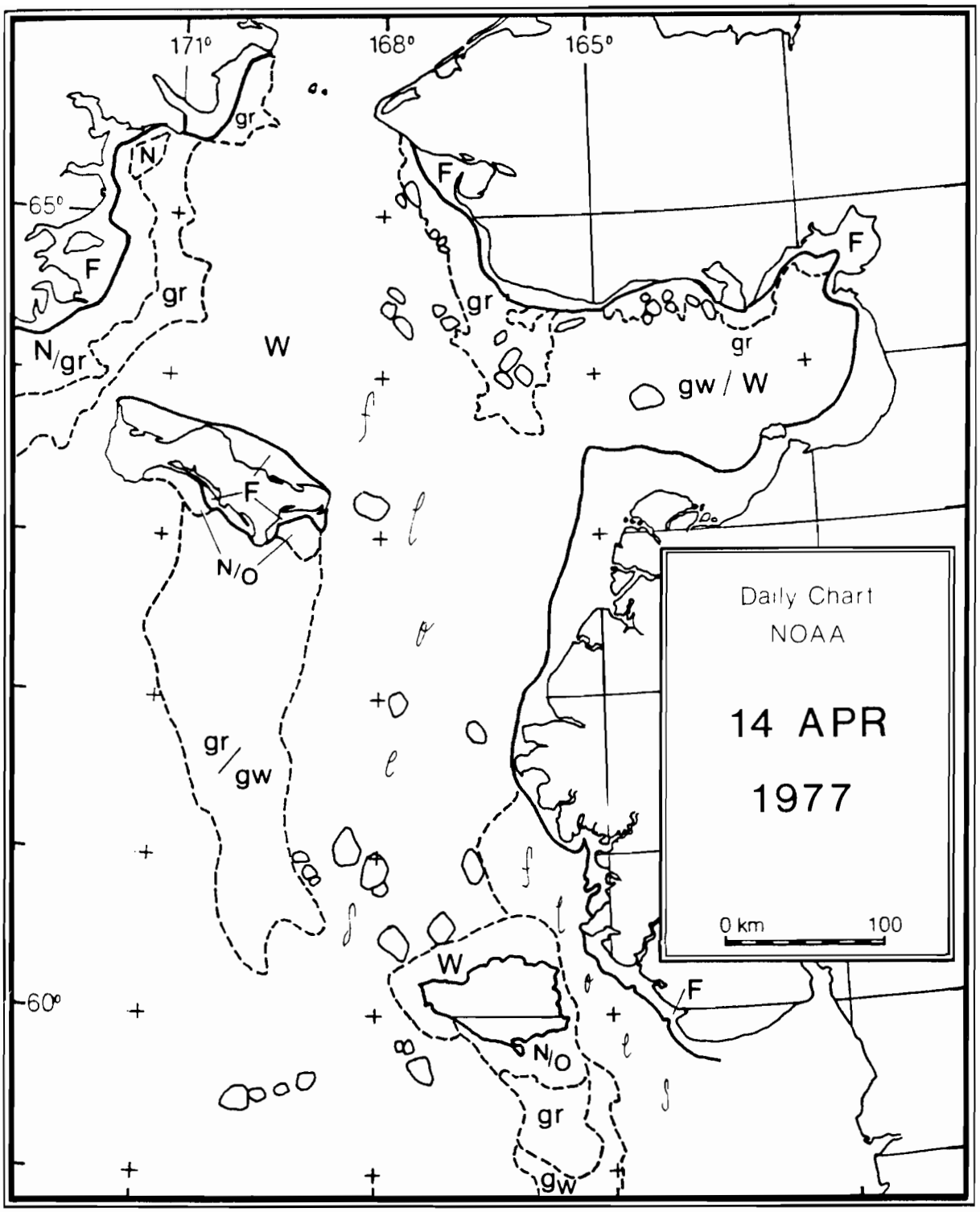

171°
W 168° F
165°
65°
60°
gw
gr
F
N/O
W
N
gr/gw
W
gr
gw
Daily Chart
NOAA
26 MAR
1977
0 km
100

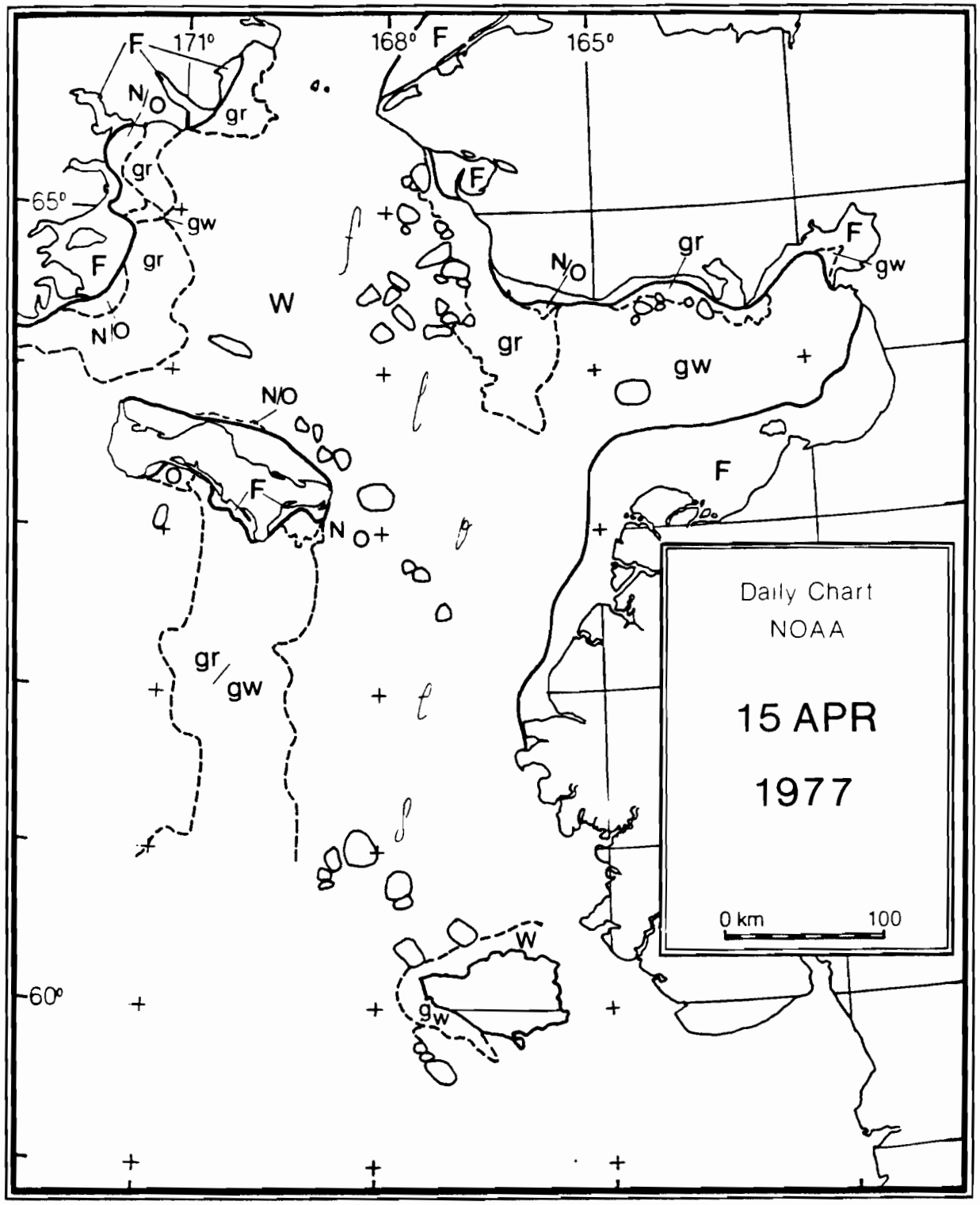

171°
168°
165°
65°
60°
N/gr
F
N/O
gr/gw
N/O
F
gr
gr
F
streamers
ice edge
floes
Daily Chart
NOAA
29 MAR
1977
0 km
100


171°
168°
165°
65°
60°
F
gr
N/O
N
F
N/O
N/O
gr/gw
N/O
F
F
gr
F
N/O
F
Daily Chart
NOAA
30 MAR
1977
0 km
100


171°
168°
165°
65°
60°
F
F
N/O
N/O
F
F
N/gr
gr/gw
gr
F
N/O
Daily Chart
NOAA
31 MAR
1977
0 km
100


171°
168°
165°
65°
60°
F
N/O
gr
W
gw
gw/W
Daily Chart
NOAA
13 APR
1977
0 km
100


171°
168°
165°
65°
60°
gr
N
F
W
N/gr
gw / W
N/O
gr/gw
Daily Chart
NOAA
14 APR
1977
0 km
100
gw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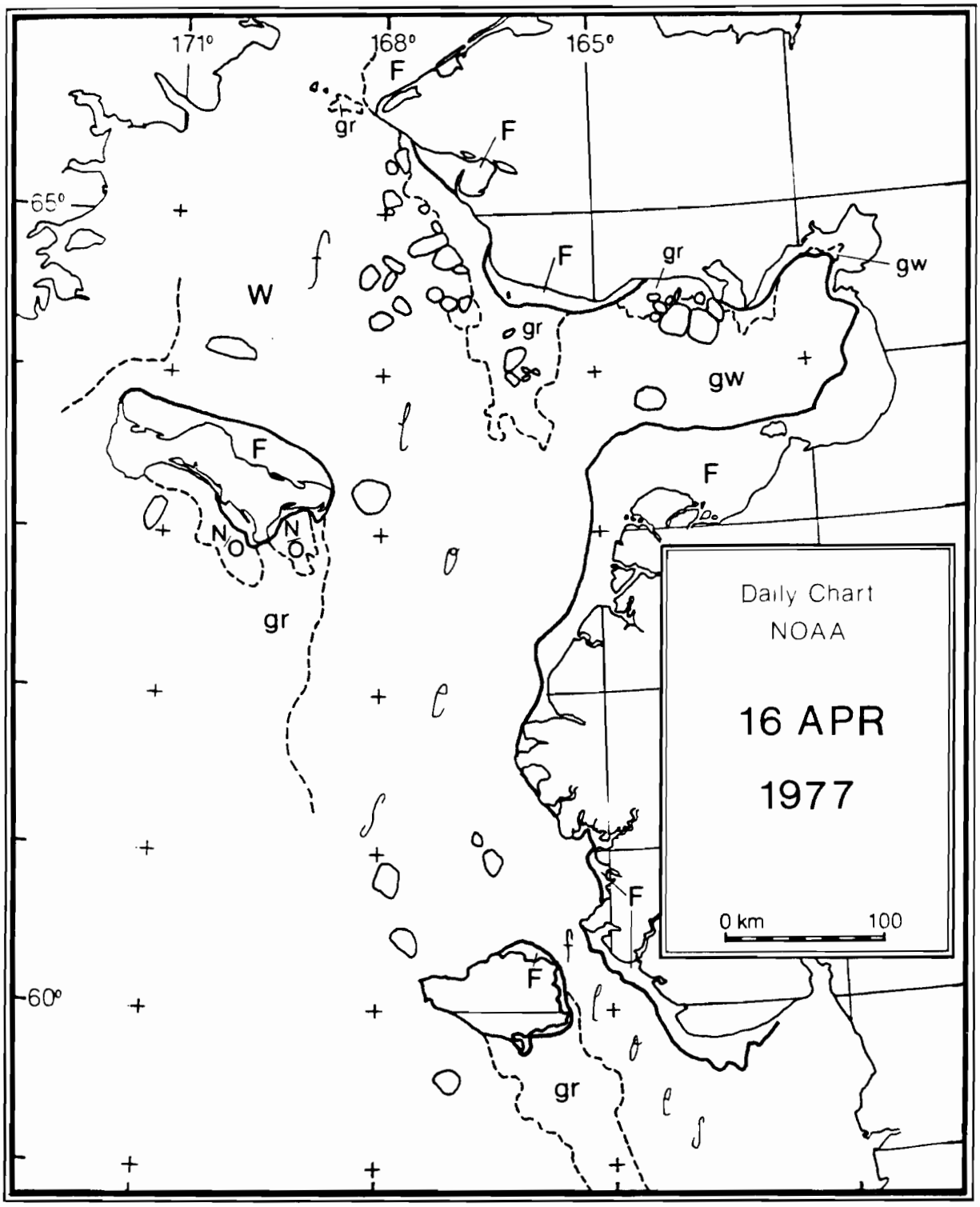
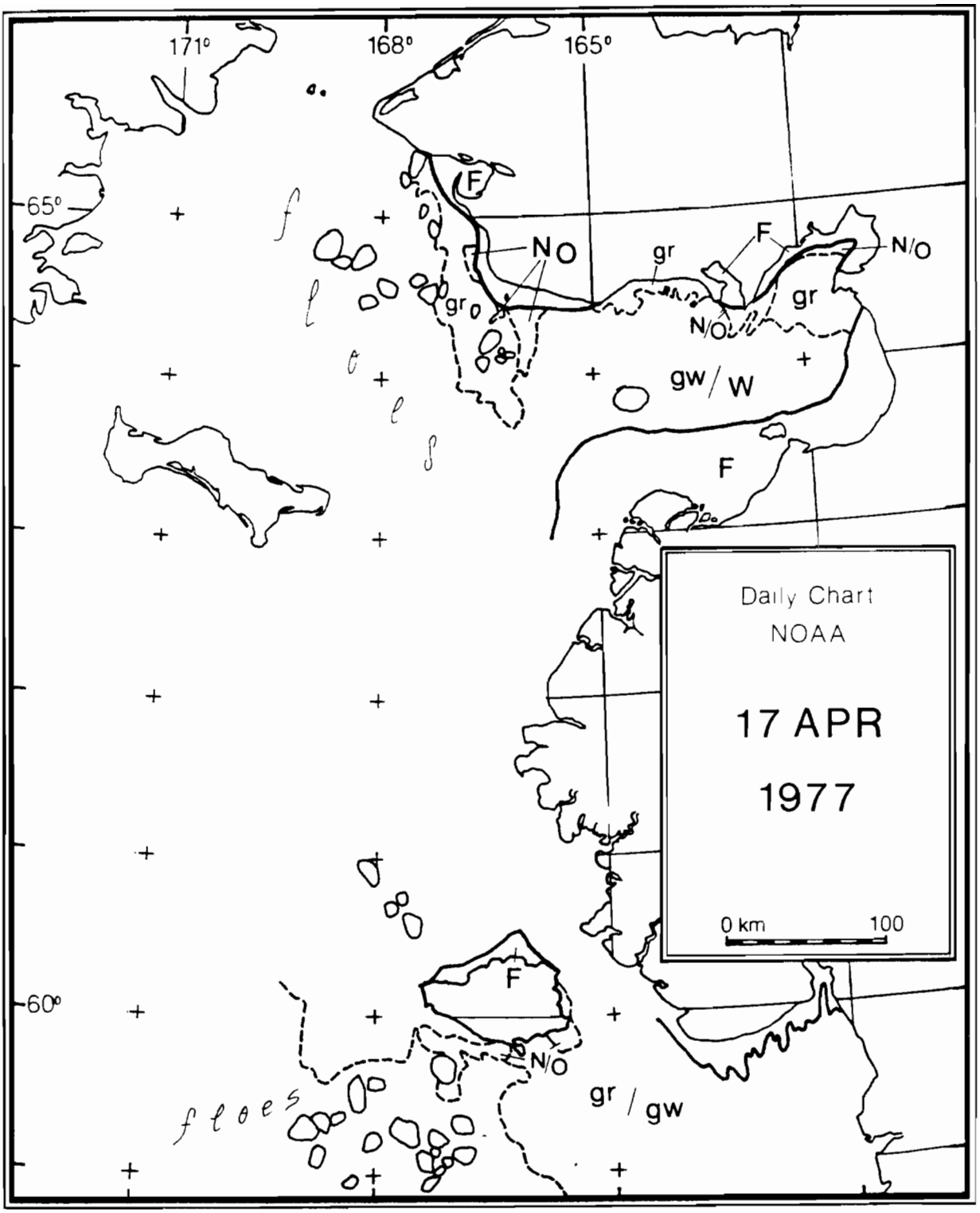
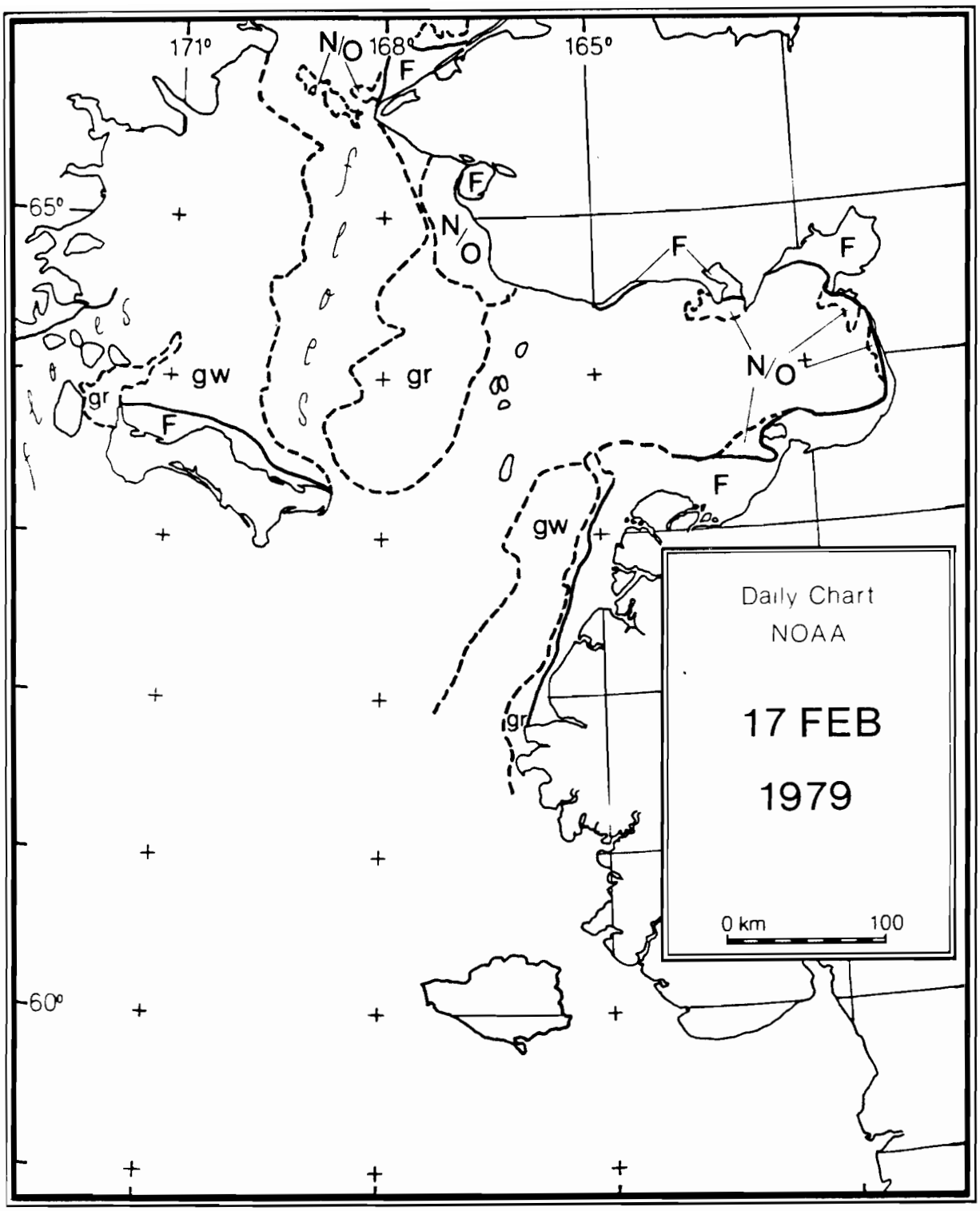
168°
165°
65°
60°
F
N/O
gr
gw
W
Daily Chart
NOAA
15 APR
1977
0 km
100


171°
168°
165°
65°
60°
F
gr
W
gw
N
O
Daily Chart
NOAA
16 APR
1977
0 km
100


171°
168°
165°
65°
60°
F
NO
gr
F
N/O
gr
N/O
gr
gw / W
F
floes
floes
F
N/O
gr / gw
Daily Chart
NOAA
17 APR
1977
0 km
100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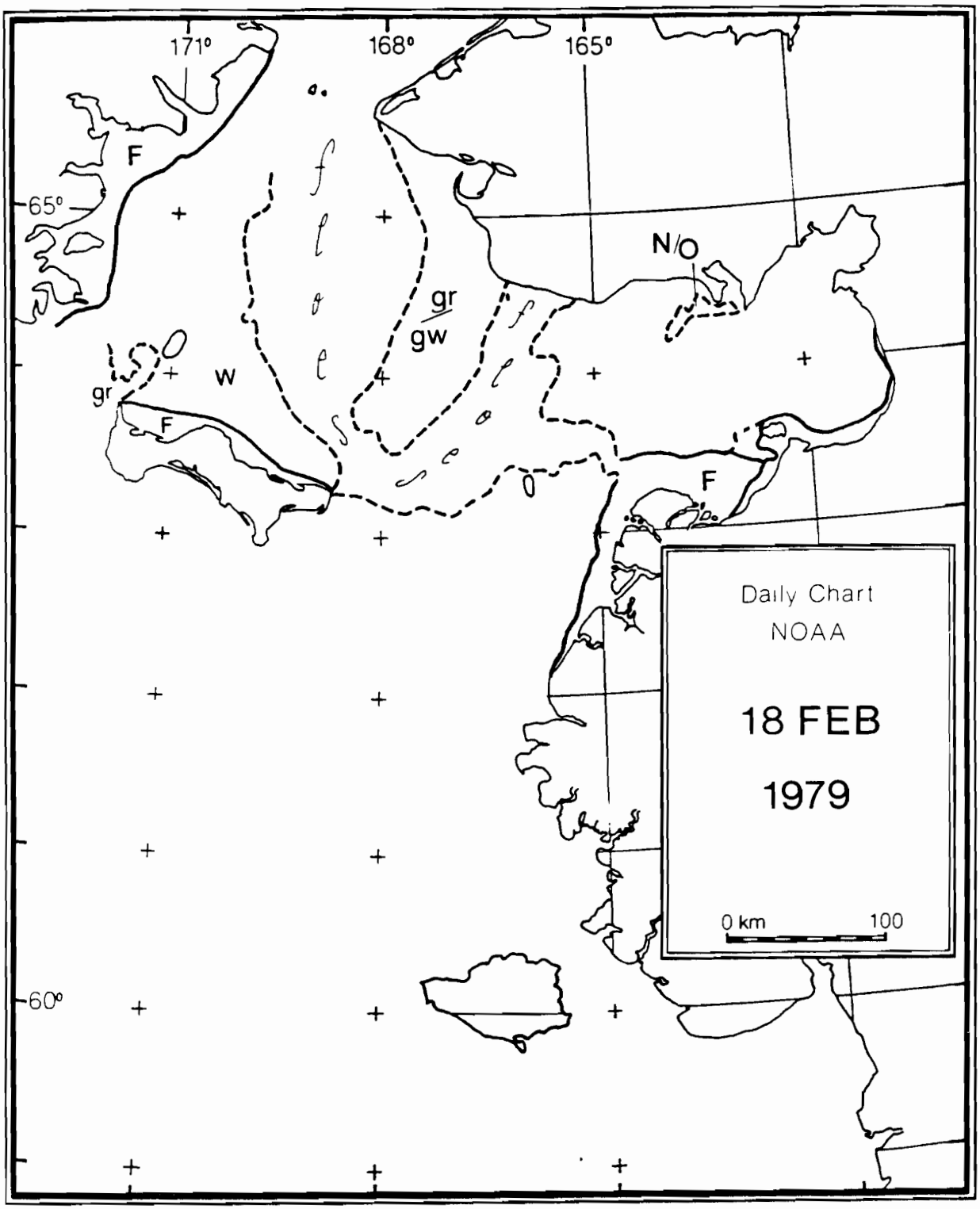
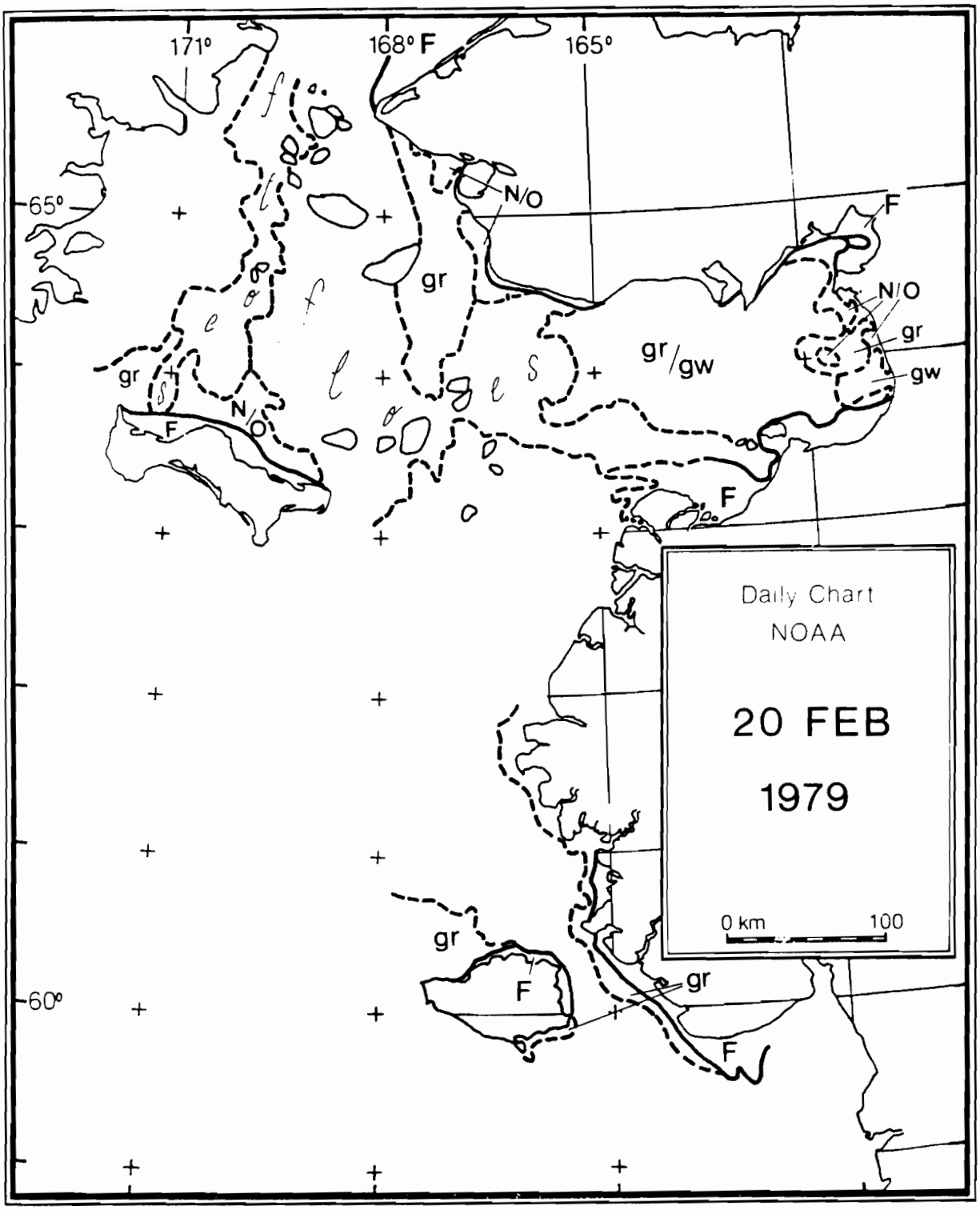
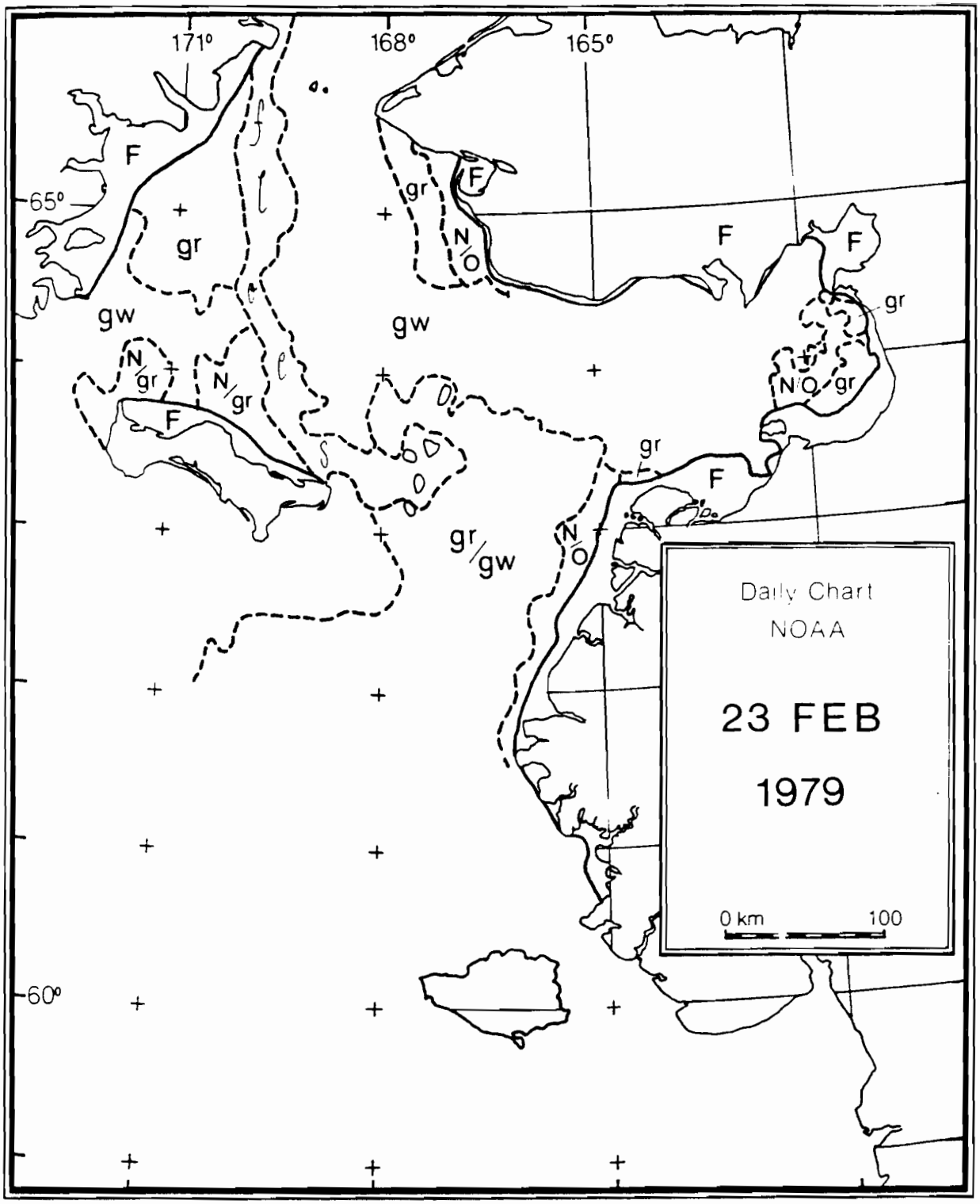
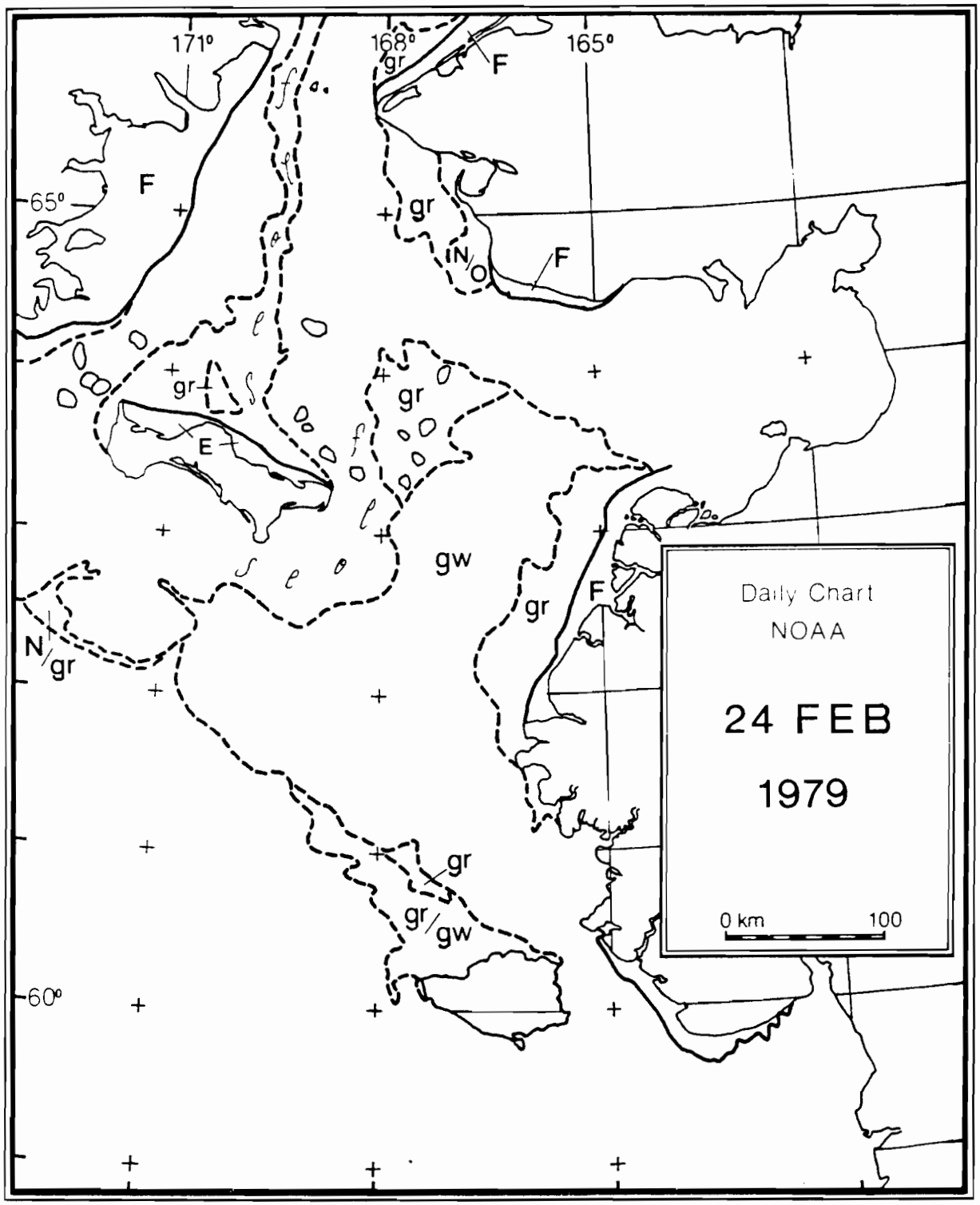
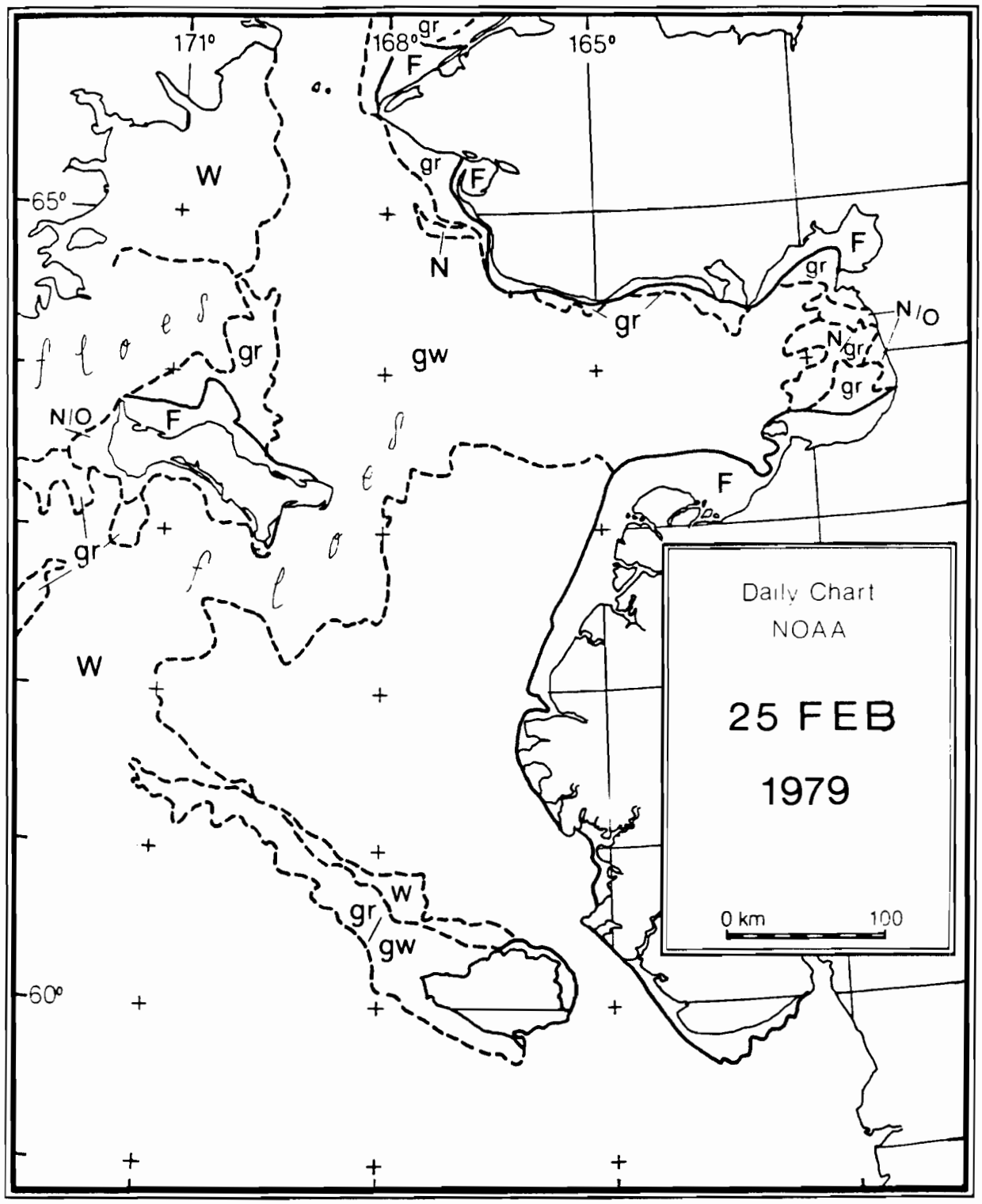
168°
165°
65°
60°
N/O
F
gw
gr
Daily Chart
NOAA
17 FEB
1979
0 km
100

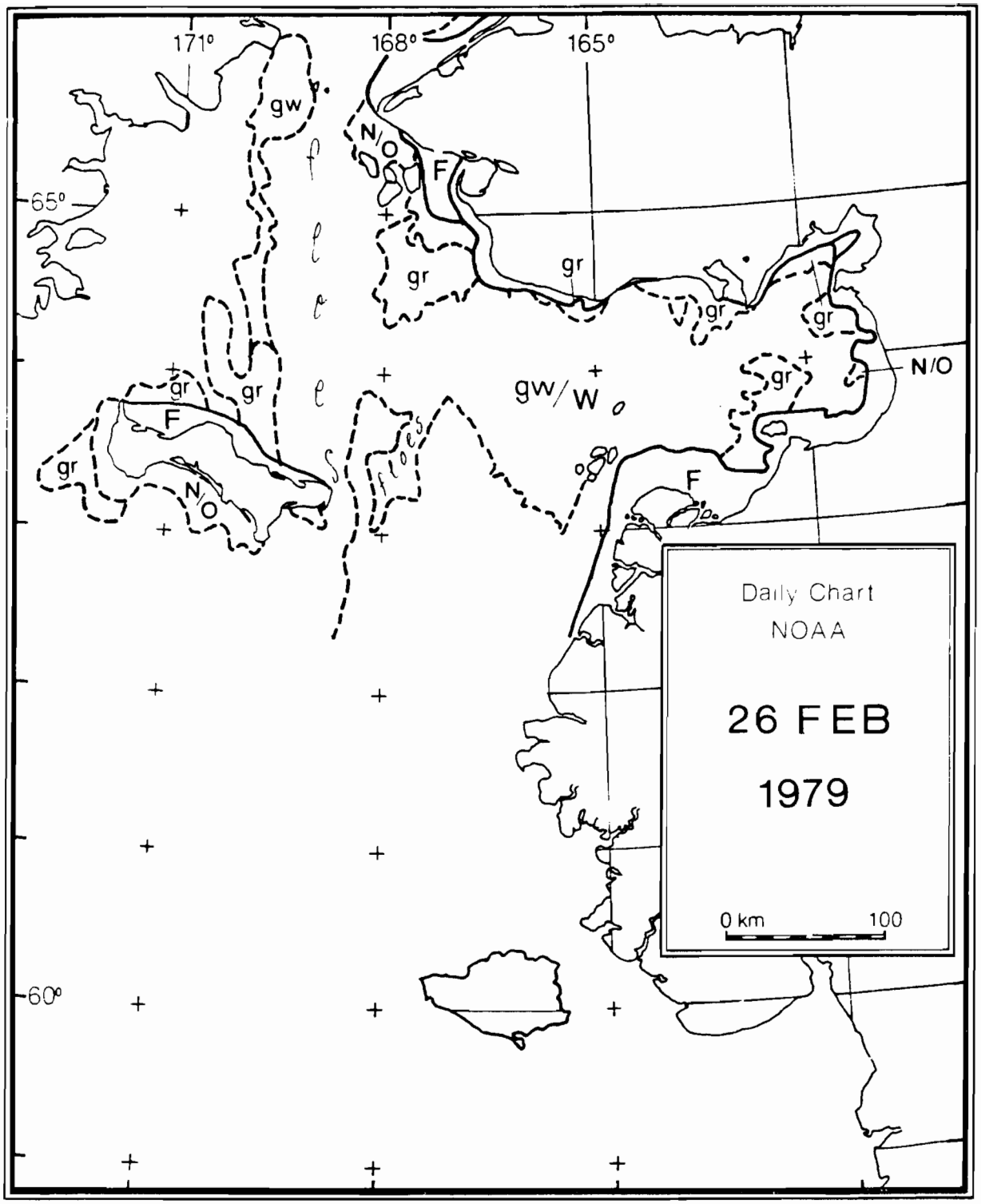

171°
168°
165°
65°
60°
F
N/O
gr
gw
W
gr
F
F
Daily Chart
NOAA
18 FEB
1979
0 km
100

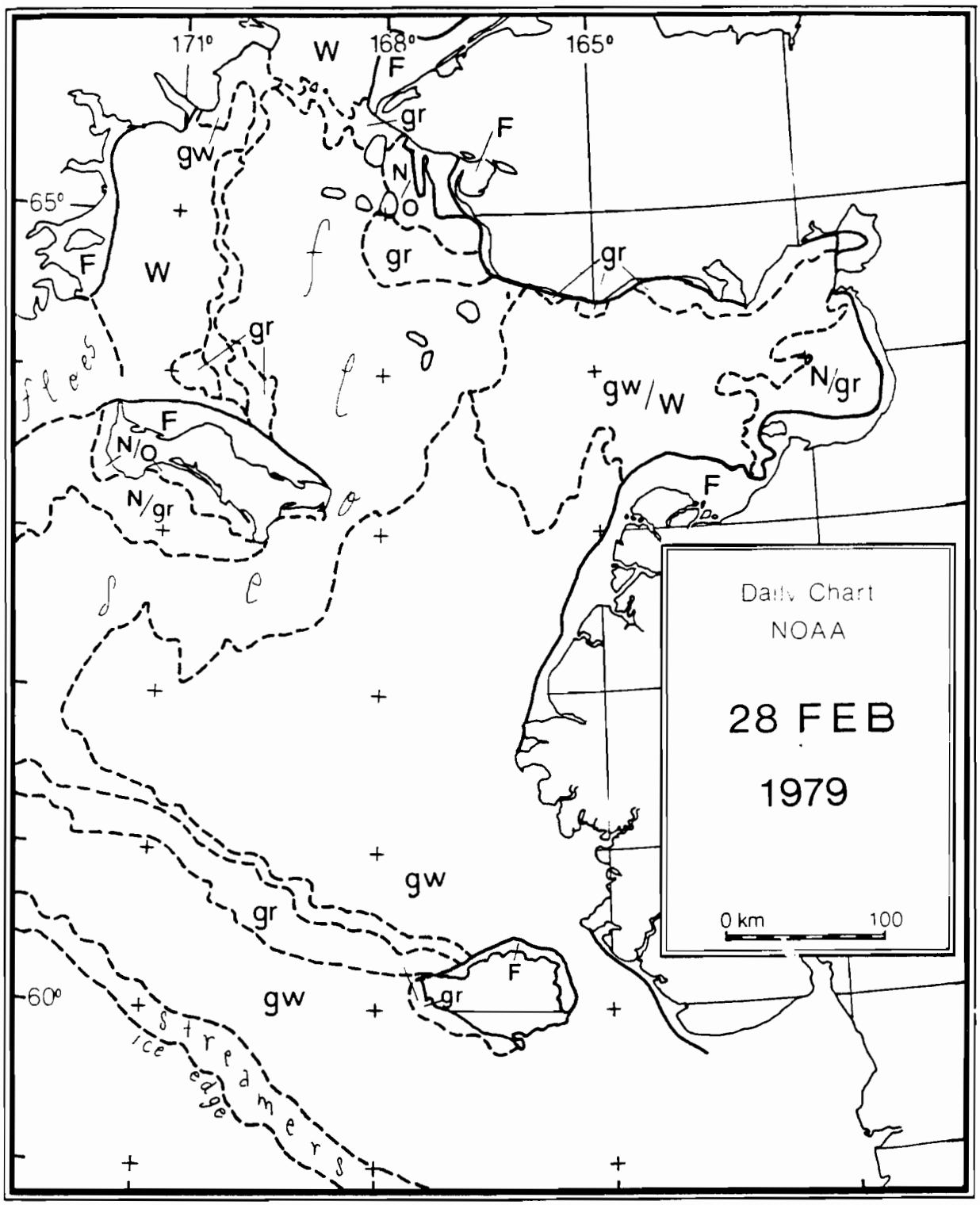

171°
168° F
165°
65°
60°
N/O
F
gr
gr/gw
gw
Daily Chart
NOAA
20 FEB
1979
0 km
100

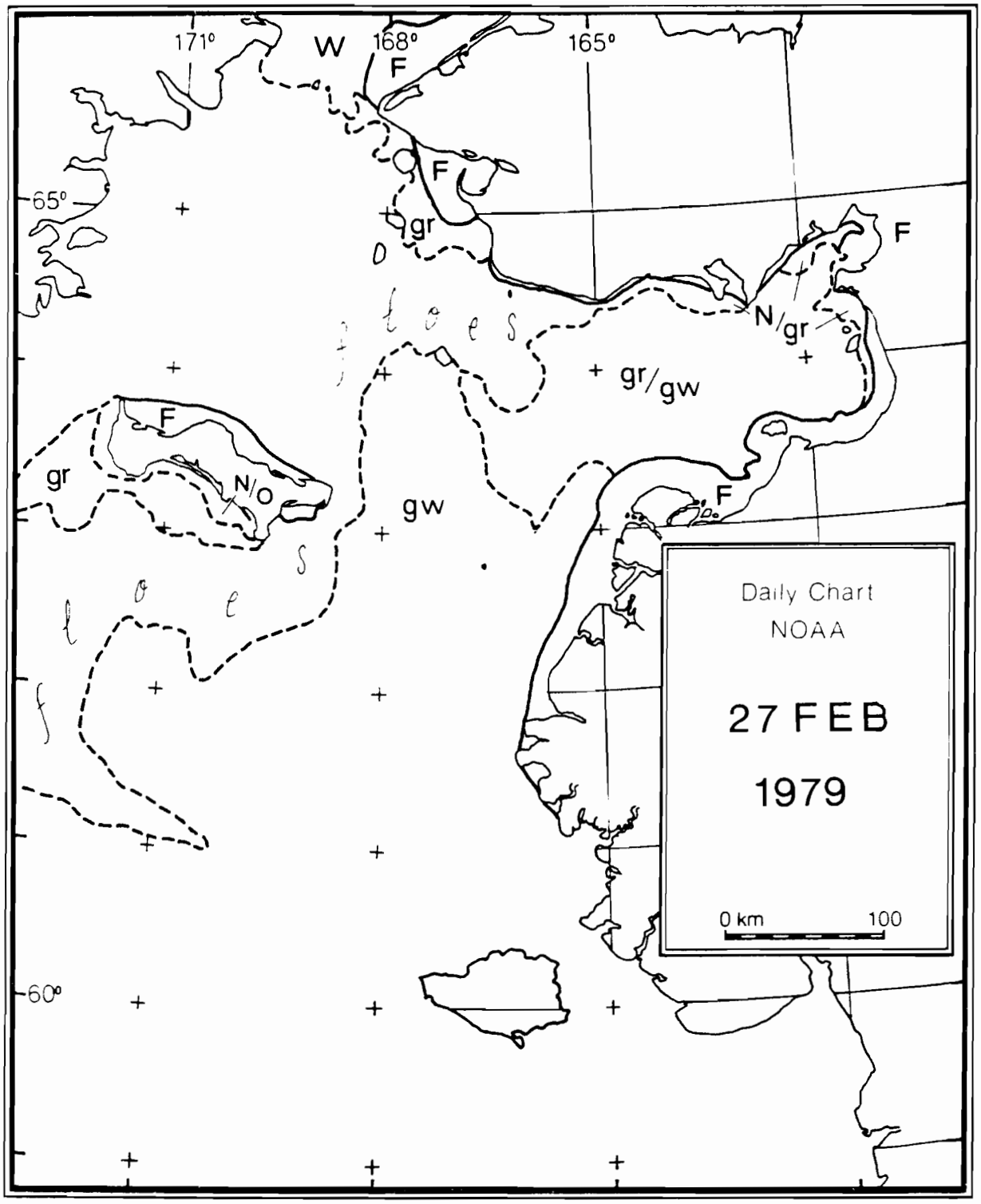

171°
168°
165°
65°
60°
F
gr
gw
N/gr
N/O
gr/gw
Daily Chart
NOAA
23 FEB
1979
0 km
100


171°
168°
gr
F
165°
65°
F
gr
N/O
F
gr
gr
E
gw
gr
F
N/gr
Daily Chart
NOAA
24 FEB
1979
0 km
100
gr
gr/gw
60°


171°
168°
165°
65°
60°
W
F
gr
N
gw
N/O
floes
Daily Chart
NOAA
25 FEB
1979
0 km
100


171°
168°
165°
65°
60°
gw
N/O
F
gr
gw/W
Daily Chart
NOAA
26 FEB
1979
0 km
100


171°
W
168°
F
165°
gr
F
gw
N/O
65°
F
W
f
gr
gr
gr
fleet
l
gw/W
N/gr
F
N/O
N/gr
o
d
e
F
Daily Chart
NOAA
28 FEB
1979
0 km
100
gw
gr
F
60°
gw
gr
ice edge
Streamers


171°
W
168°
F
165°
F
65°
gr
F
N/gr
gr/gw
F
gr
N/O
gw
F
Daily Chart
NOAA
27 FEB
1979
0 km
100
60°

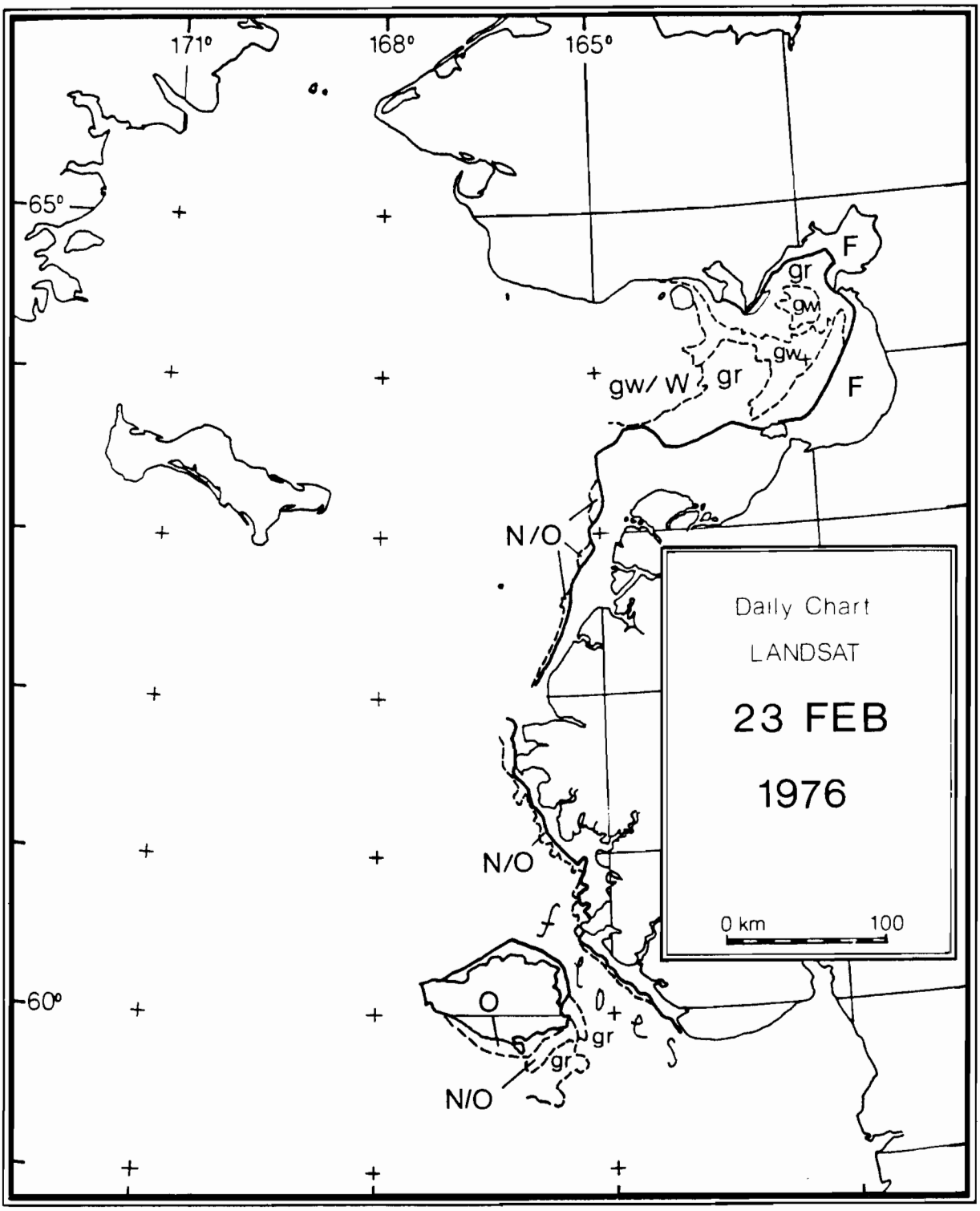
Appendix III

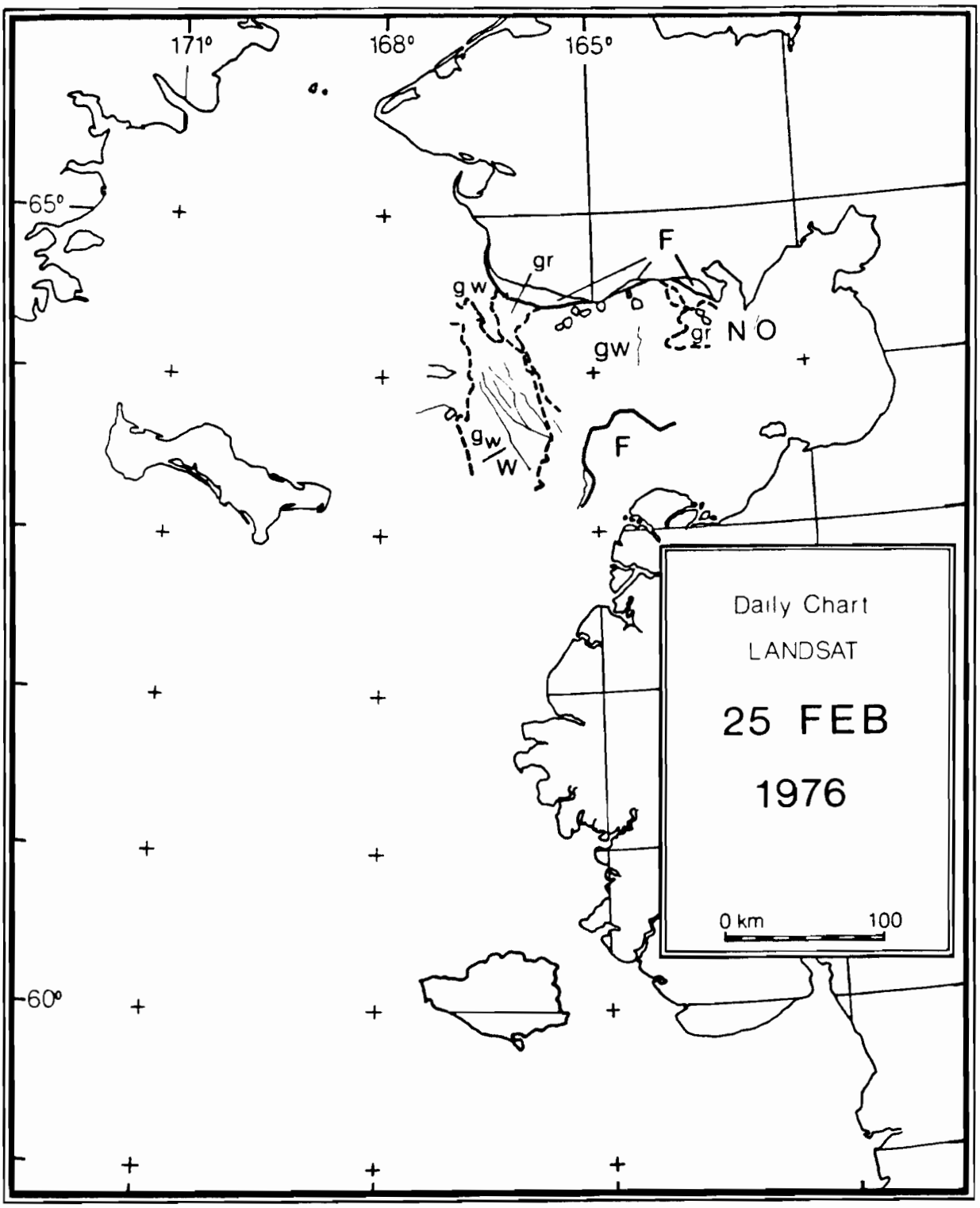
LANDSAT--Daily Charts of Ice Conditions

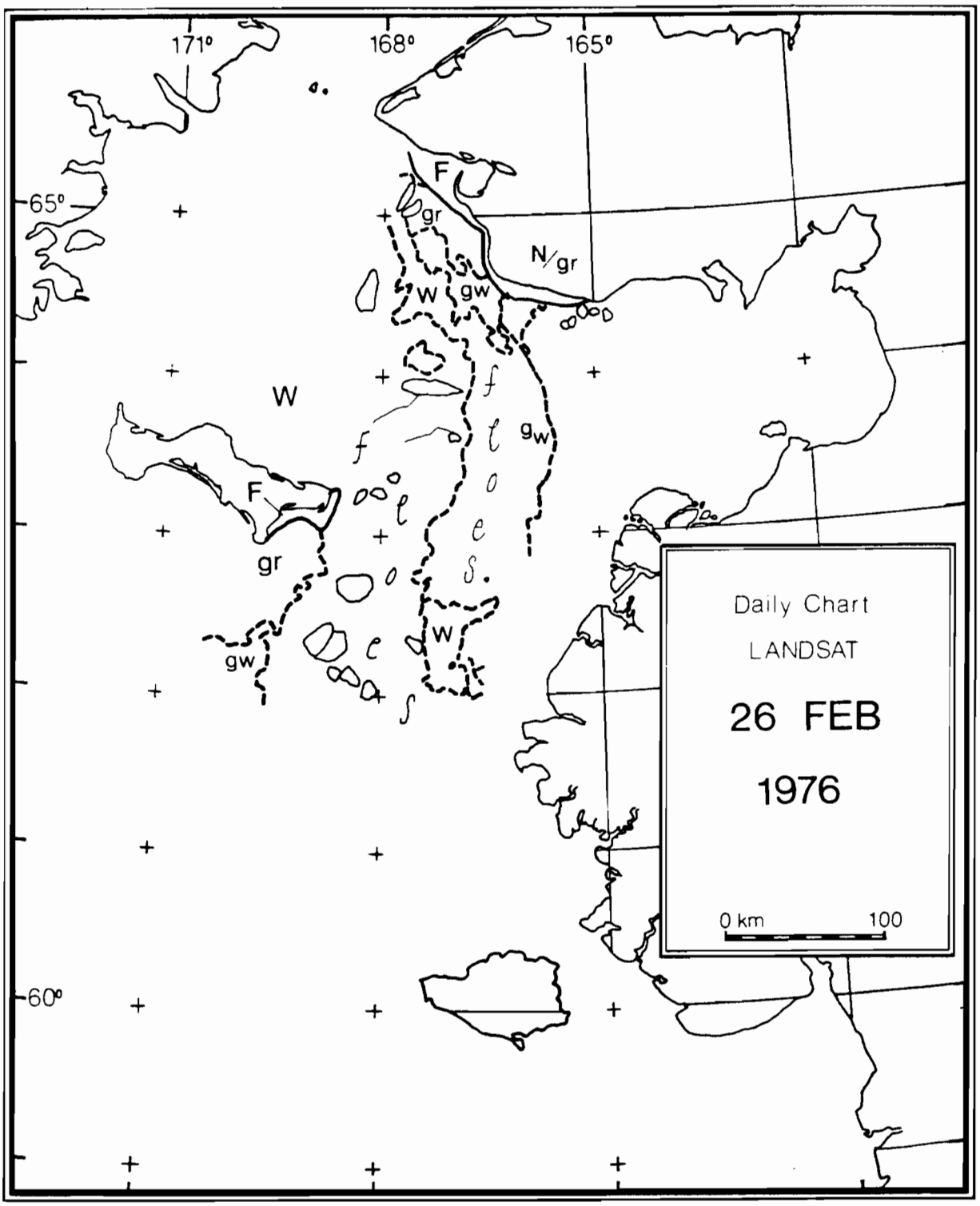
The LANDSAT imagery listed in Appendix I provided the daily ice data which has been transfered to the base map in Figure 1. The legend on the following page explains the line symbols and ice-type abbreviations used. All ice definitions refer to WMO classifications (1970), but show a grey scale distinction in ice color on each image, not actual ice type of thickness.

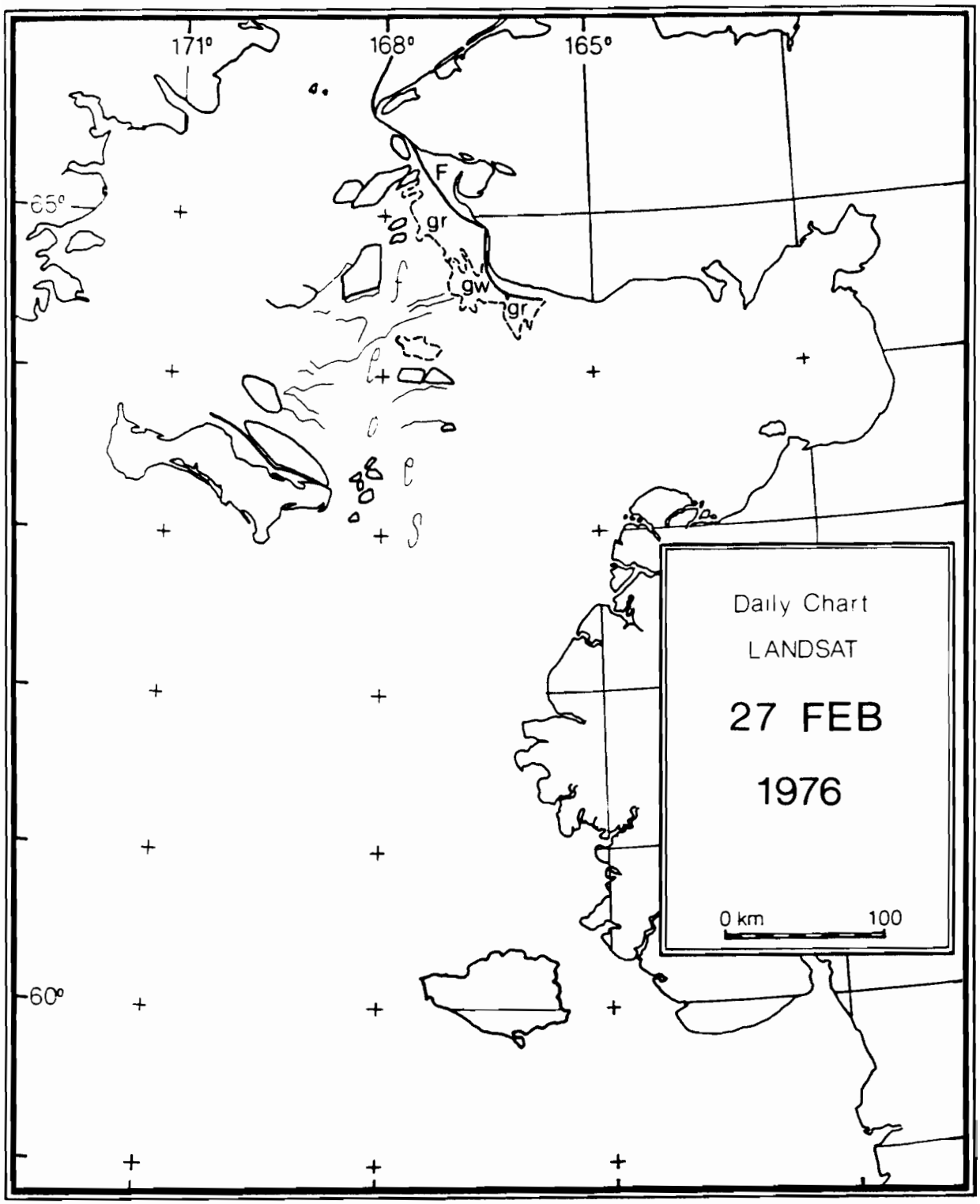
LEGEND

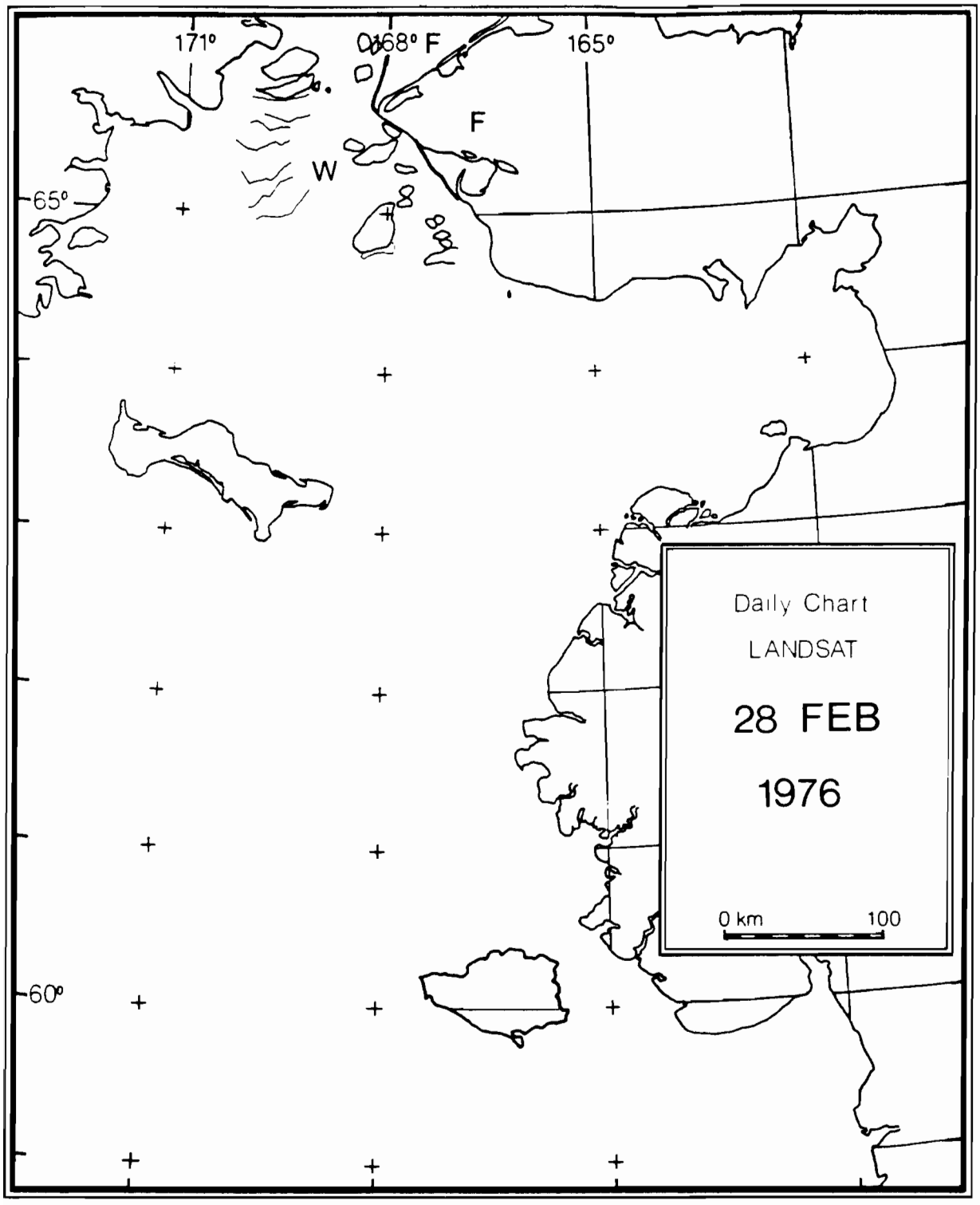
▬▬	land-fast ice
- - -	border of change from one ice color to another
——	lead
0	open water
N	new ice
gr	grey ice
gw	grey-white ice
W	white ice
◯	ice floe

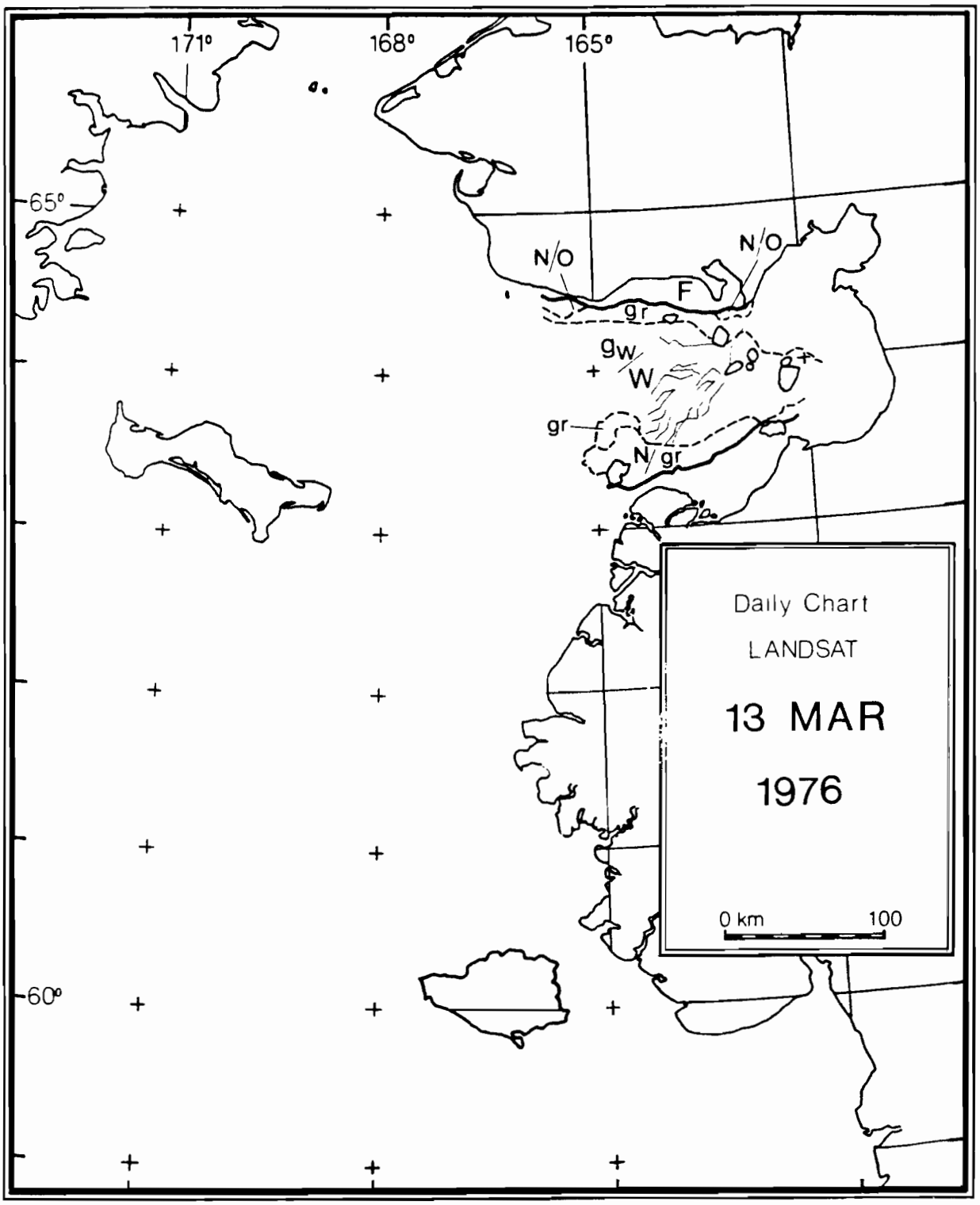

171°
168°
165°
65°
60°
F
gr
gw
gw
gw/ W, gr
F
N/O
N/O
O
gr
gr
N/O
Daily Chart
LANDSAT
23 FEB
1976
0 km
100

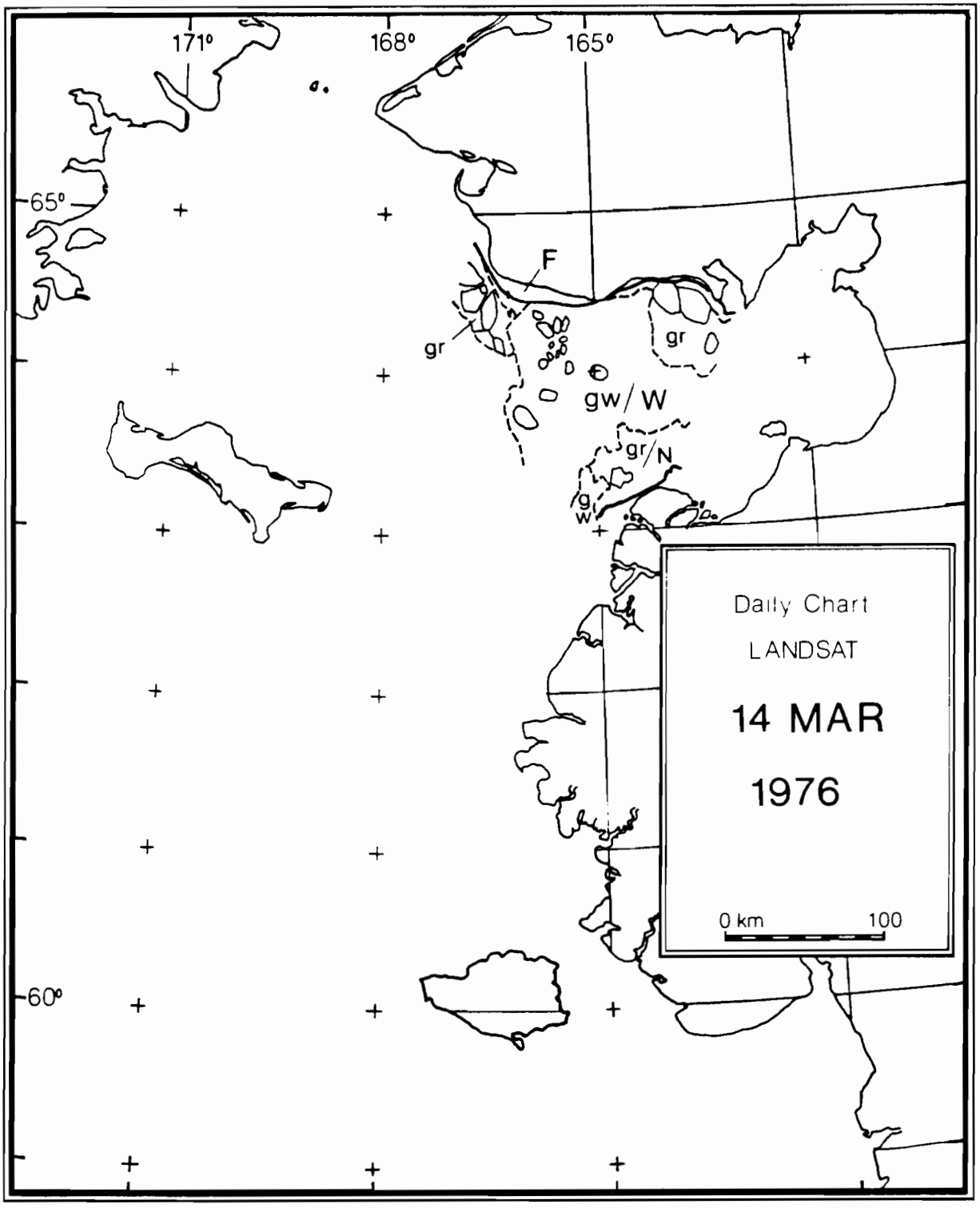

171°
168°
165°
65°
60°
F
gr
gw
gr
N O
gw
F
gw
W
Daily Chart
LANDSAT
25 FEB
1976
0 km
100

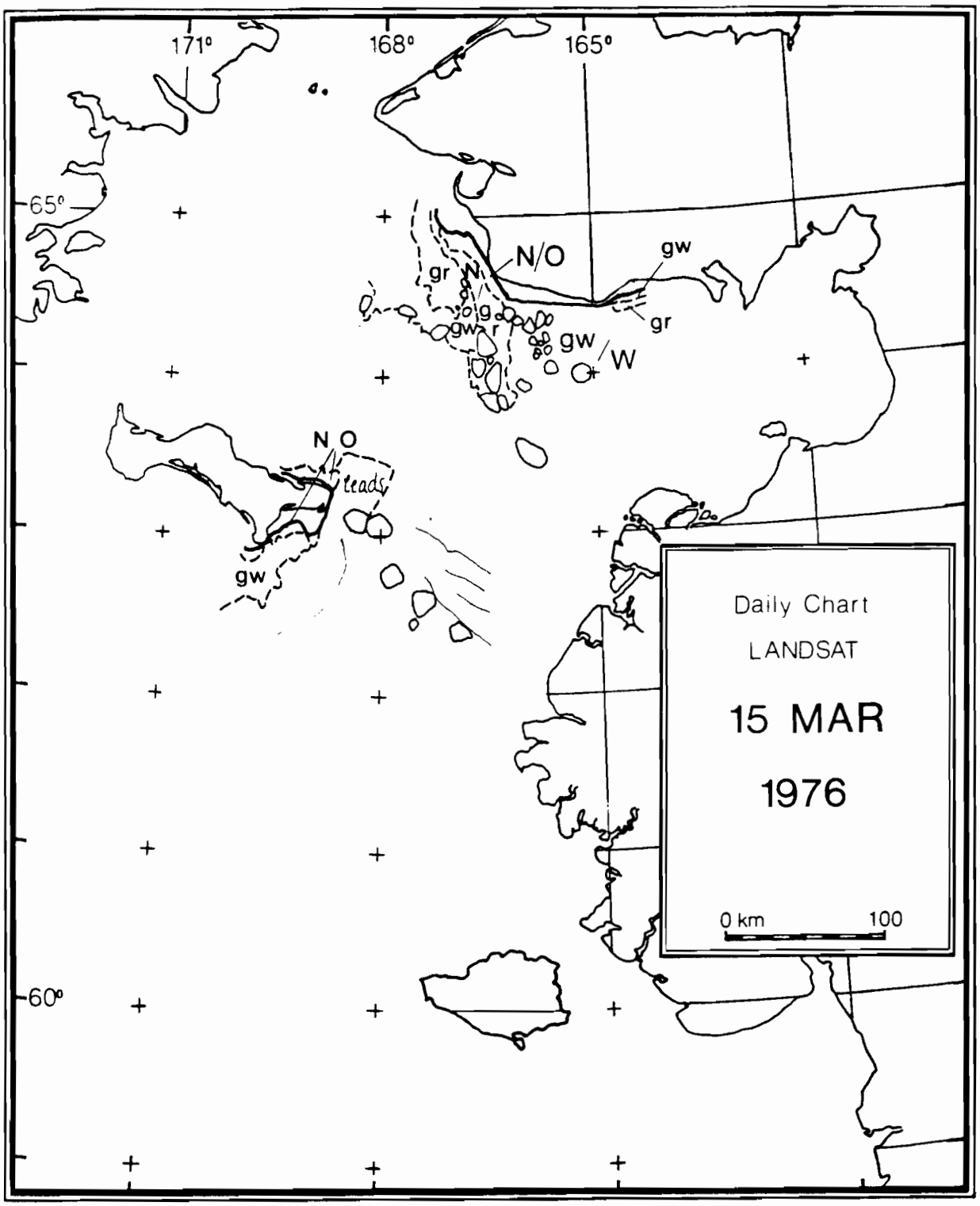

171°
168°
165°
65°
60°
F
gr
N/gr
W
gw
W
f
l
o
e
s.
gw
F
gr
W
gw
Daily Chart
LANDSAT
26 FEB
1976
0 km
100

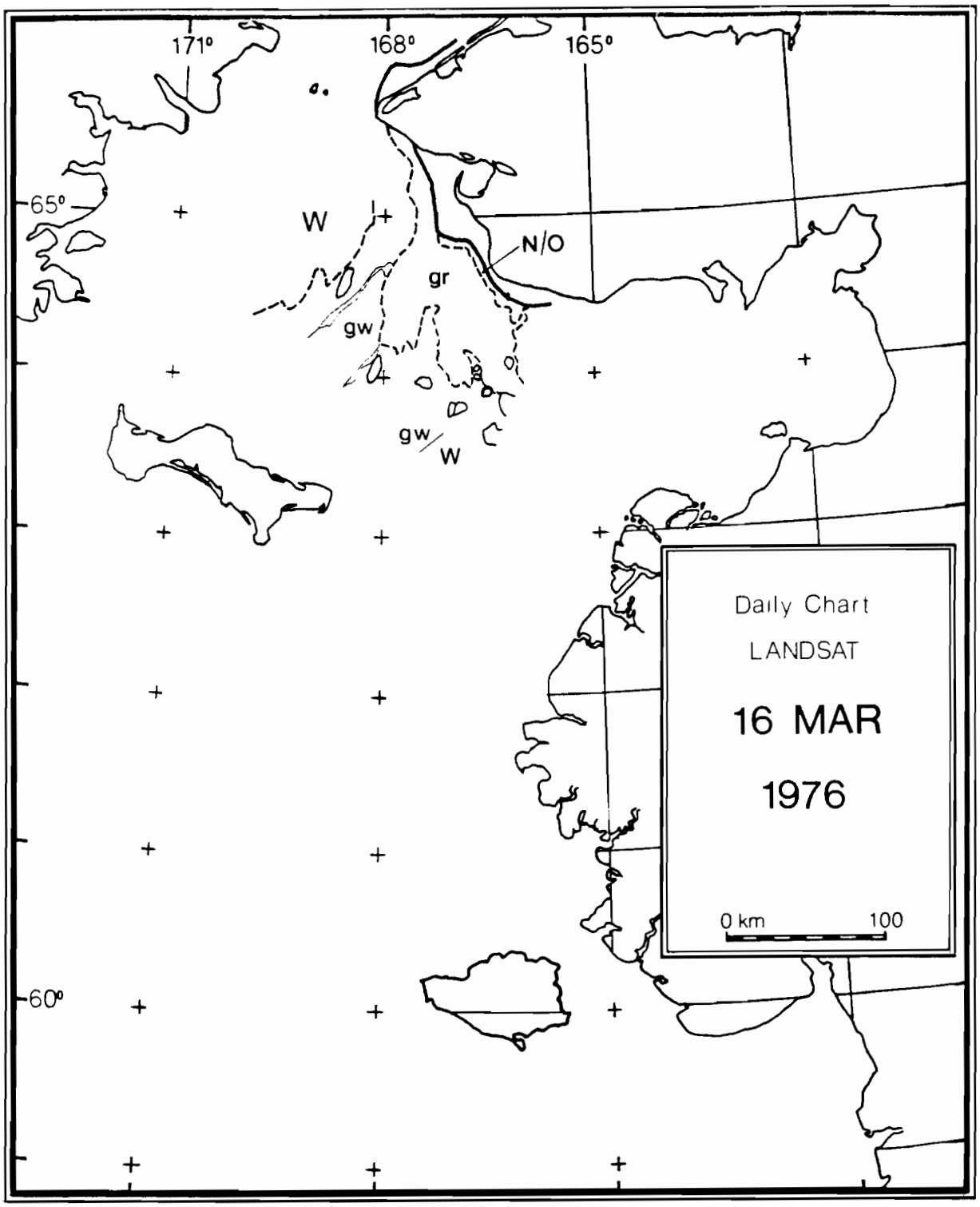

171°
168°
165°
65°
60°
F
gr
gw
gr
Daily Chart
LANDSAT
27 FEB
1976
0 km
100

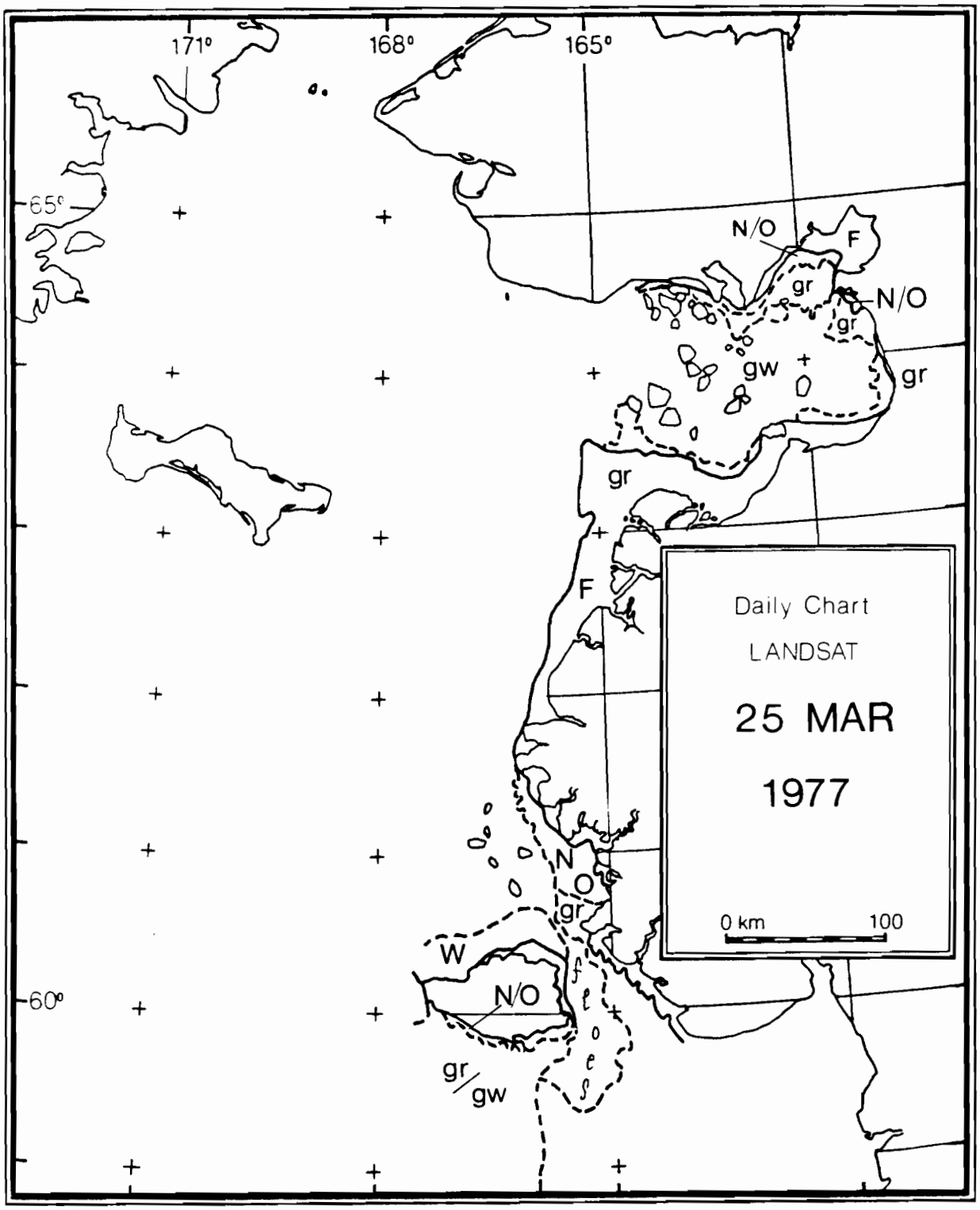

171°
168° F
165°
F
W
65°
60°
Daily Chart
LANDSAT
28 FEB
1976
0 km
100

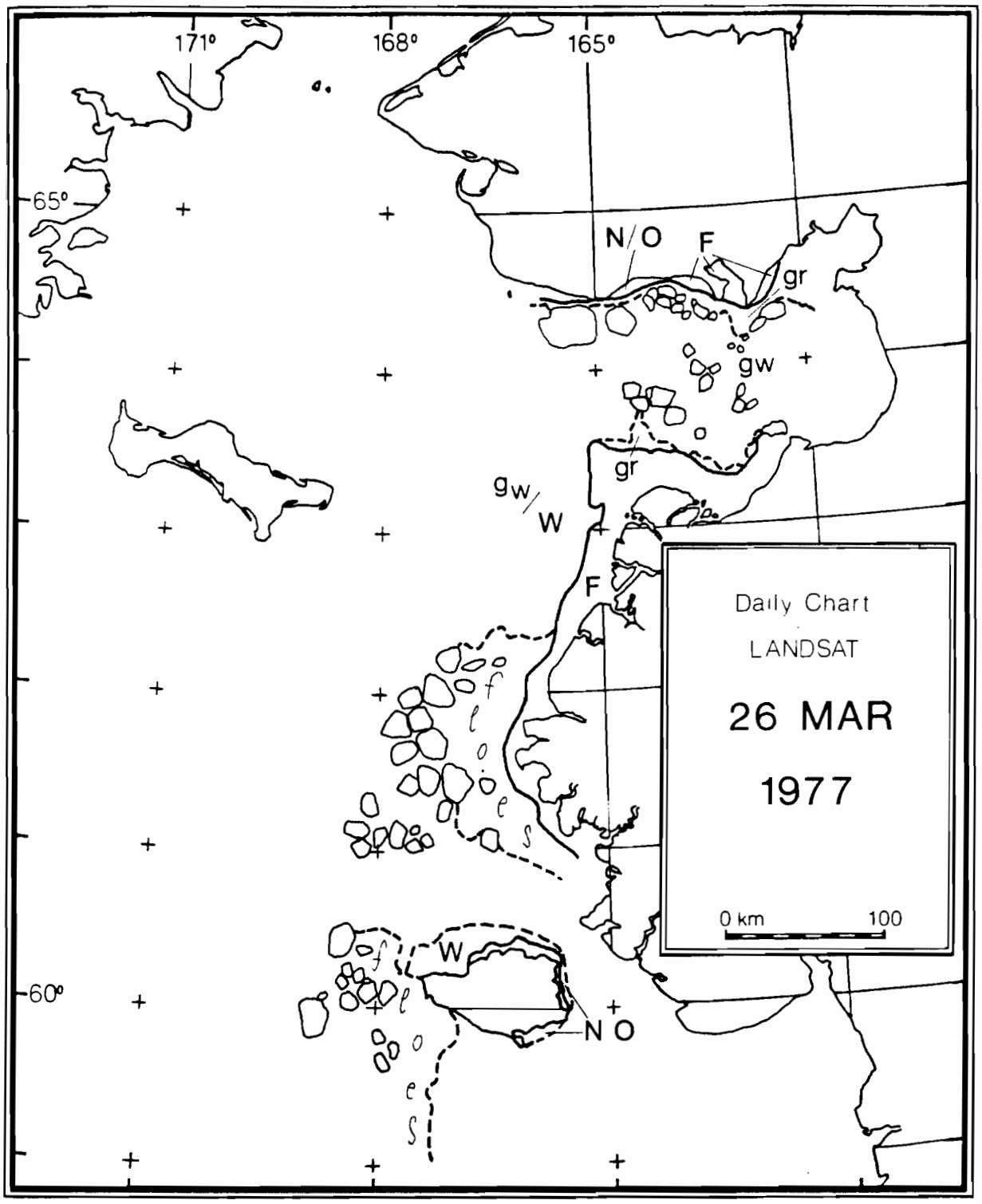

171°
168°
165°
65°
60°
N/O
N/O
F
gr
gw
W
gr
N/ gr
Daily Chart
LANDSAT
13 MAR
1976
0 km
100

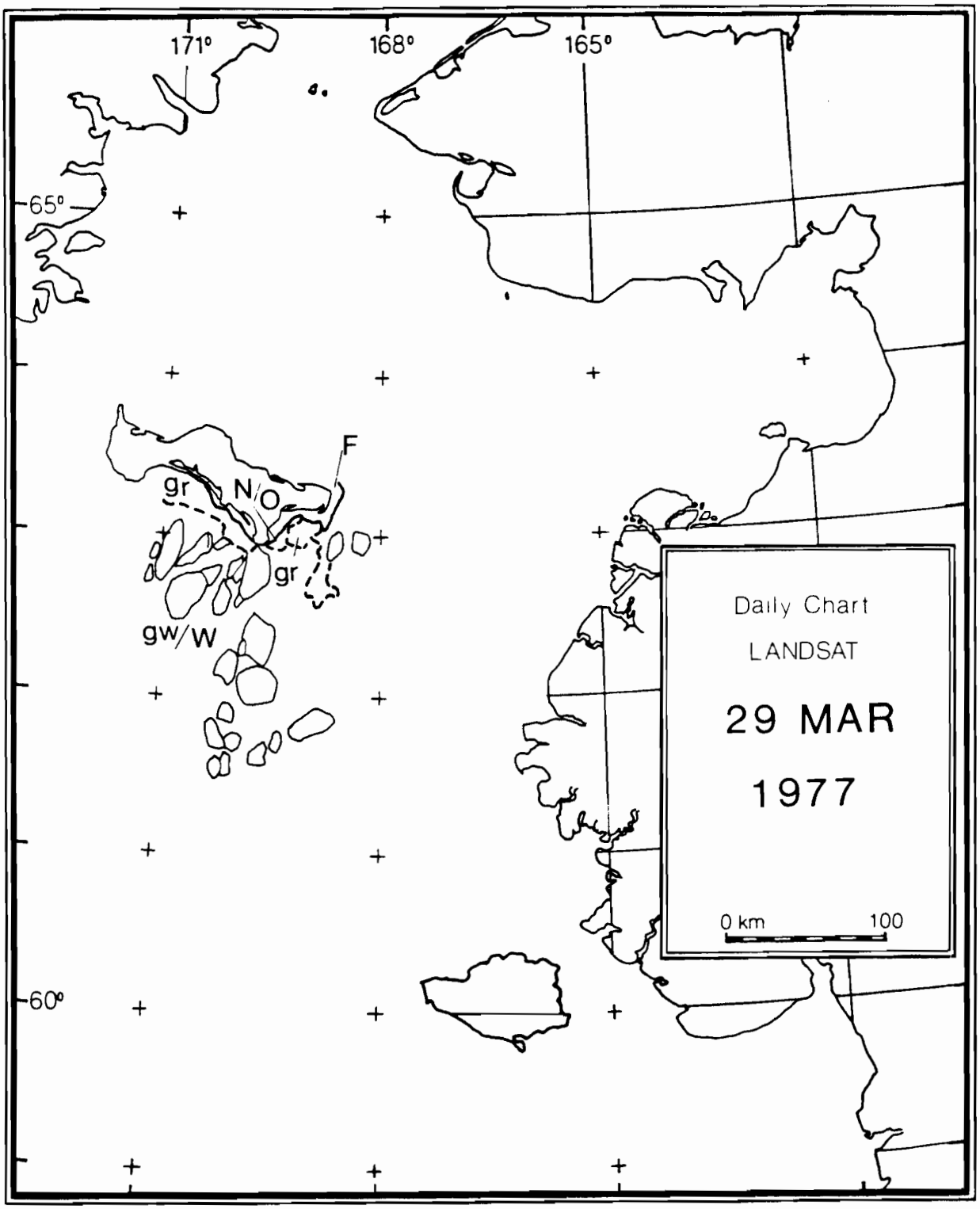

171°
168°
165°
65°
60°
F
gr
gr
gw/W
gr/N
g
w
Daily Chart
LANDSAT
14 MAR
1976
0 km
100

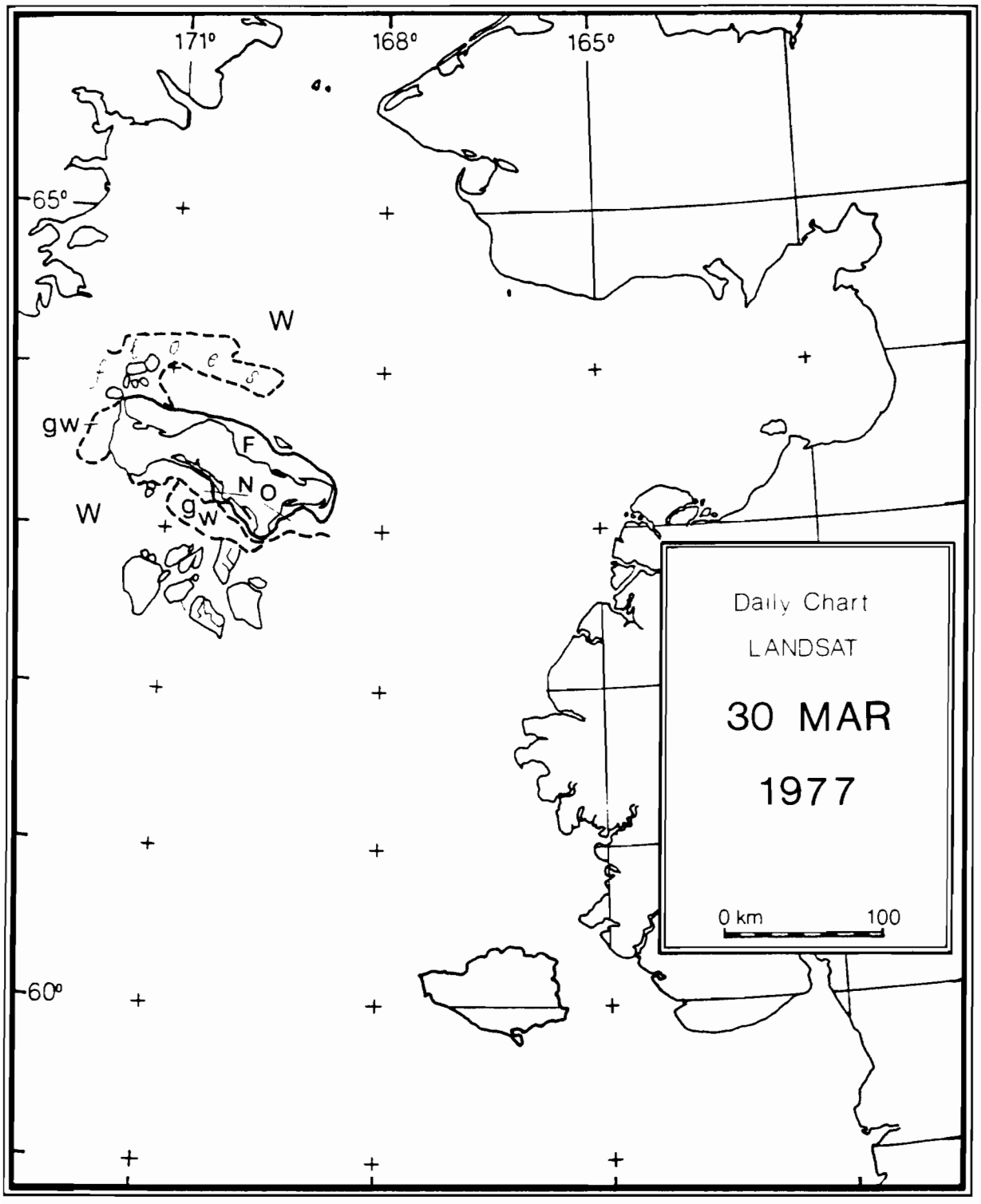

171°
168°
165°
65°
60°
N/O
gw
gr
gw
W
N O
leads
gw
Daily Chart
LANDSAT
15 MAR
1976
0 km
100

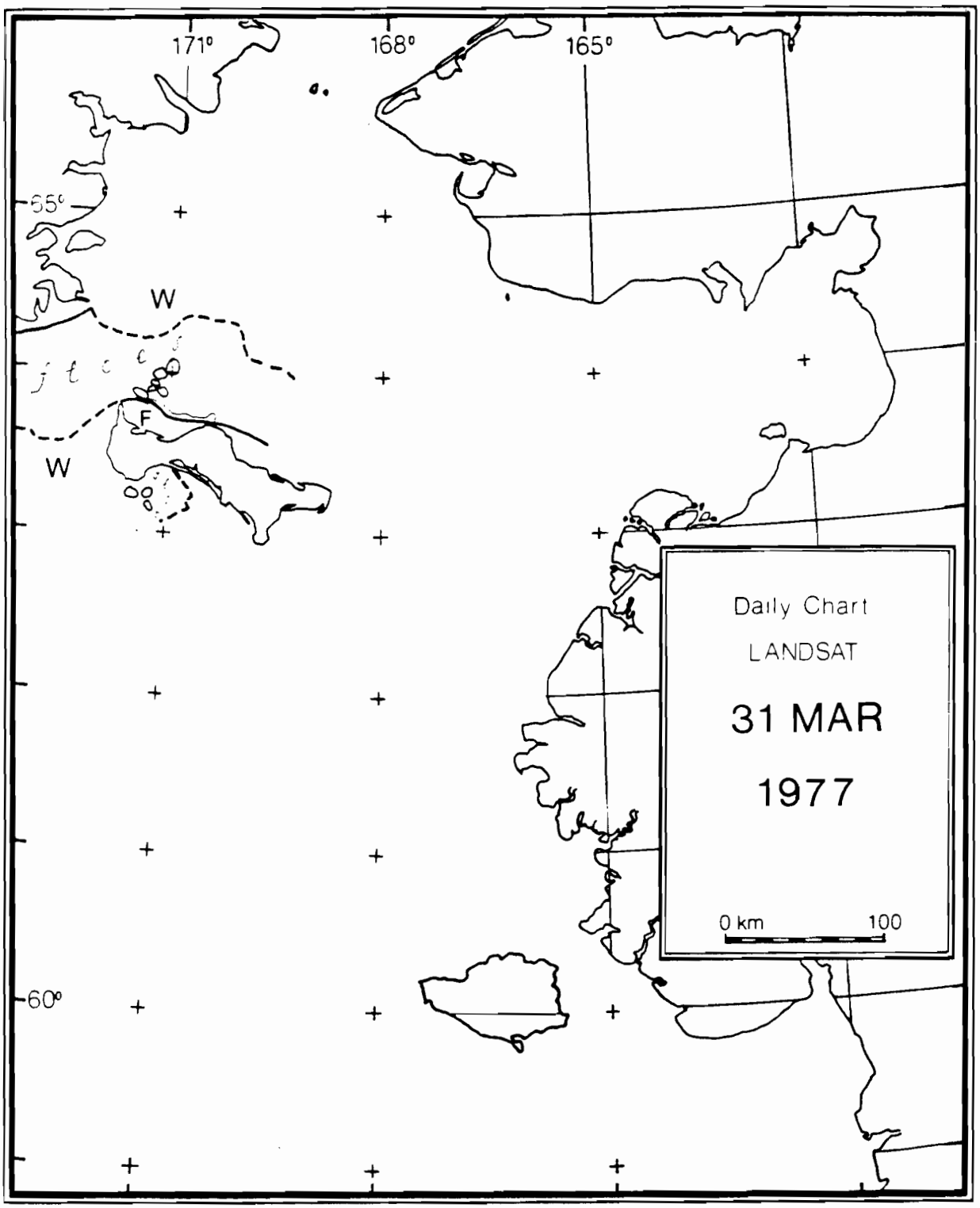

171°
168°
165°
65°
60°
W
N/O
gr
gw
gw
W
Daily Chart
LANDSAT
16 MAR
1976
0 km
100

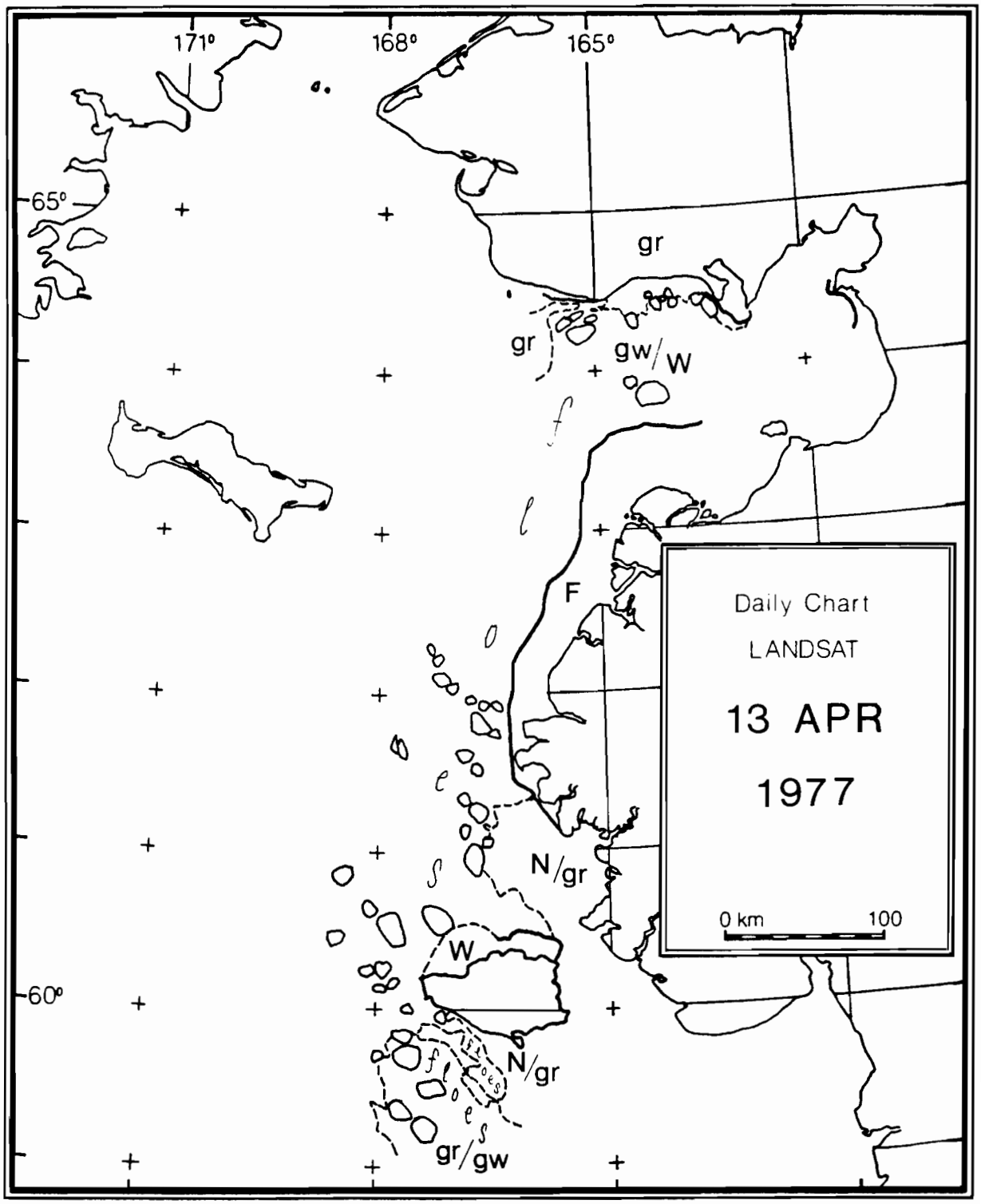

171°
168°
165°
65°
60°
N/O
F
gr
N/O
gr
gw
gr
gr
F
Daily Chart
LANDSAT
25 MAR
1977
0 km
100
N
O
gr
W
N/O
gr/gw
floes

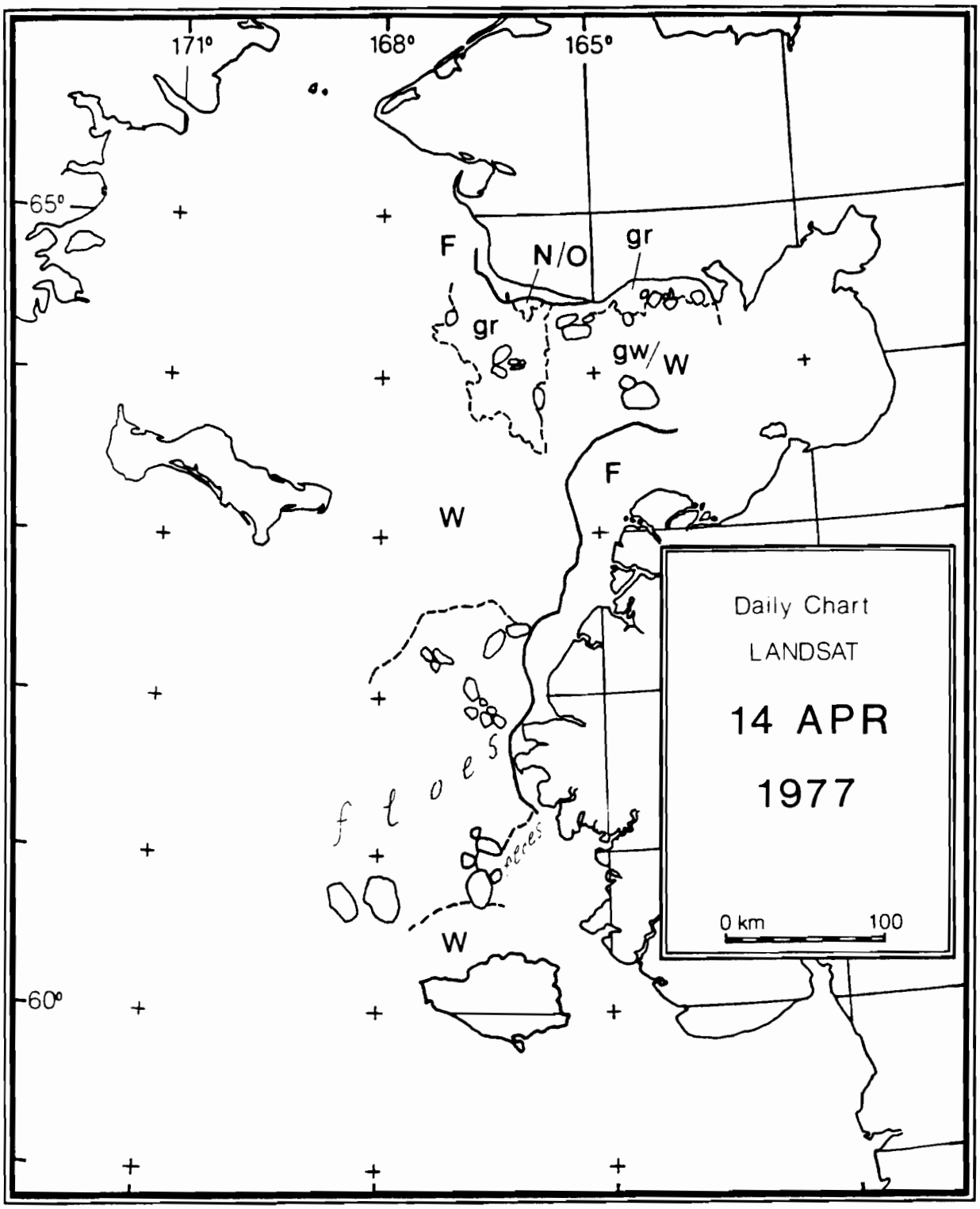

171°
168°
165°
65°
60°
N/O
F
gr
gw
gr
gw/W
F
W
N O
Daily Chart
LANDSAT
26 MAR
1977
0 km
100

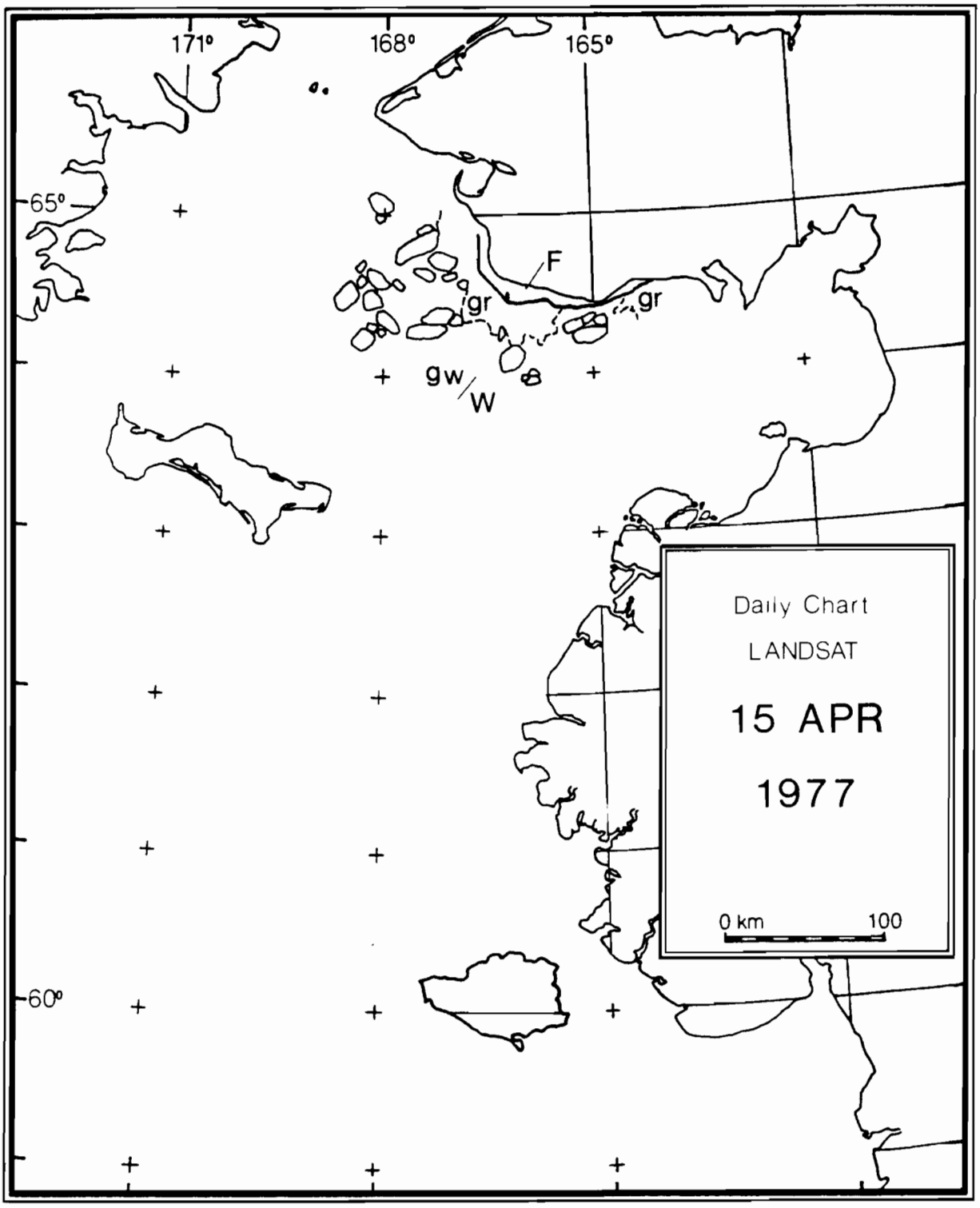

171°
168°
165°
65°
60°
F
gr
N/O
gr
gw/W
Daily Chart
LANDSAT
29 MAR
1977
0 km
100

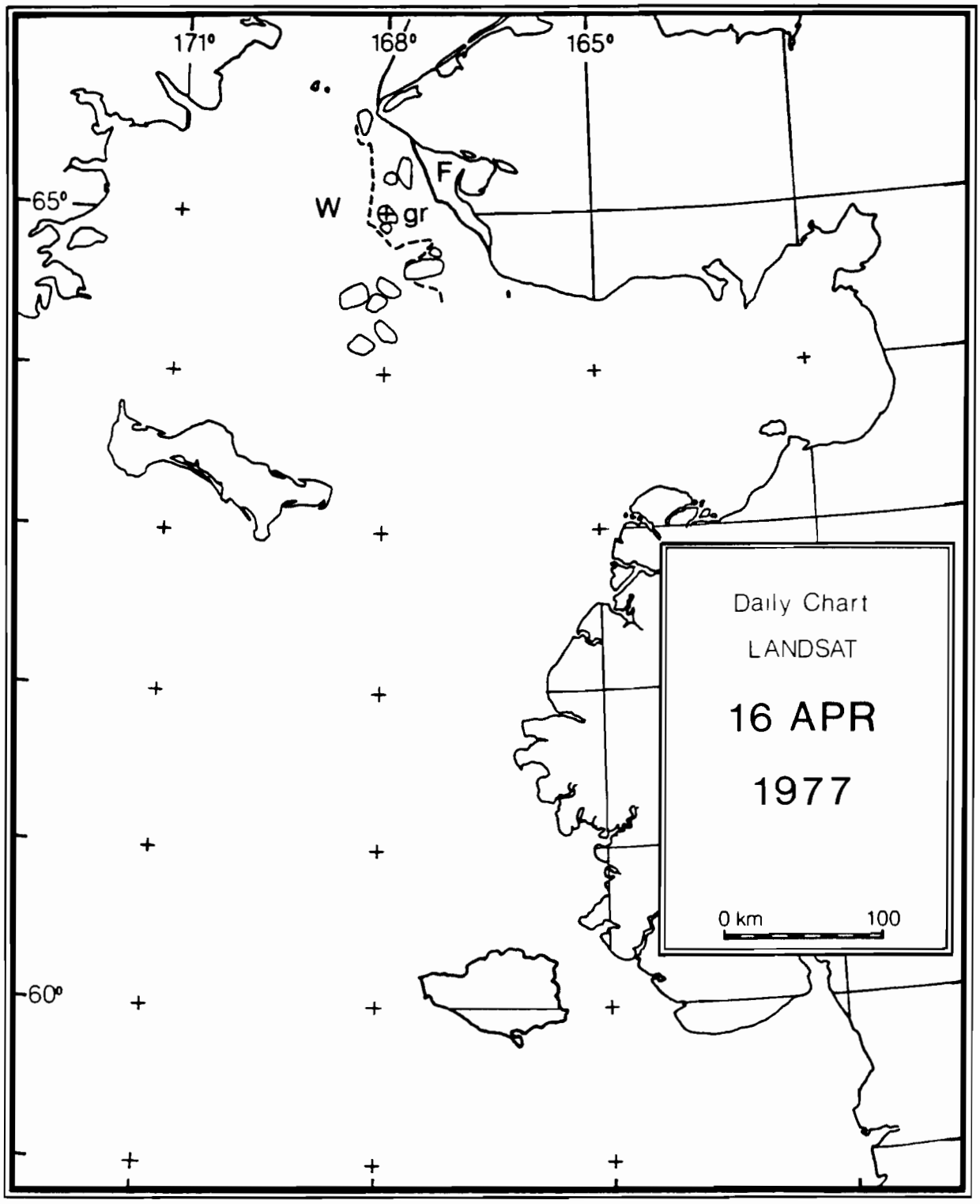

171°
168°
165°
65°
60°
W
W
gw
F
N
O
gw
Daily Chart
LANDSAT
30 MAR
1977
0 km
100

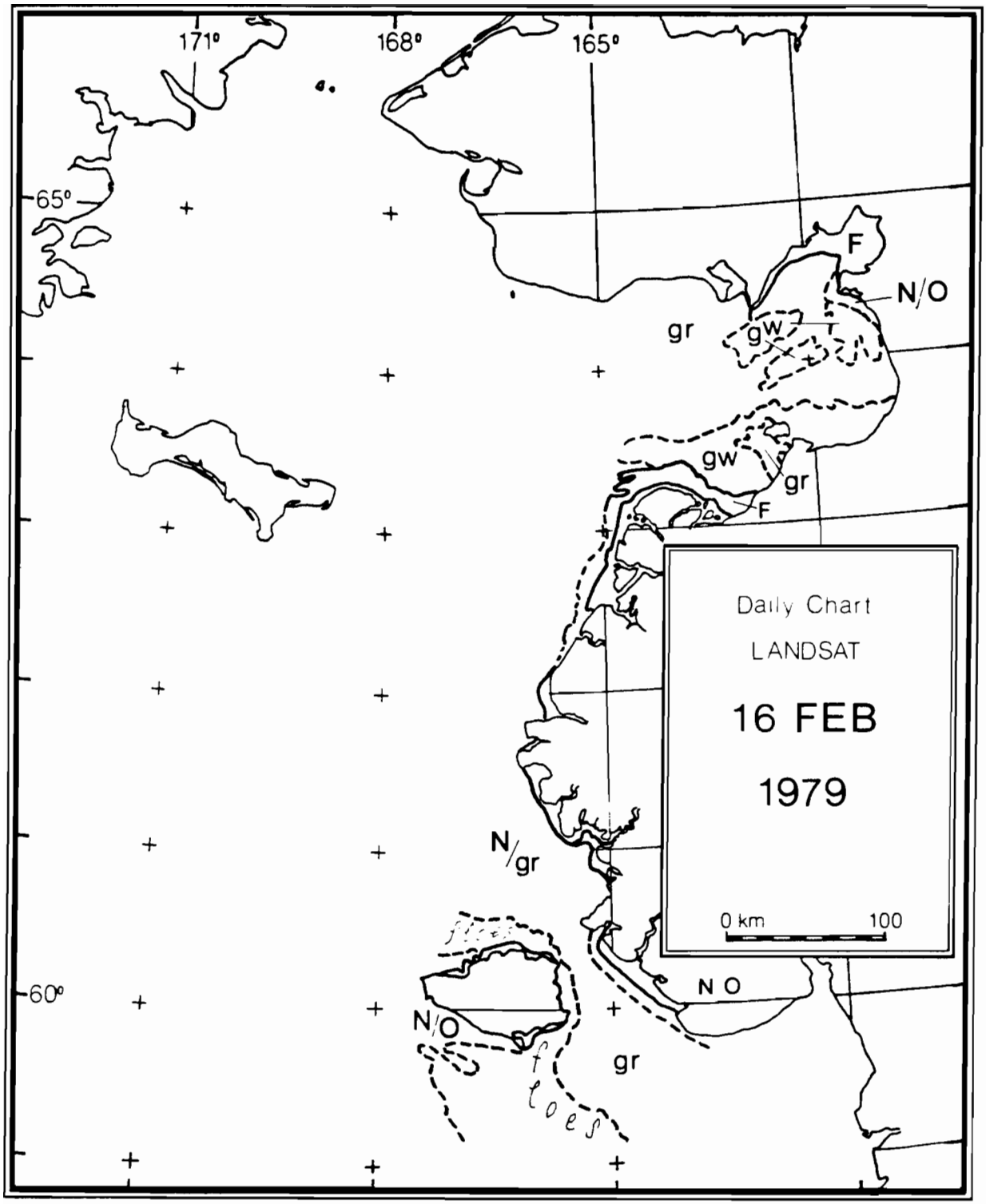

171°
168°
165°
55°
W
W
F
60°
Daily Chart
LANDSAT
31 MAR
1977
0 km
100

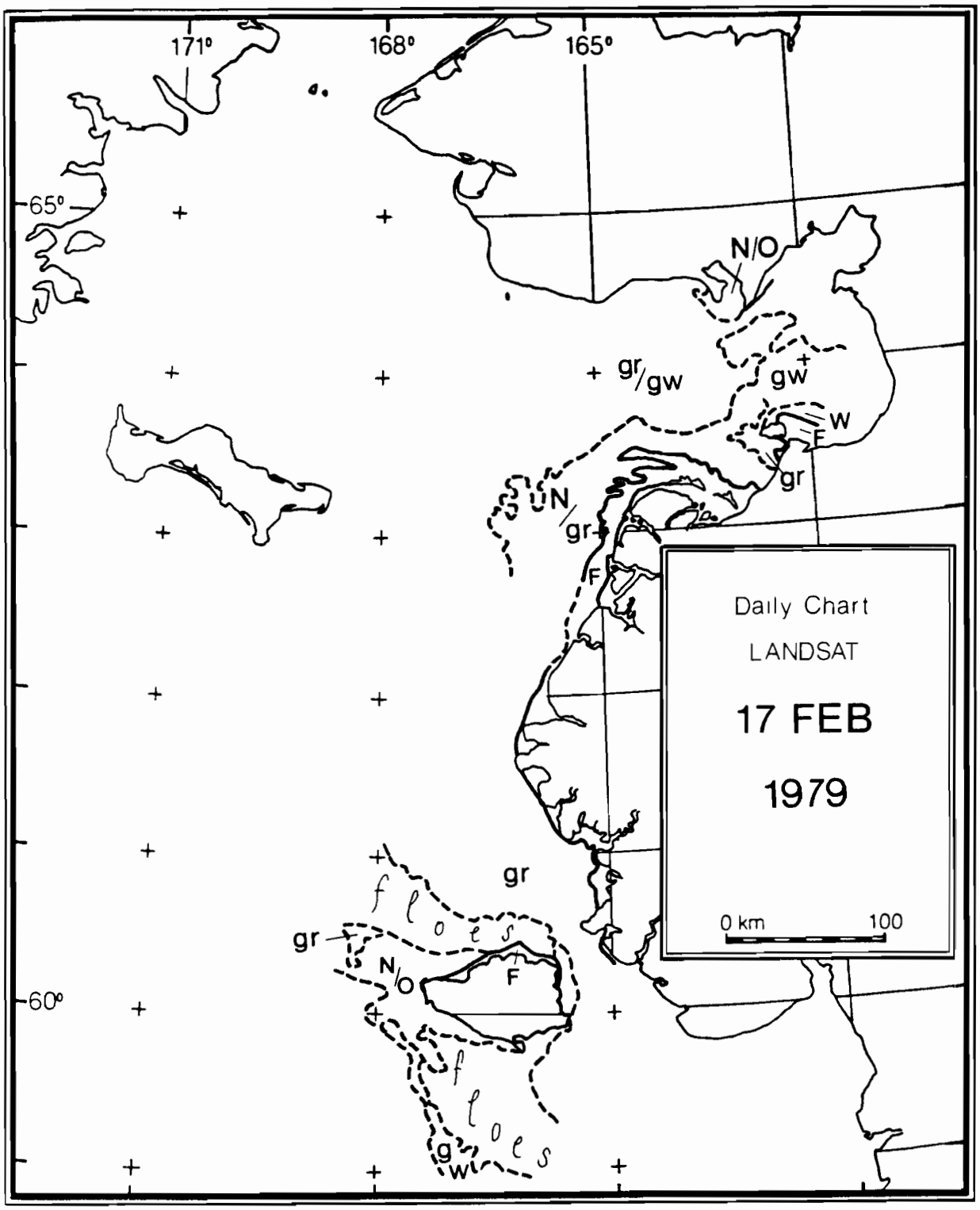

171°
168°
165°
65°
60°
gr
gr
gw/W
F
N/gr
W
N/gr
gr/gw
Daily Chart
LANDSAT
13 APR
1977
0 km
100

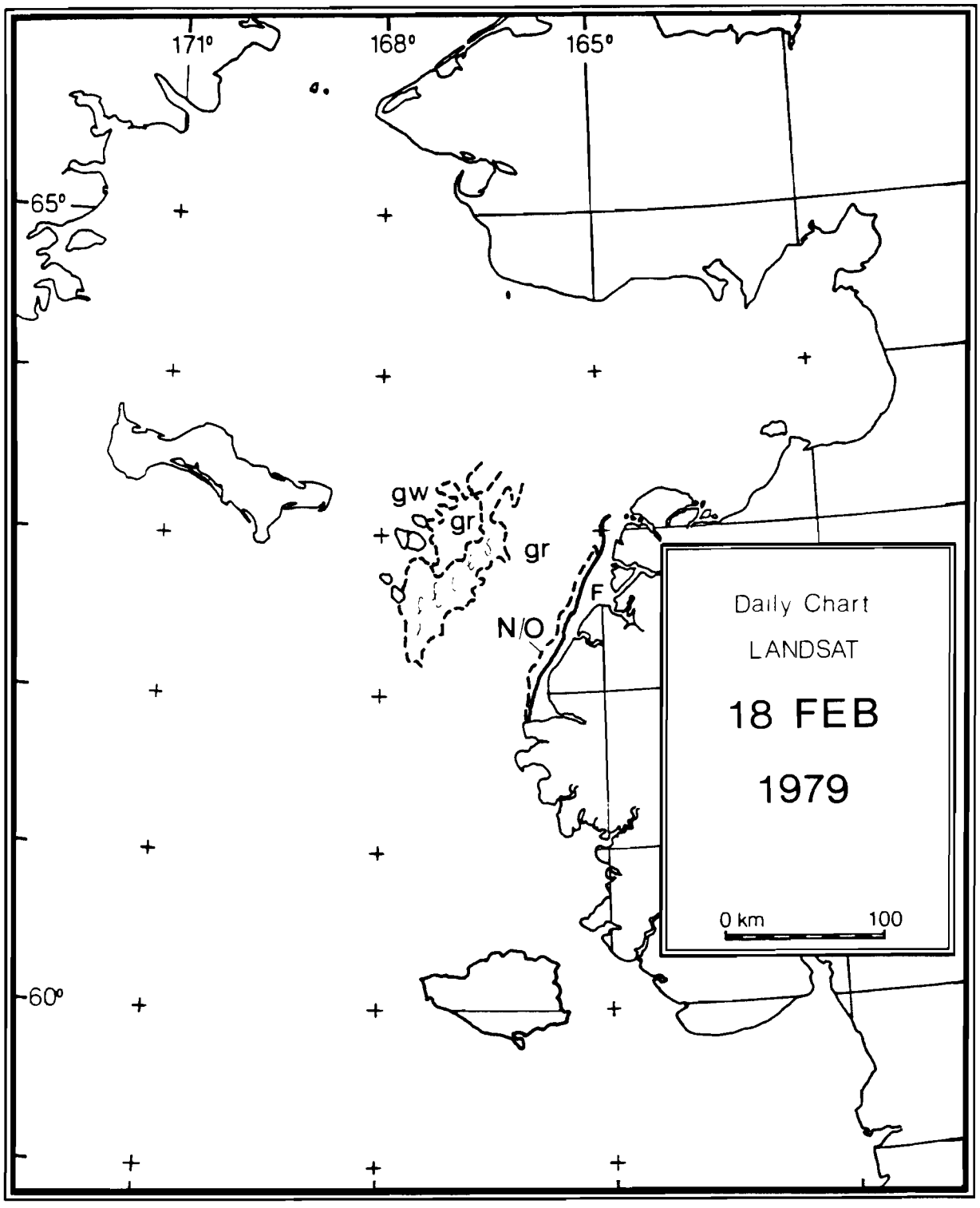

171°
168°
165°
65°
60°
F
N/O
gr
gr
gw/W
F
W
W
Daily Chart
LANDSAT
14 APR
1977
0 km
100

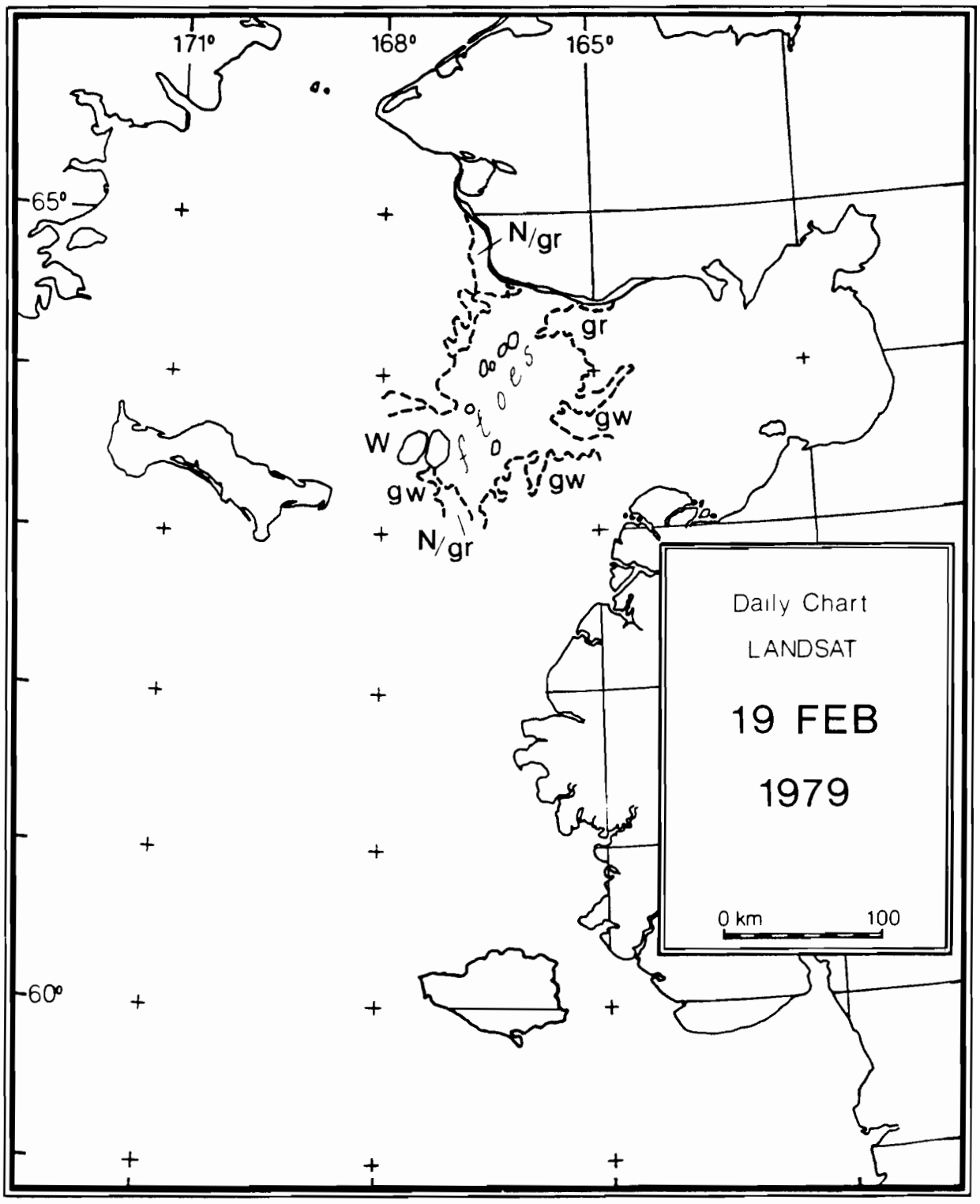

171°
168°
165°
65°
60°
F
gr
gr
gw
W
Daily Chart
LANDSAT
15 APR
1977
0 km
100

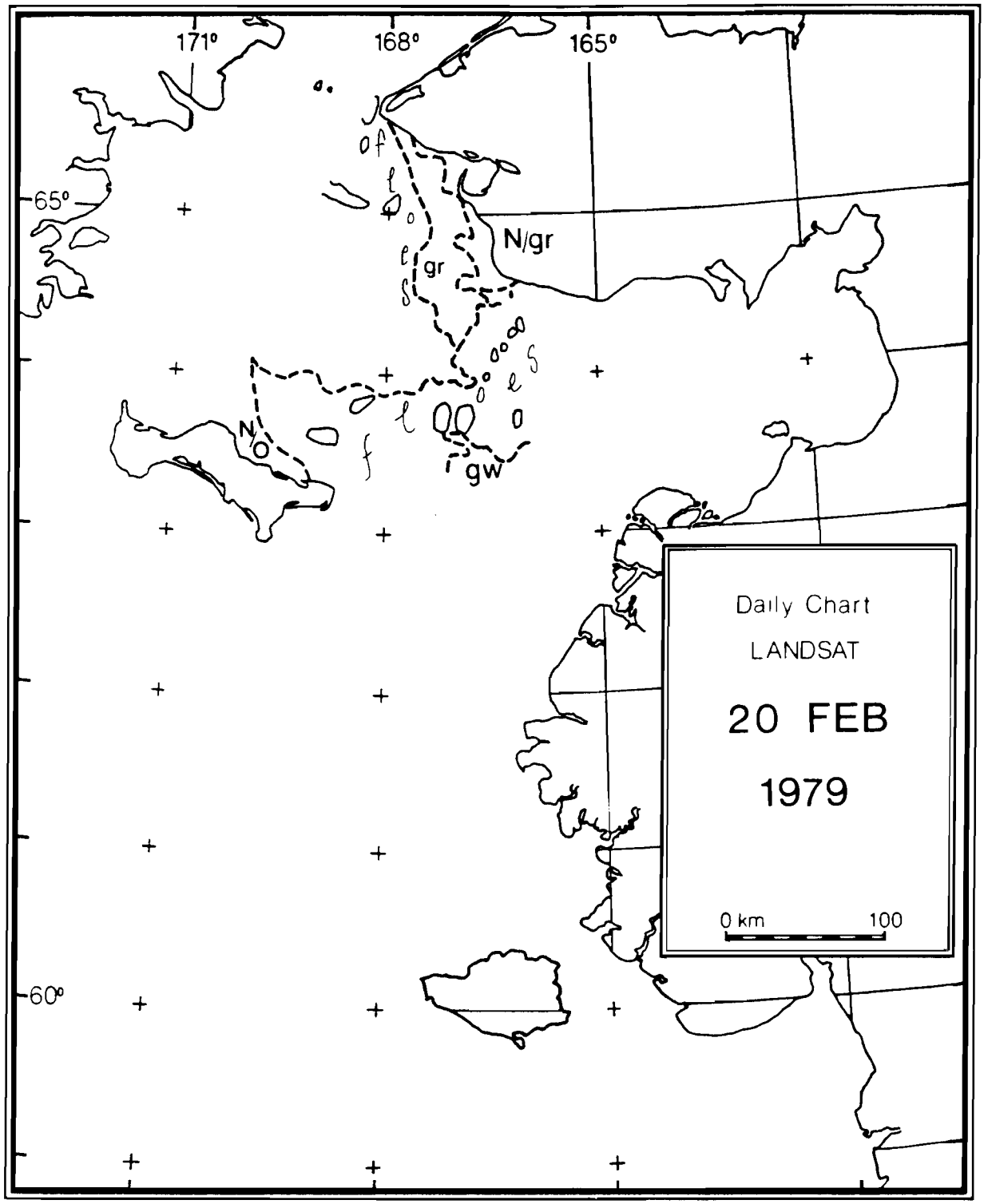

171°
168°
165°
65°
60°
W
gr
F
Daily Chart
LANDSAT
16 APR
1977
0 km
100

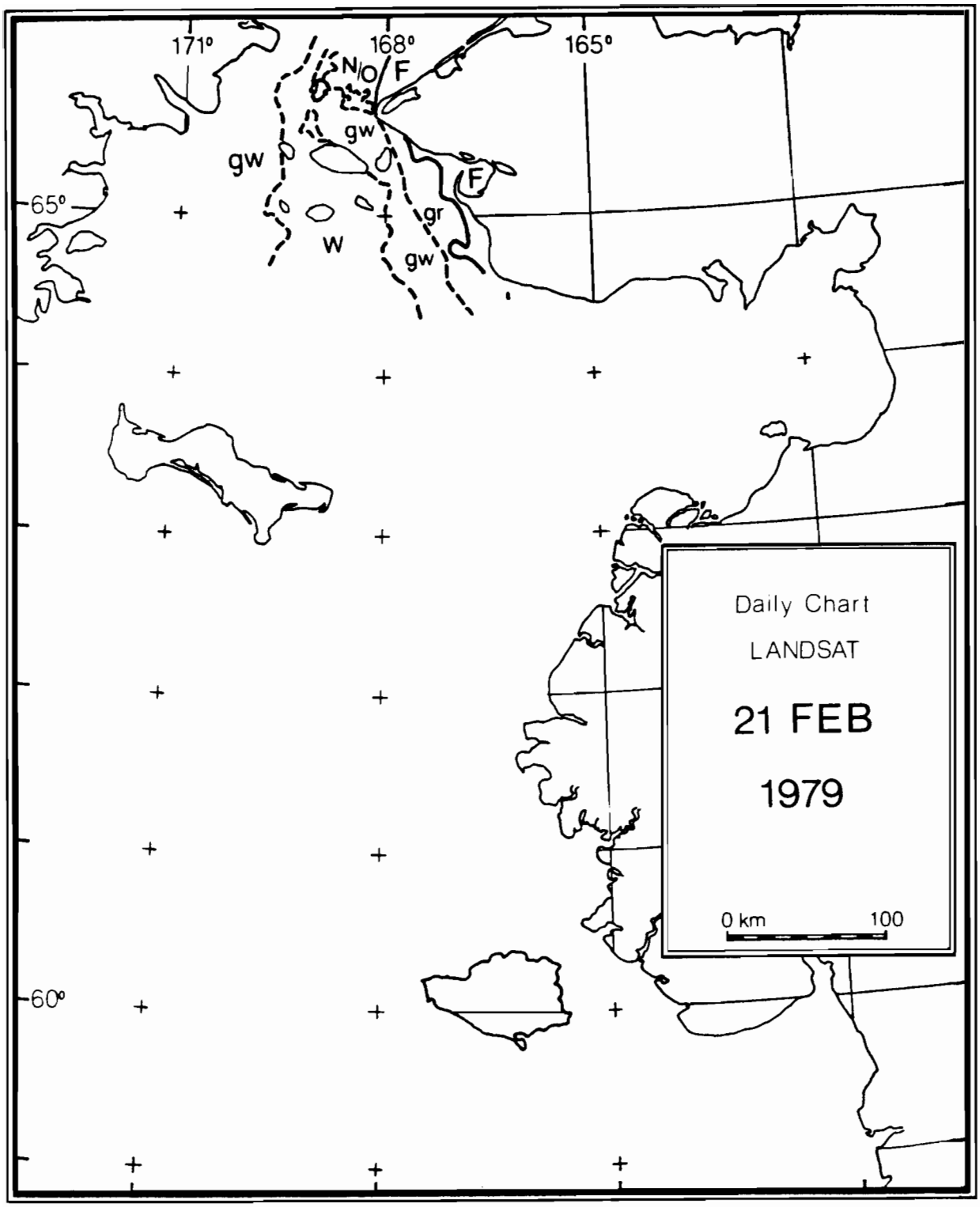

171°
168°
165°
65°
60°
F
N/O
gr
gw
gw
gr
F
Daily Chart
LANDSAT
16 FEB
1979
0 km
100
N/gr
N O
N/O
gr
floes

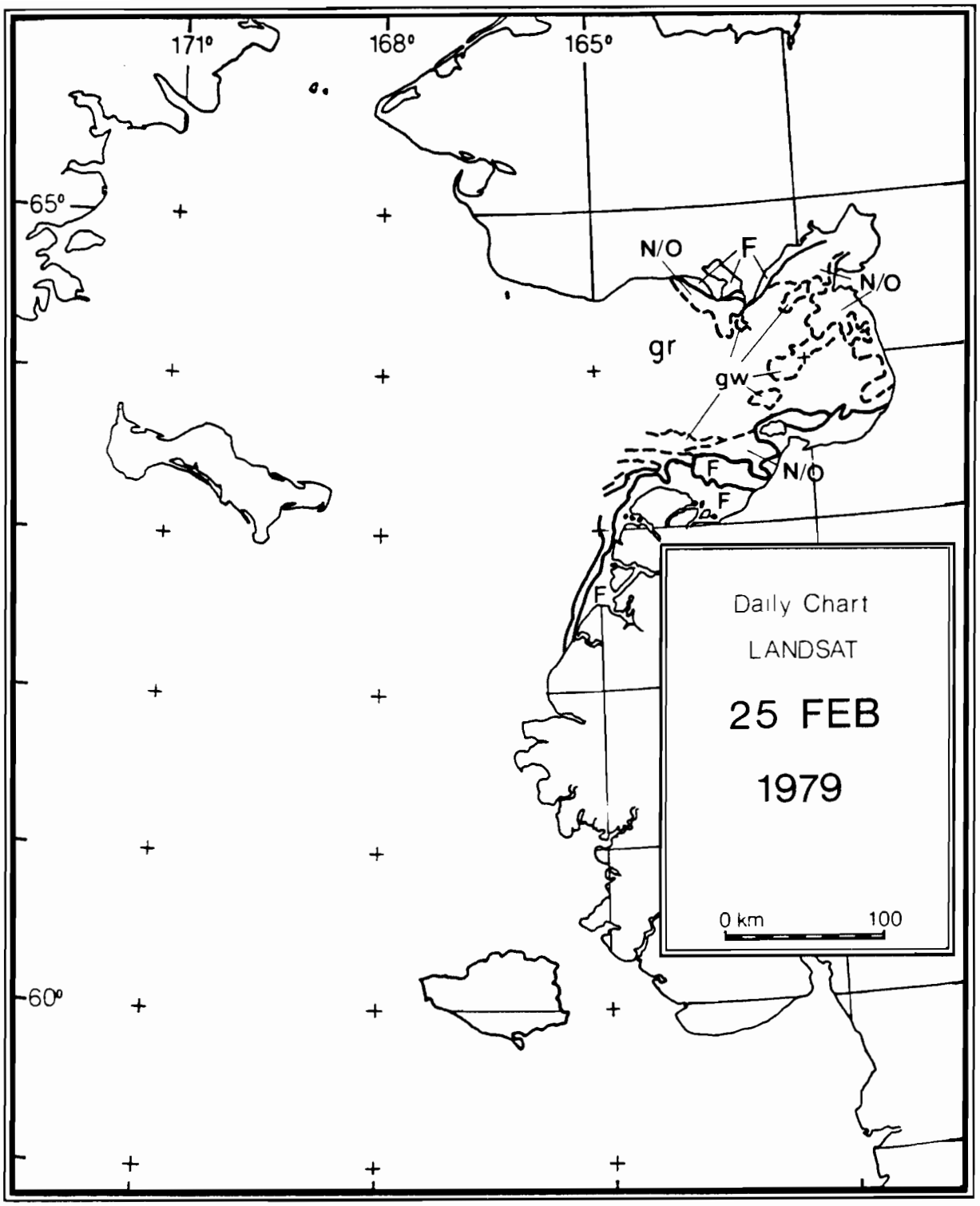

171°
168°
165°
65°
60°
N/O
gr/gw
gw
w
F
gr
N/
gr
F
Daily Chart
LANDSAT
17 FEB
1979
0 km
100
gr
floes
gr
N/O
F
floes
gw

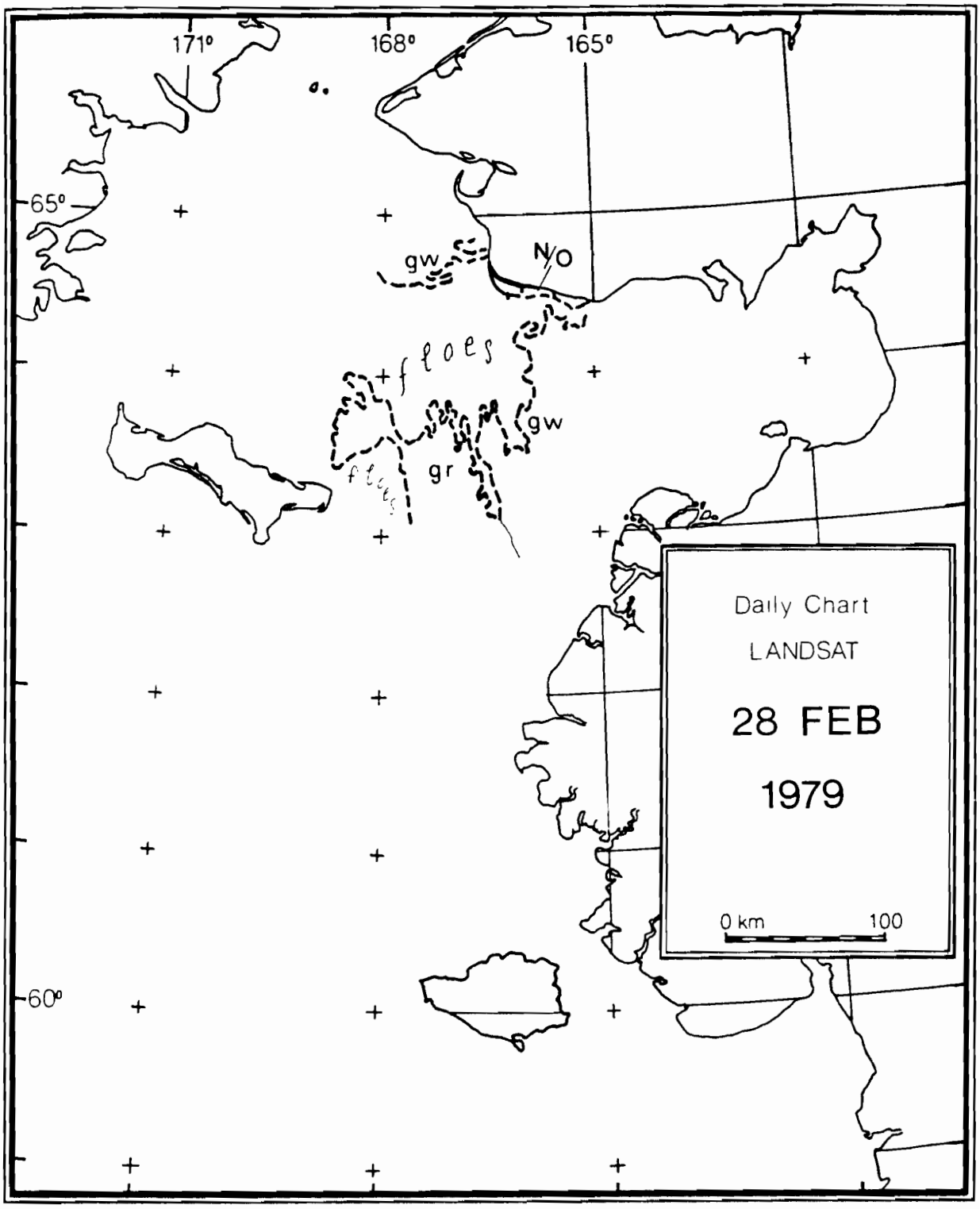

171°
168°
165°
65°
60°
gw
gr
gr
F
N/O
Daily Chart
LANDSAT
18 FEB
1979
0 km
100


171°
168°
165°
65°
60°
N/gr
gr
gw
W
gw
gw
N/gr
floes
Daily Chart
LANDSAT
19 FEB
1979
0 km
100


171°
168°
165°
65°
60°
N/gr
gr
gw
Daily Chart
LANDSAT
20 FEB
1979
0 km
100


171°
168°
165°
65°
60°
N/O
F
gw
gw
F
gr
W
gw
Daily Chart
LANDSAT
21 FEB
1979
0 km
100


171°
168°
165°
65°
60°
N/O
F
N/O
gr
gw
F
N/O
F
F
Daily Chart
LANDSAT
25 FEB
1979
0 km
100


171°
168°
165°
65°
gw
N/O
floes
gw
floes
gr
Daily Chart
LANDSAT
28 FEB
1979
0 km
100
60°

Appendix IV

Polynya Location Maps

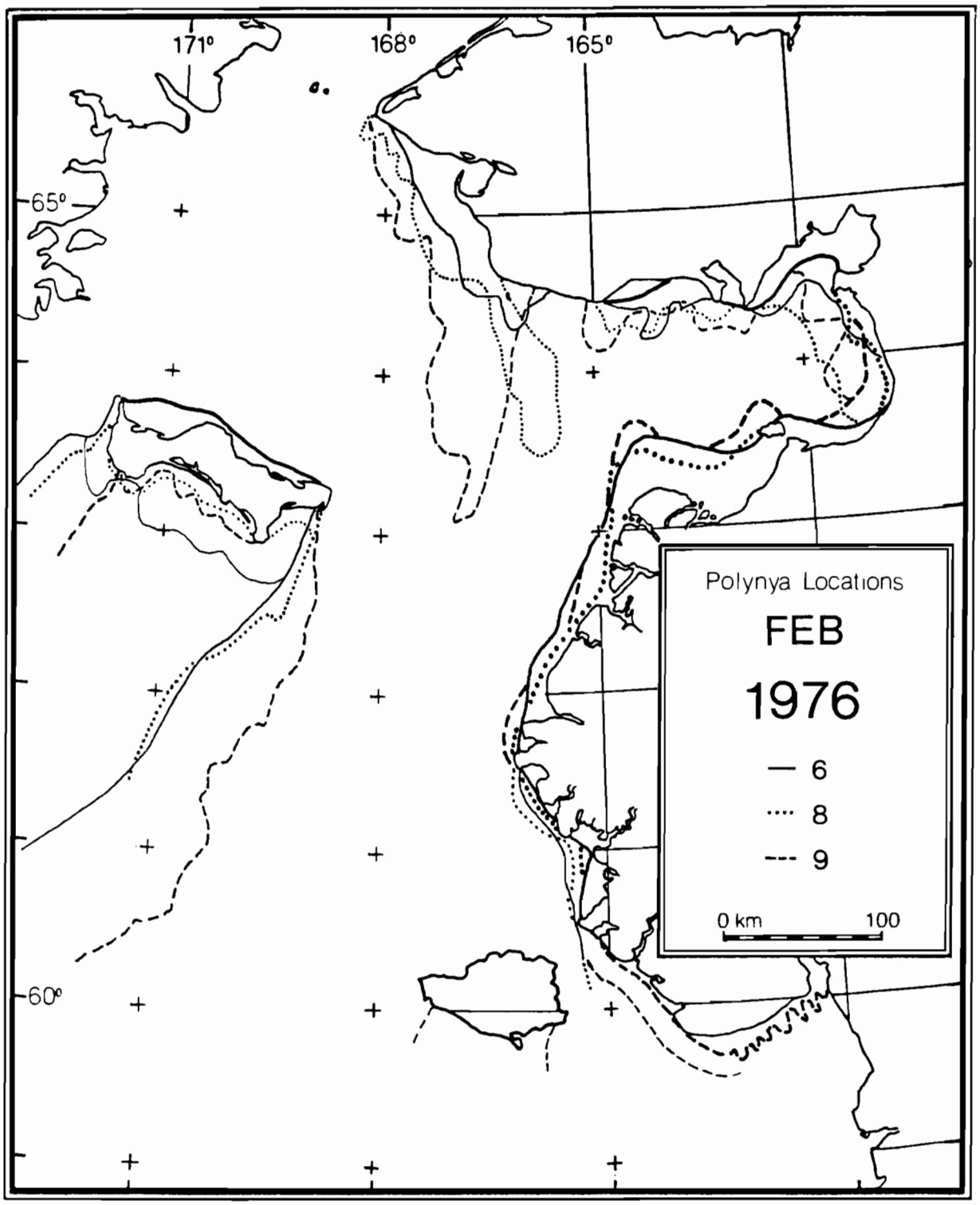
The area of grey/grey-white ice on the NOAA daily charts is used to create polynya location maps. Areas of new ice/open water are included when present. Each map shows the changes over a three day period and each day is represented by a different line symbol for all ice types. The following legend explains the use of line symbols to show these areas and to show land-fast ice.

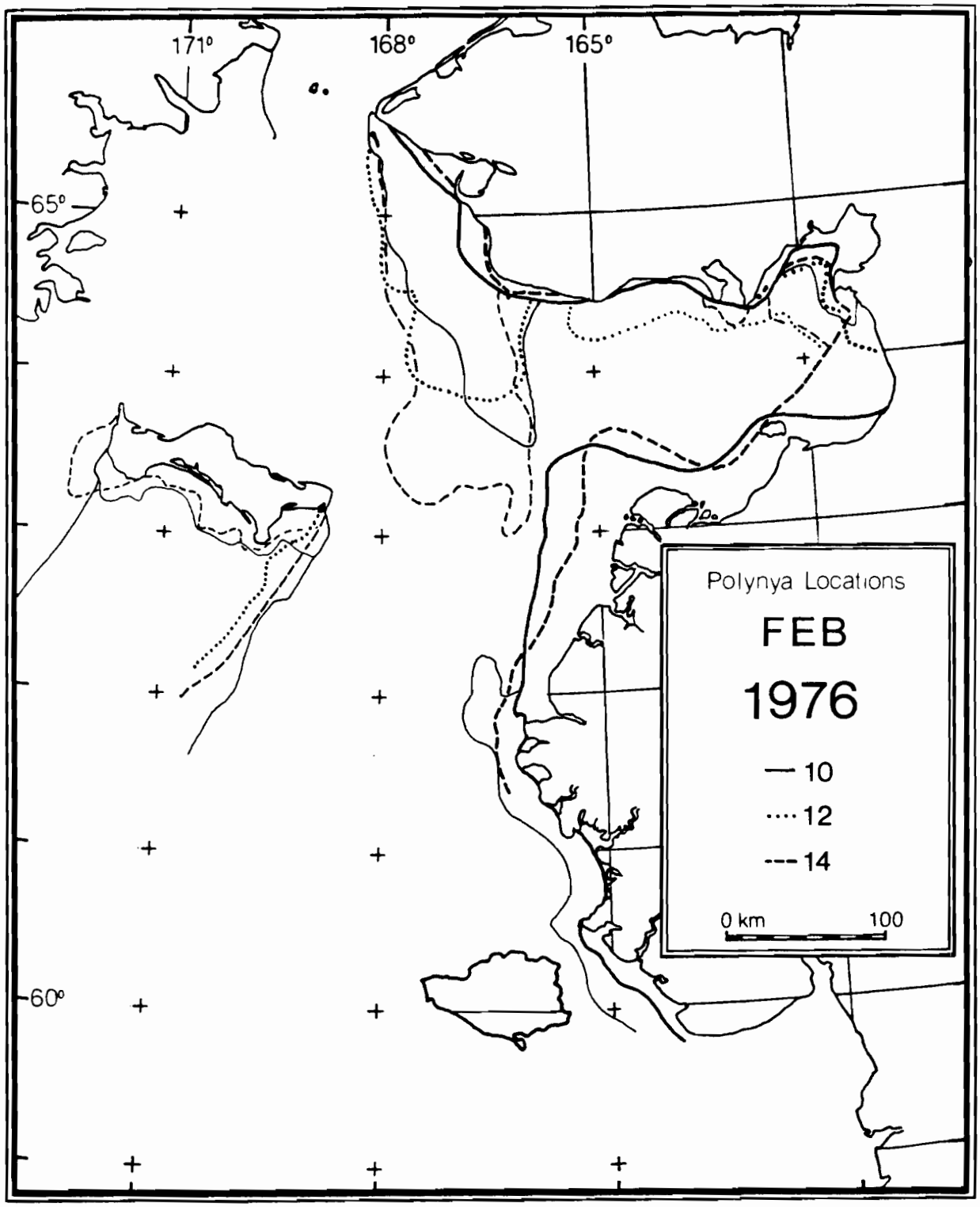
LEGEND

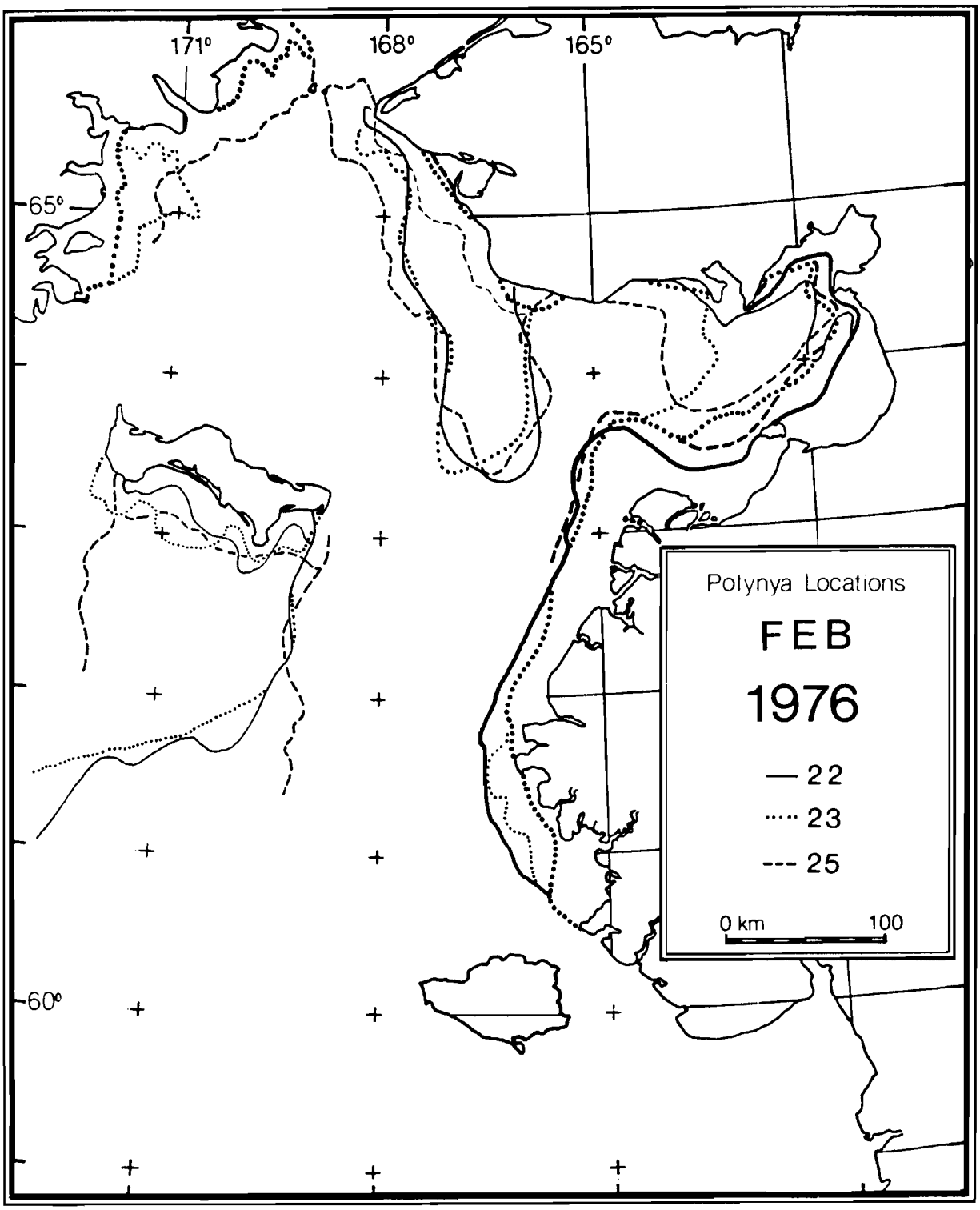
----- new ice/open water

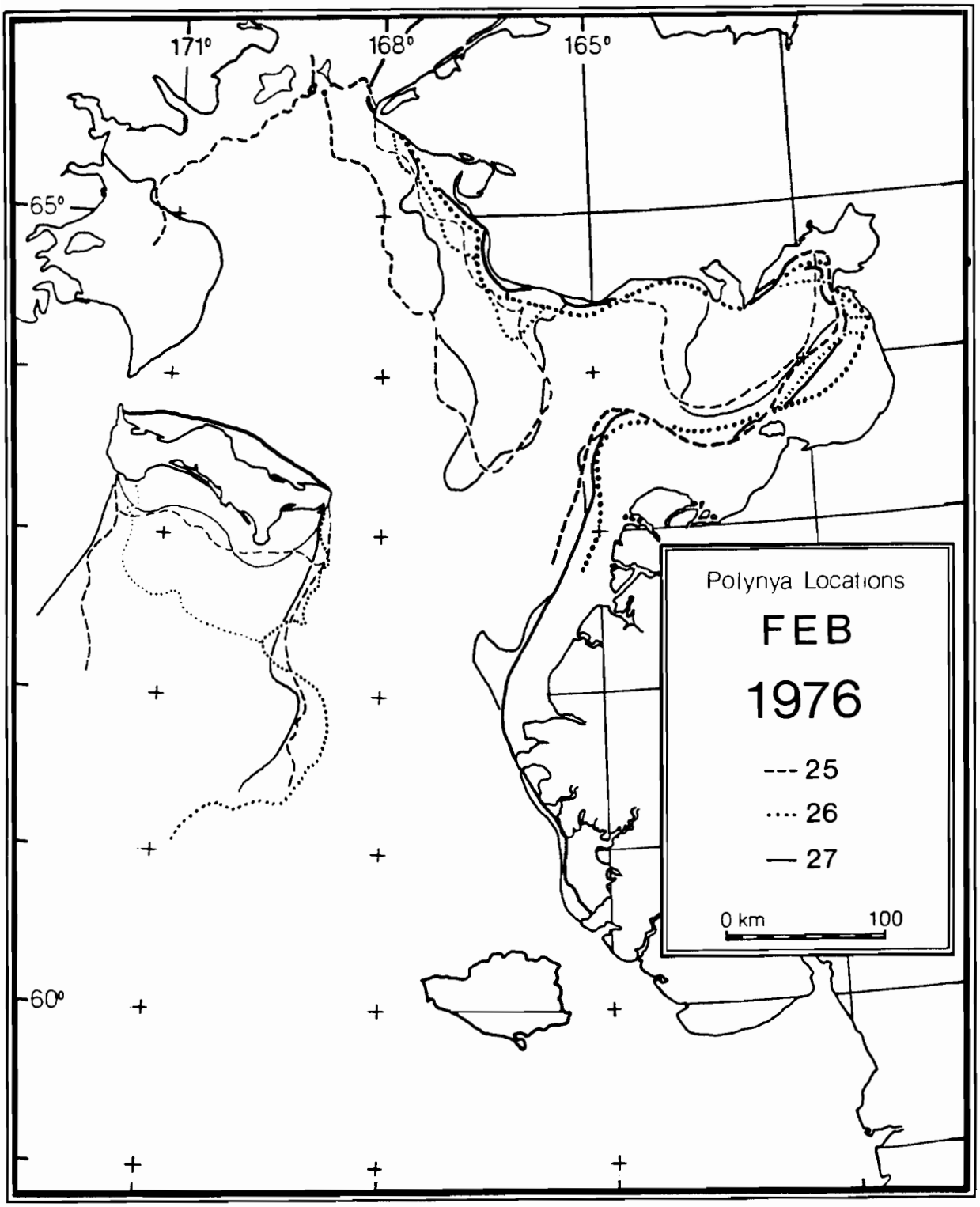
--- grey/grey-white ice

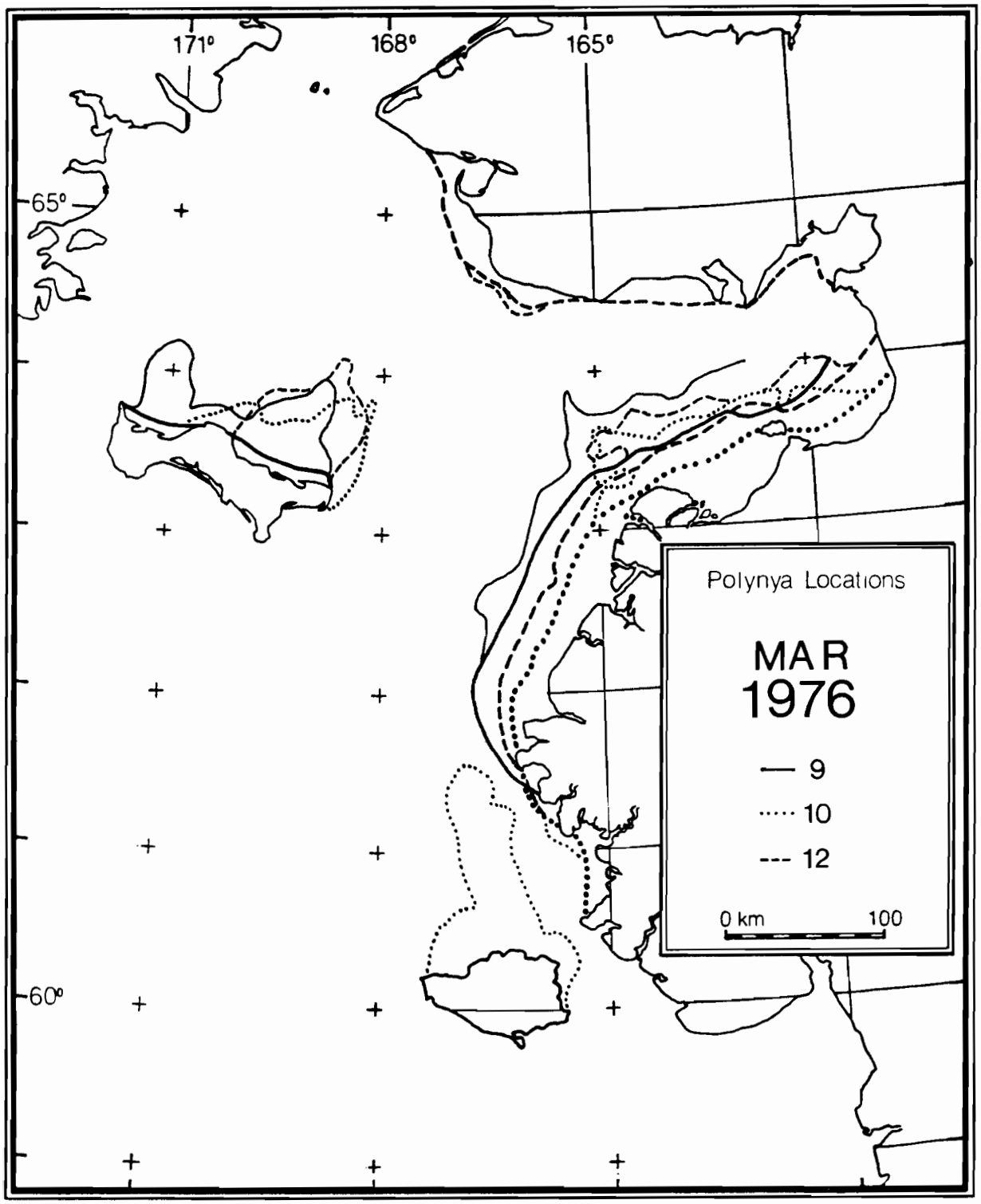
——— land-fast ice

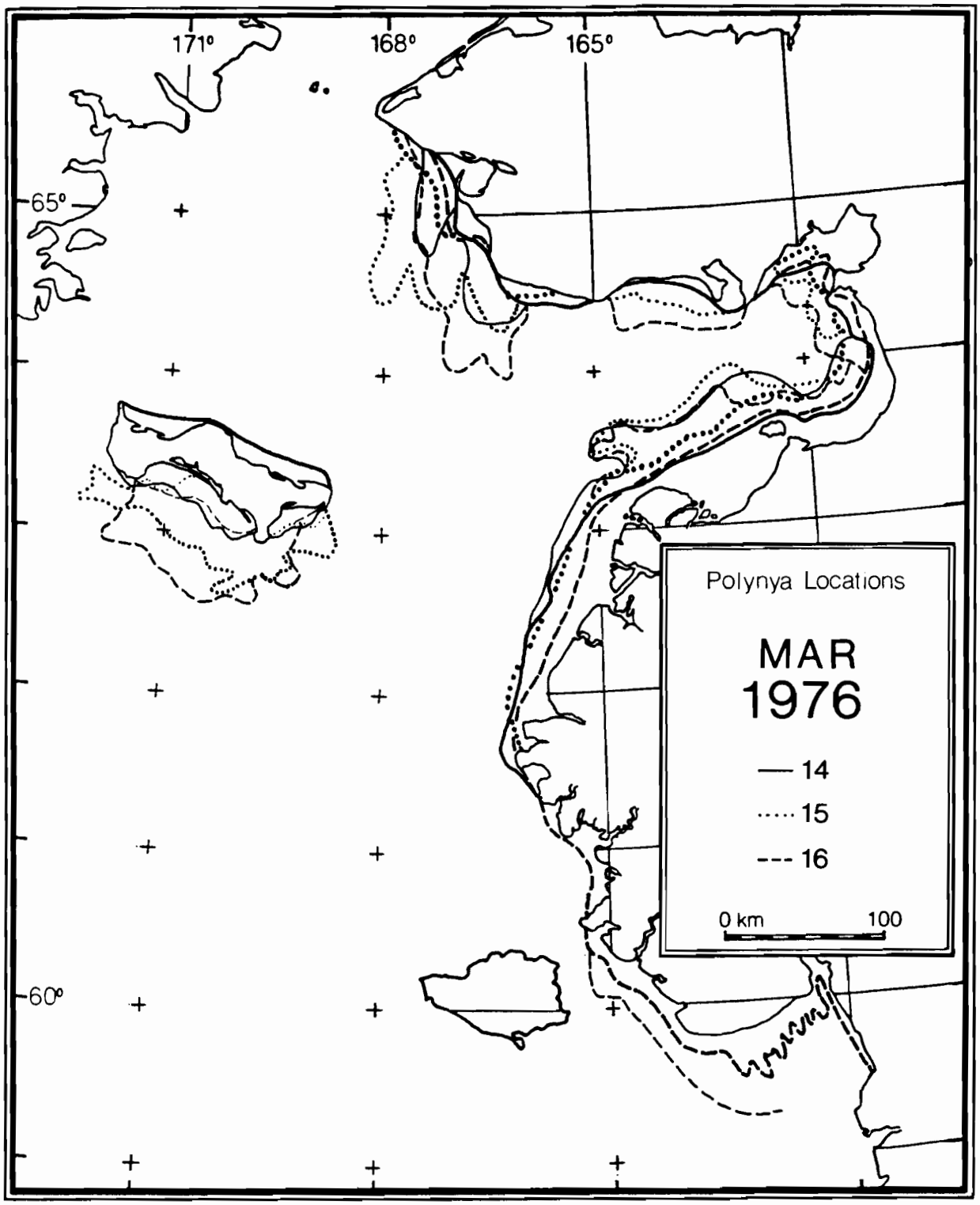

171°
168°
165°
65°
60°
Polynya Locations
FEB
1976
— 6
···· 8
--- 9
0 km
100

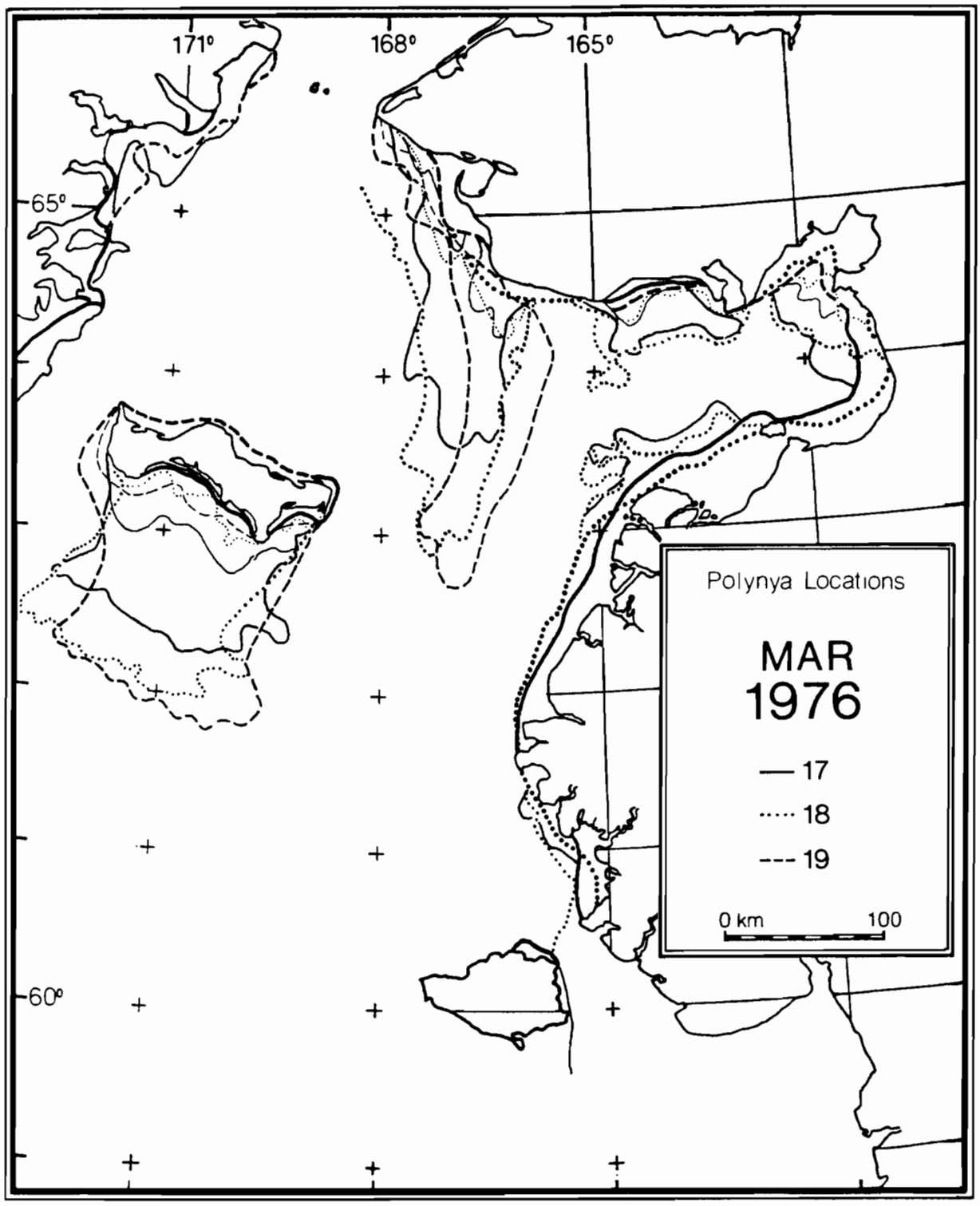

171°
168°
165°
65°
60°
Polynya Locations
FEB
1976
— 10
···· 12
--- 14
0 km
100

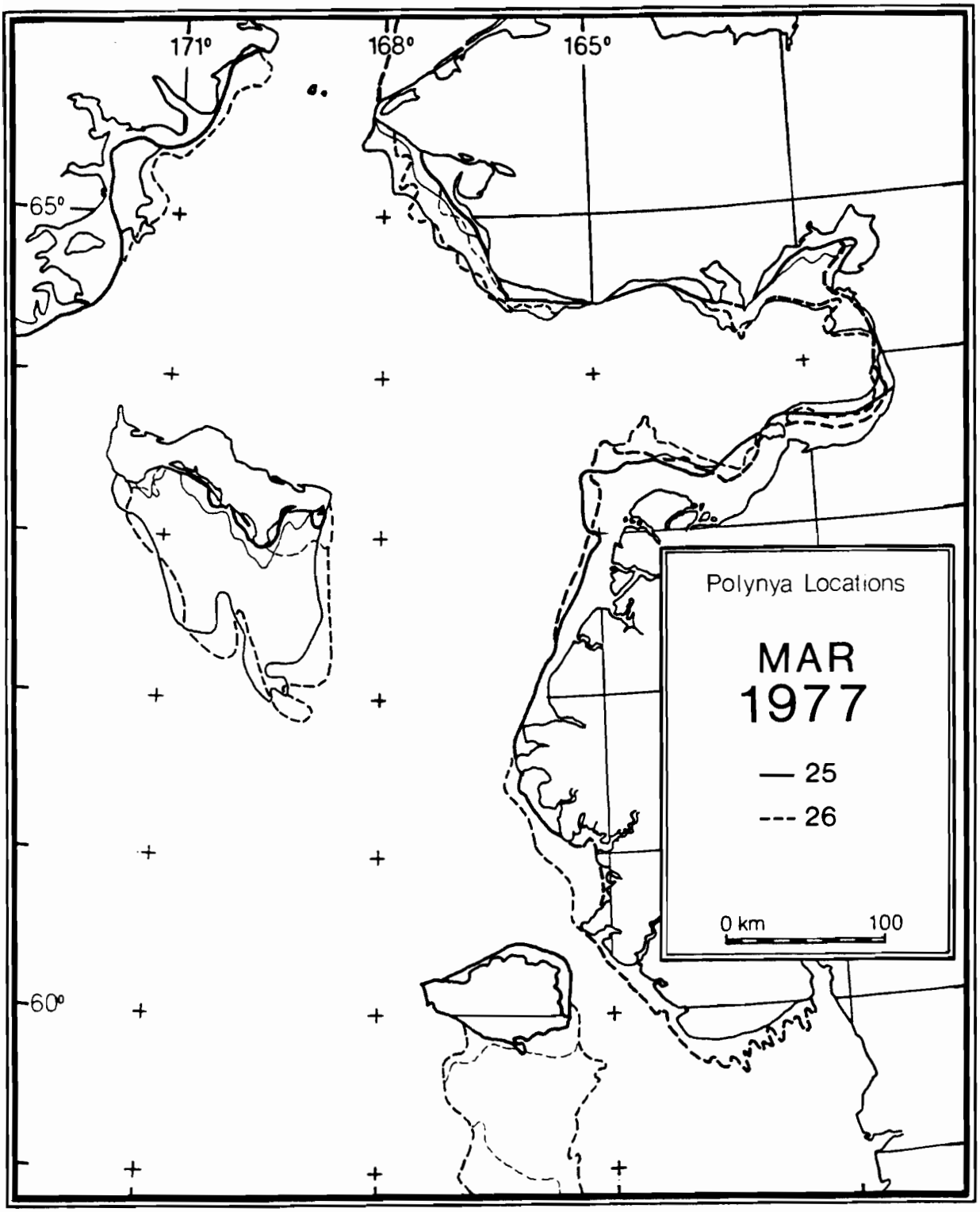

171°
168°
165°
65°
60°
Polynya Locations
FEB
1976
22
23
25
0 km
100

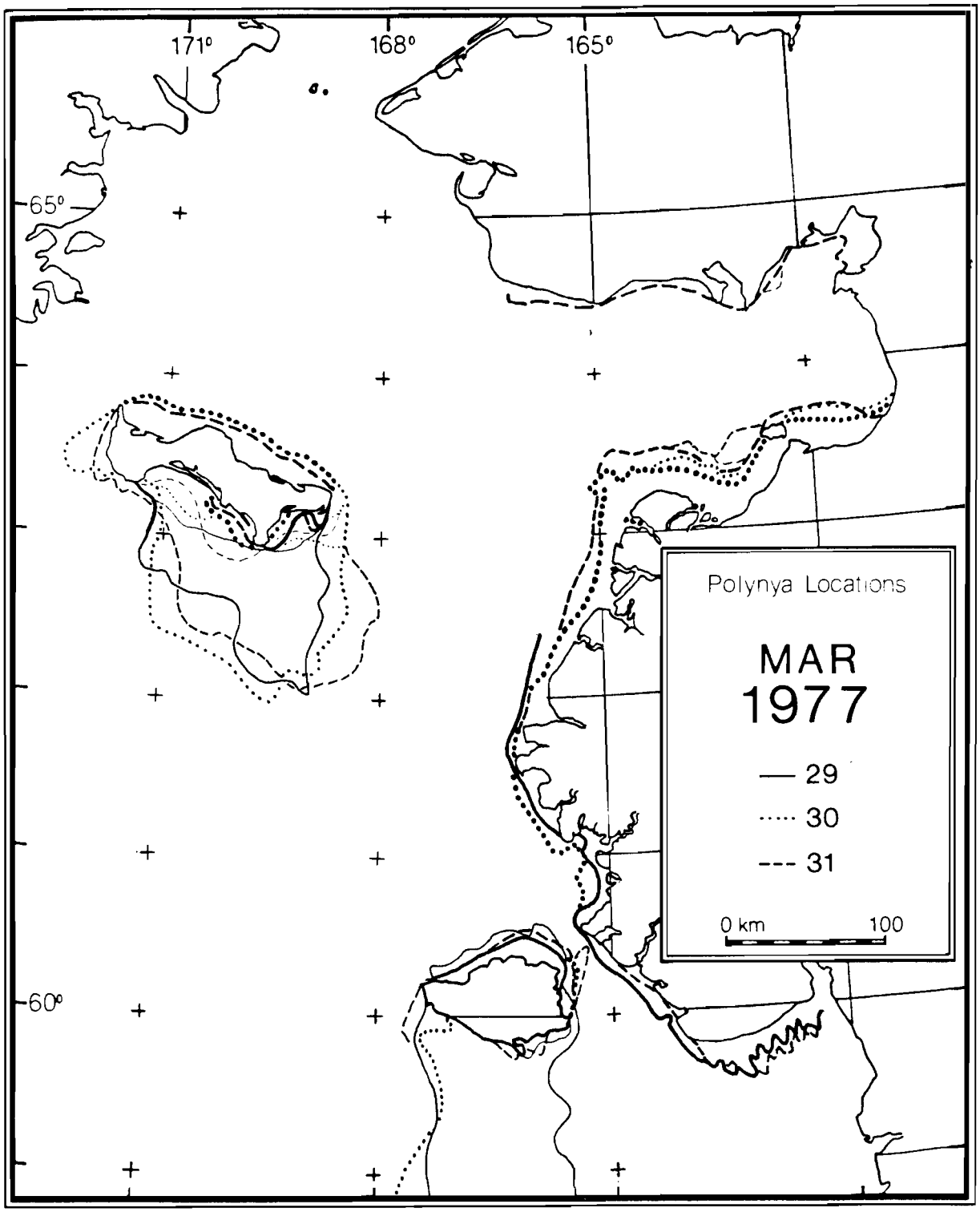

171°
168°
165°
65°
60°
Polynya Locations
FEB
1976
--- 25
···· 26
— 27
0 km
100

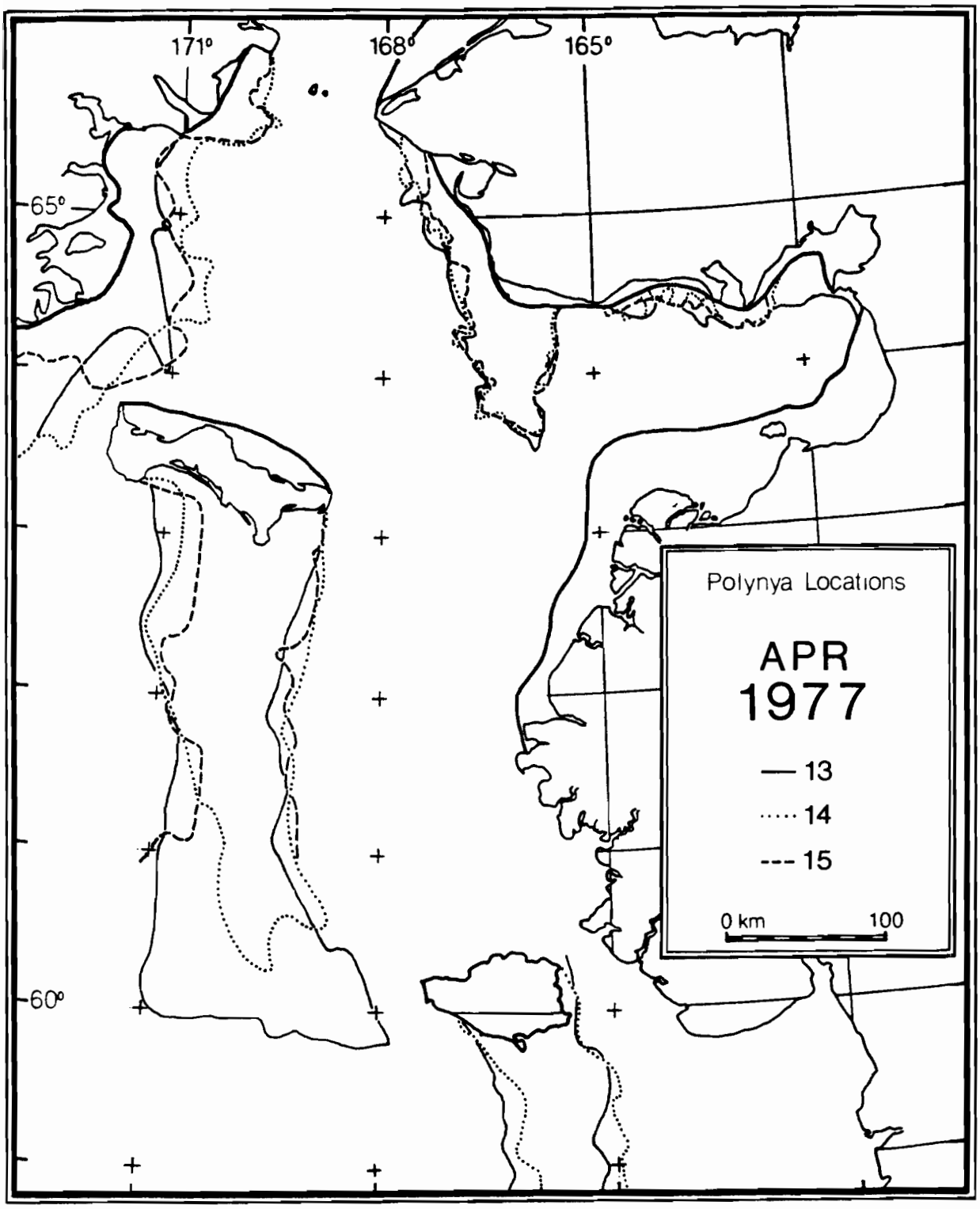

171°
168°
165°
65°
60°
Polynya Locations
MAR
1976
9
10
12
0 km
100

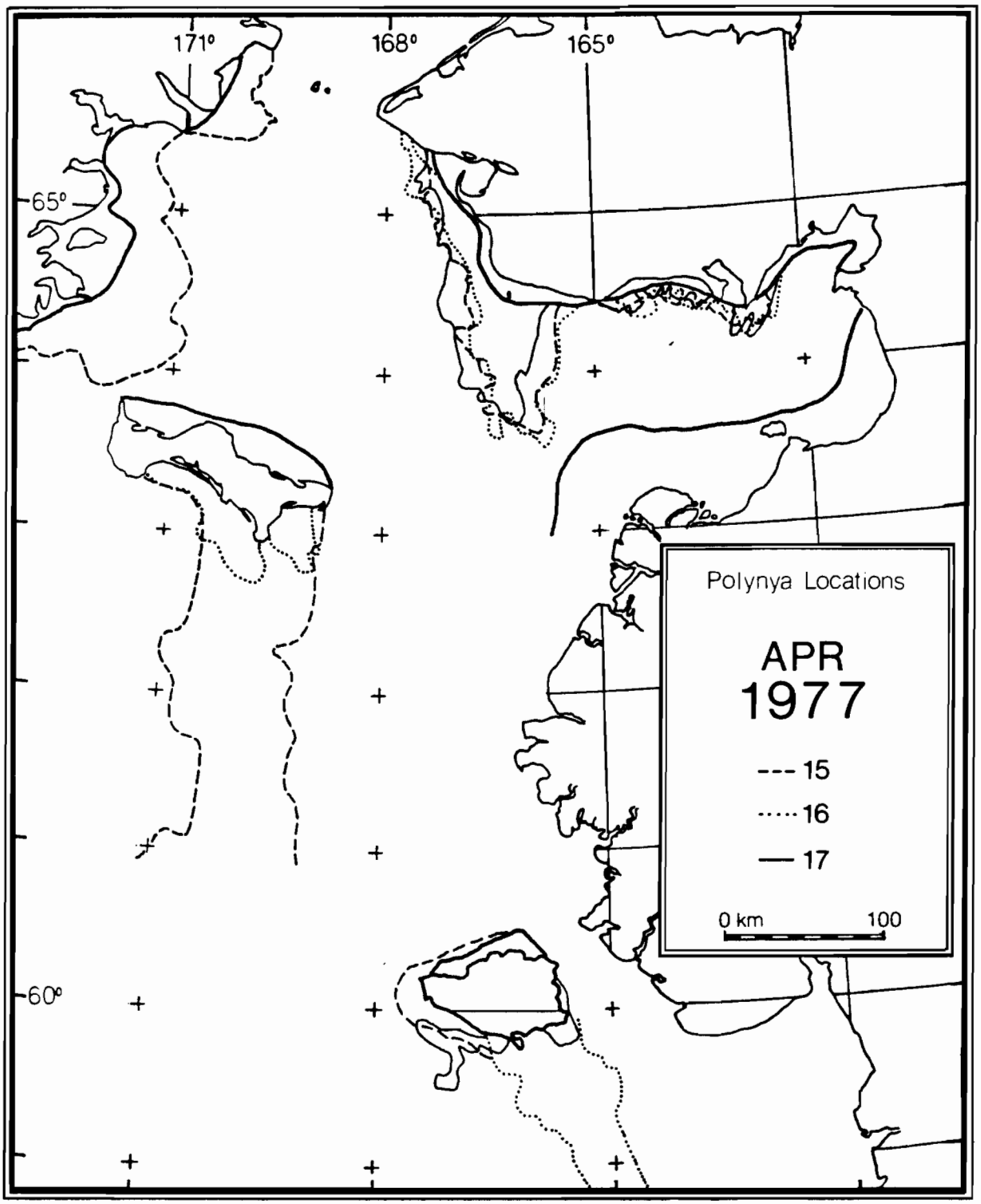

171°
168°
165°
65°
60°
Polynya Locations
MAR
1976
14
15
16
0 km
100

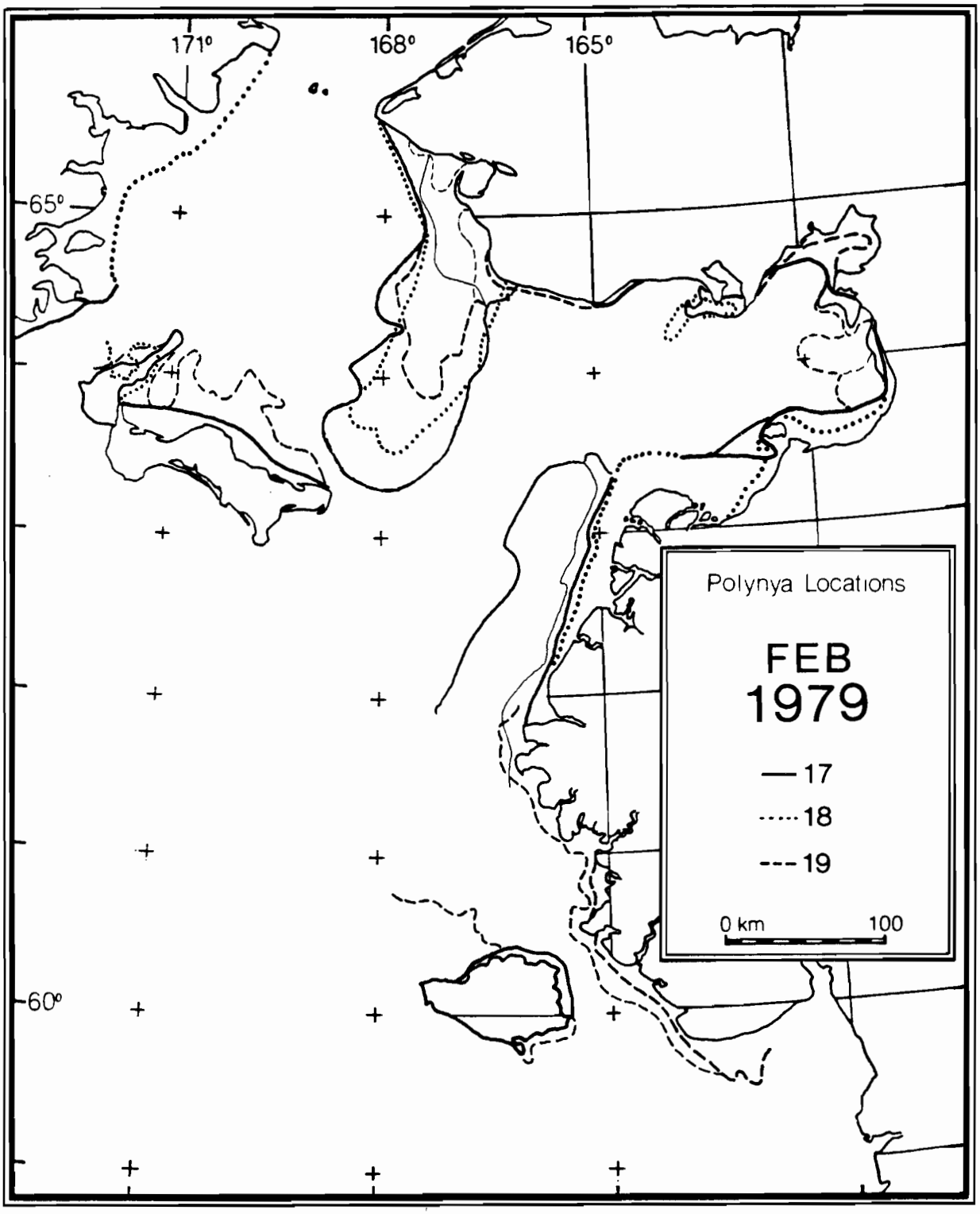

171°
168°
165°
65°
60°
Polynya Locations
MAR
1976
17
18
19
0 km
100

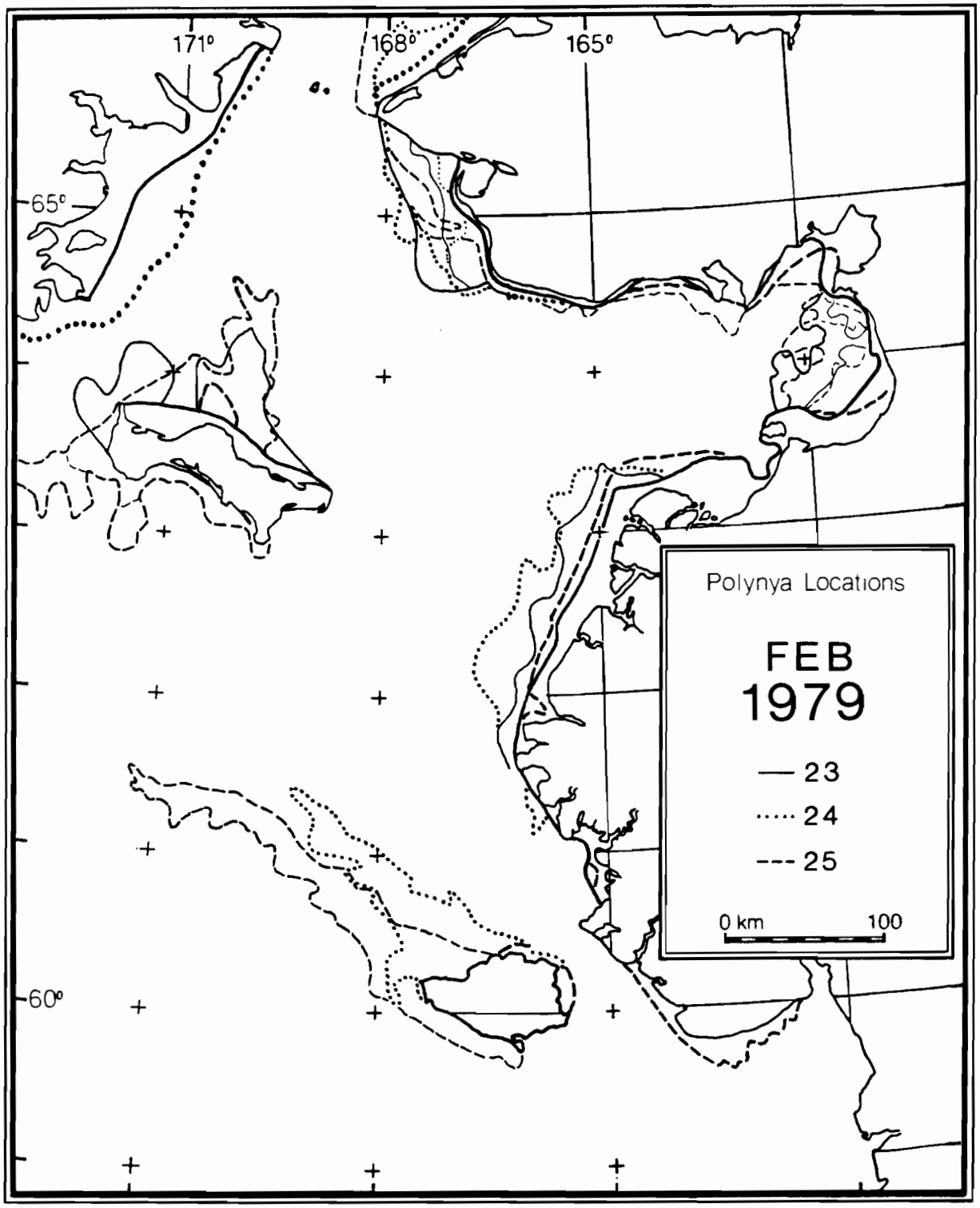

171°
168°
165°
65°
60°
Polynya Locations
MAR
1977
— 25
--- 26
0 km
100

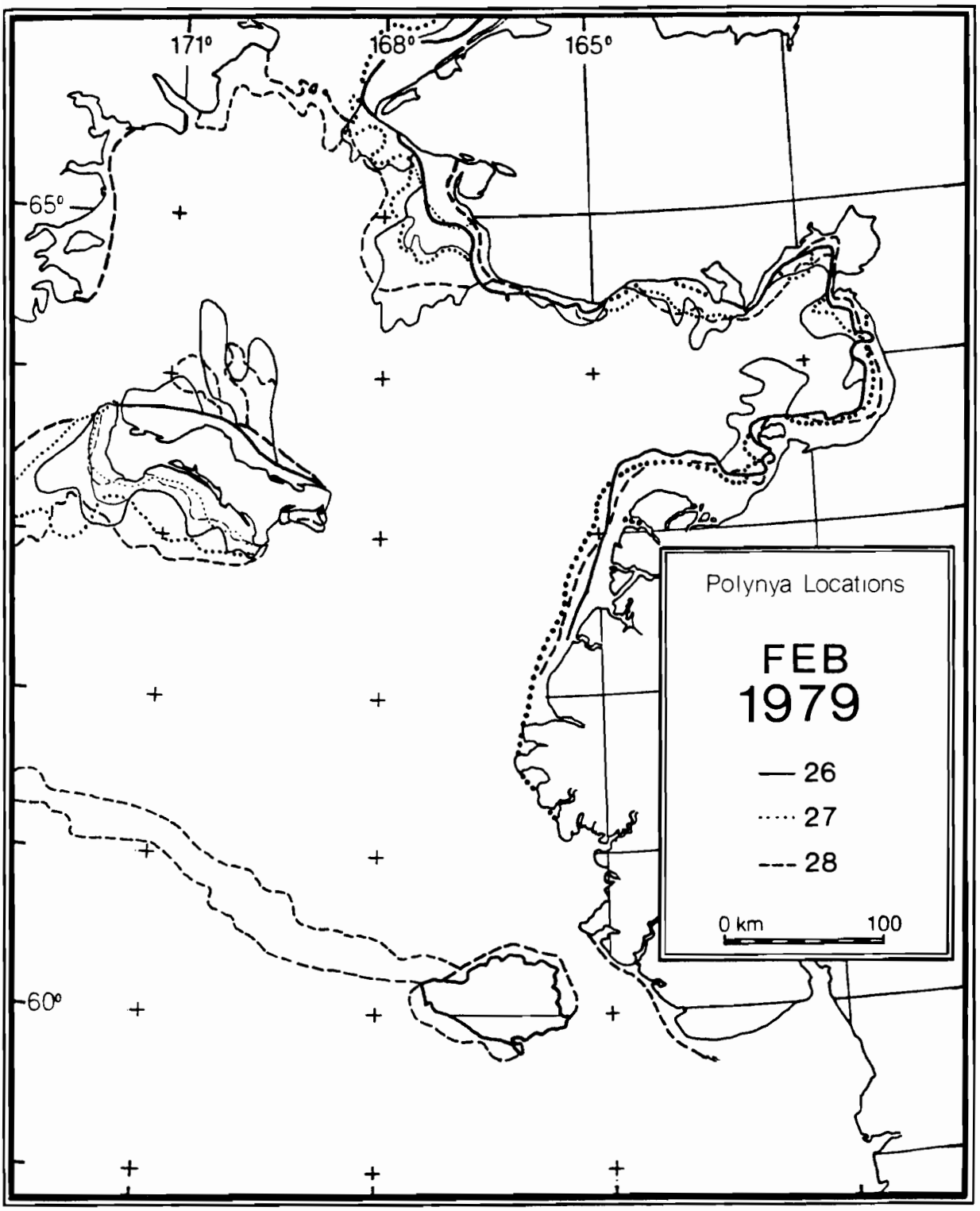

171°
168°
165°
65°
60°
Polynya Locations
MAR
1977
29
30
31
0 km
100


171°
168°
165°
65°
60°
Polynya Locations
APR
1977
13
14
15
0 km
100


171°
168°
165°
65°
60°
Polynya Locations
APR
1977
--- 15
····· 16
— 17
0 km
100


171°
168°
165°
65°
60°
Polynya Locations
FEB
1979
17
18
19
0 km
100


171°
168°
165°
65°
60°
Polynya Locations
FEB
1979
23
24
25
0 km
100


171°
168°
165°
65°
60°
Polynya Locations
FEB
1979
26
27
28
0 km
100

Appendix V

Floe Trajectory Maps

a. NOAA

Trajectories are plotted using floe positions found on the NOAA daily charts. Each floe was numbered; each map shows floe numbers and the days on which they were plotted. The dot symbol refers to the initial location of the floe; the triangle symbol shows the next plotted position and is oriented to indicate direction of travel.

22-27 February 1976

22	1
23	1-4
25	2-6
26	2-6
27	2,3,5,6

9-29 March 1976

9	1,2
10	1-3
13	1,2
14	1-3,6-8
15	3-9
16	1,2,4-15
17	1-15
18	4,5,9,10,14,15
21	4,5
27	4,5,16-18
29	4,5,16-18

25-31 March 1977

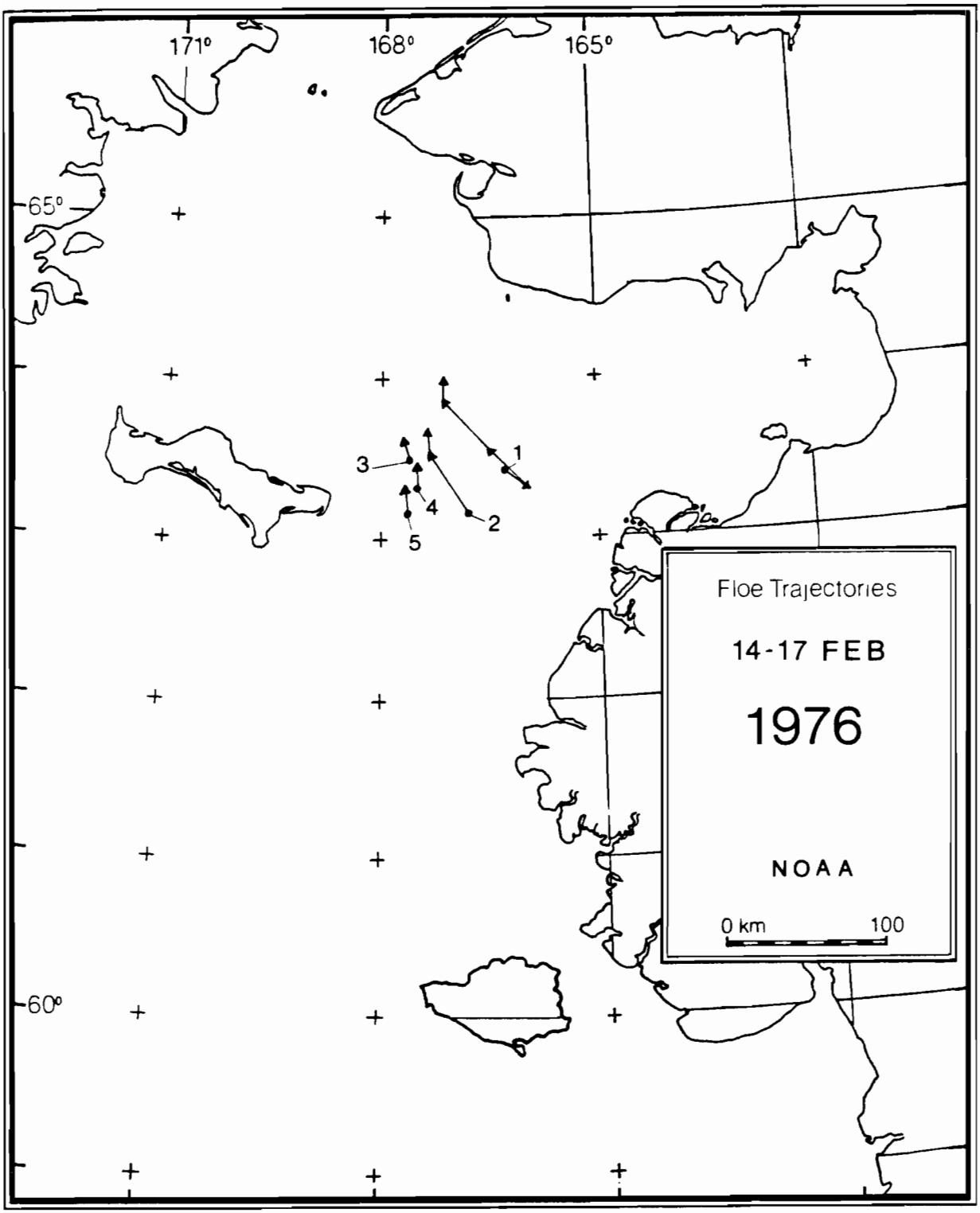
25	1-40
26	1-40
29	18,19,25,32,33,41-48
30	18,19,25,32,41-48
31	18,19,25,32,41-48

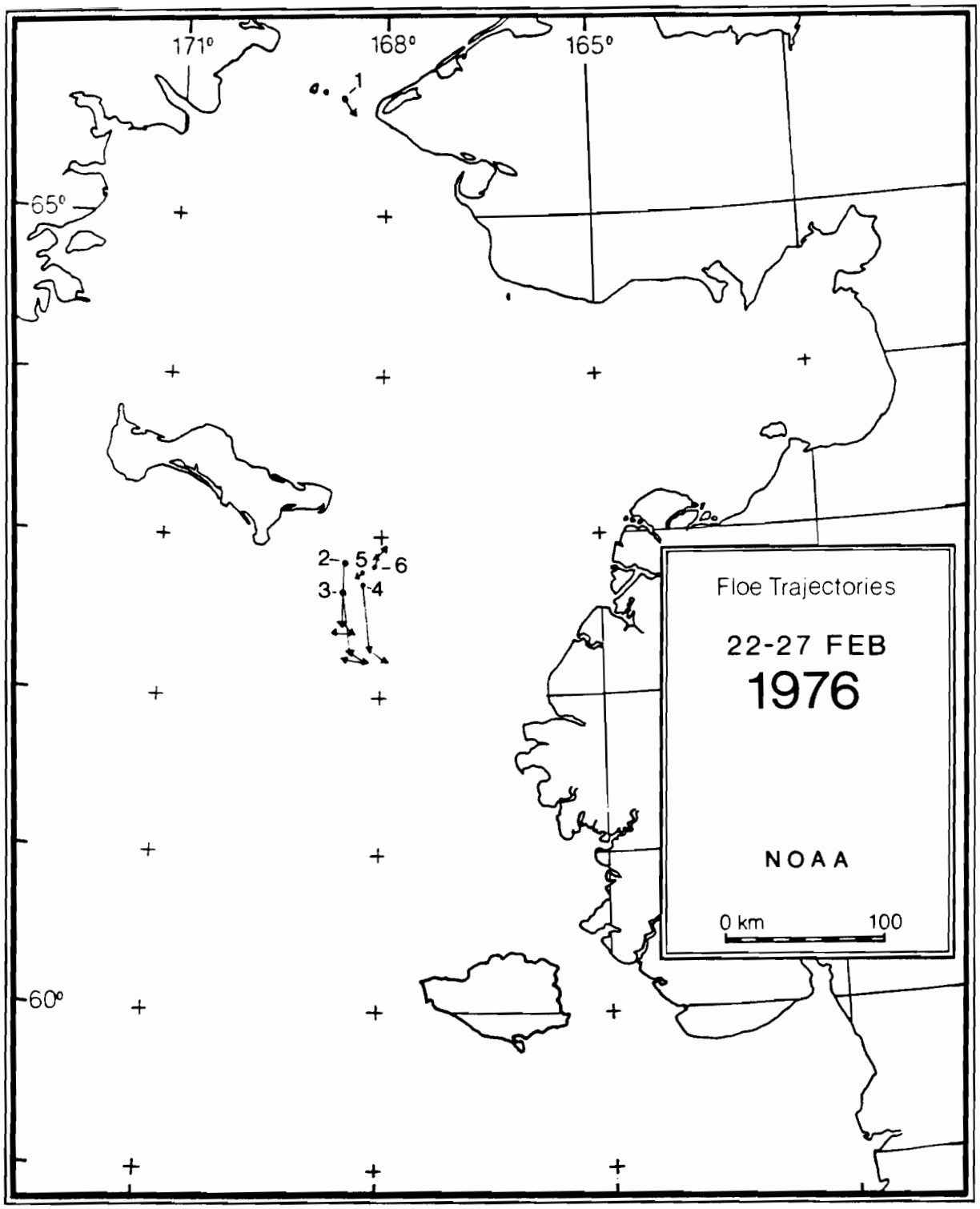
13-17 April 1977

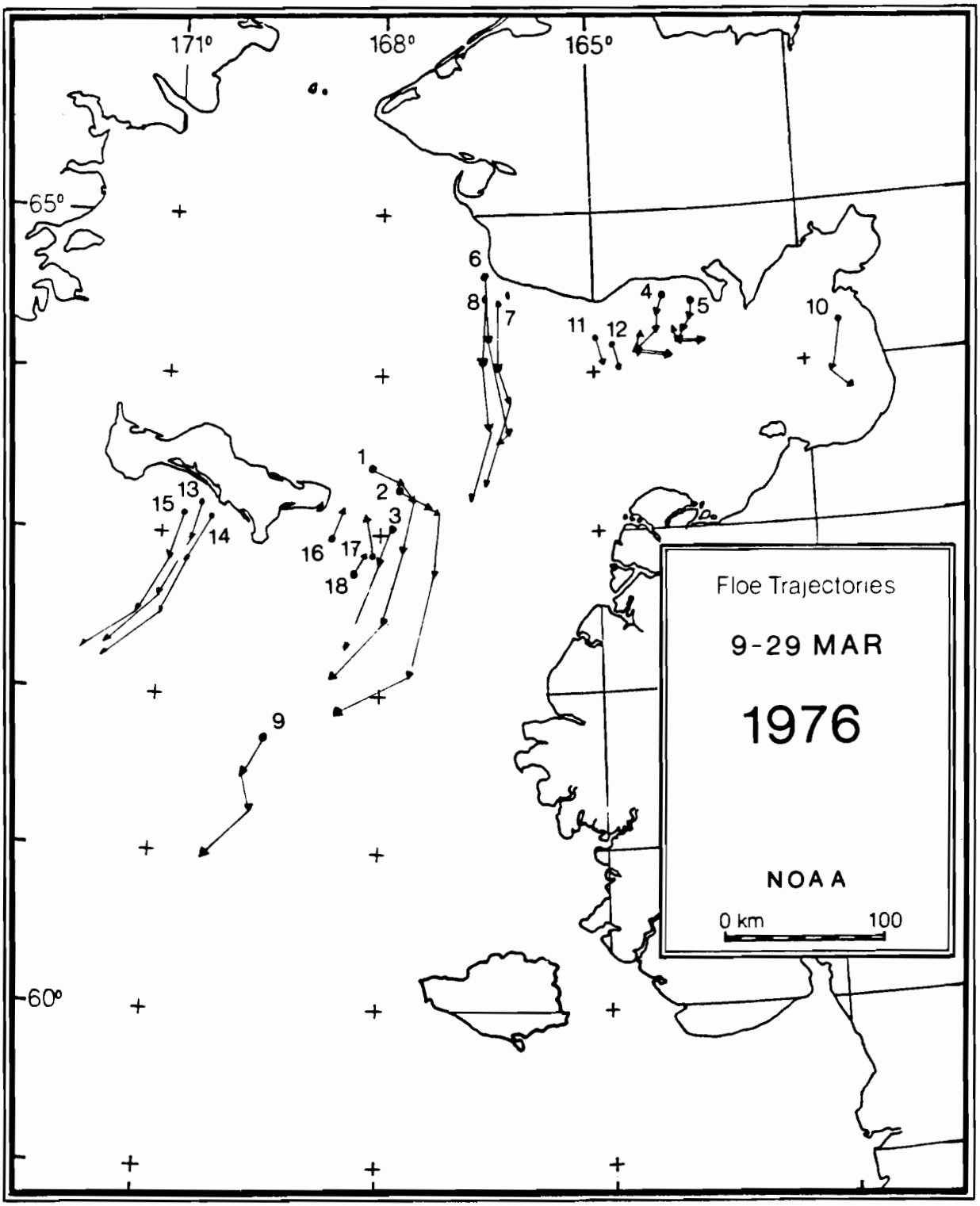
13	1-39
14	1-39
15	1-5,8-15,17-29,32-35,40-46
16	1-5,8-15,17-24,26-28,40-46
17	1,2,5,10-15,23,28,34,40,43,44

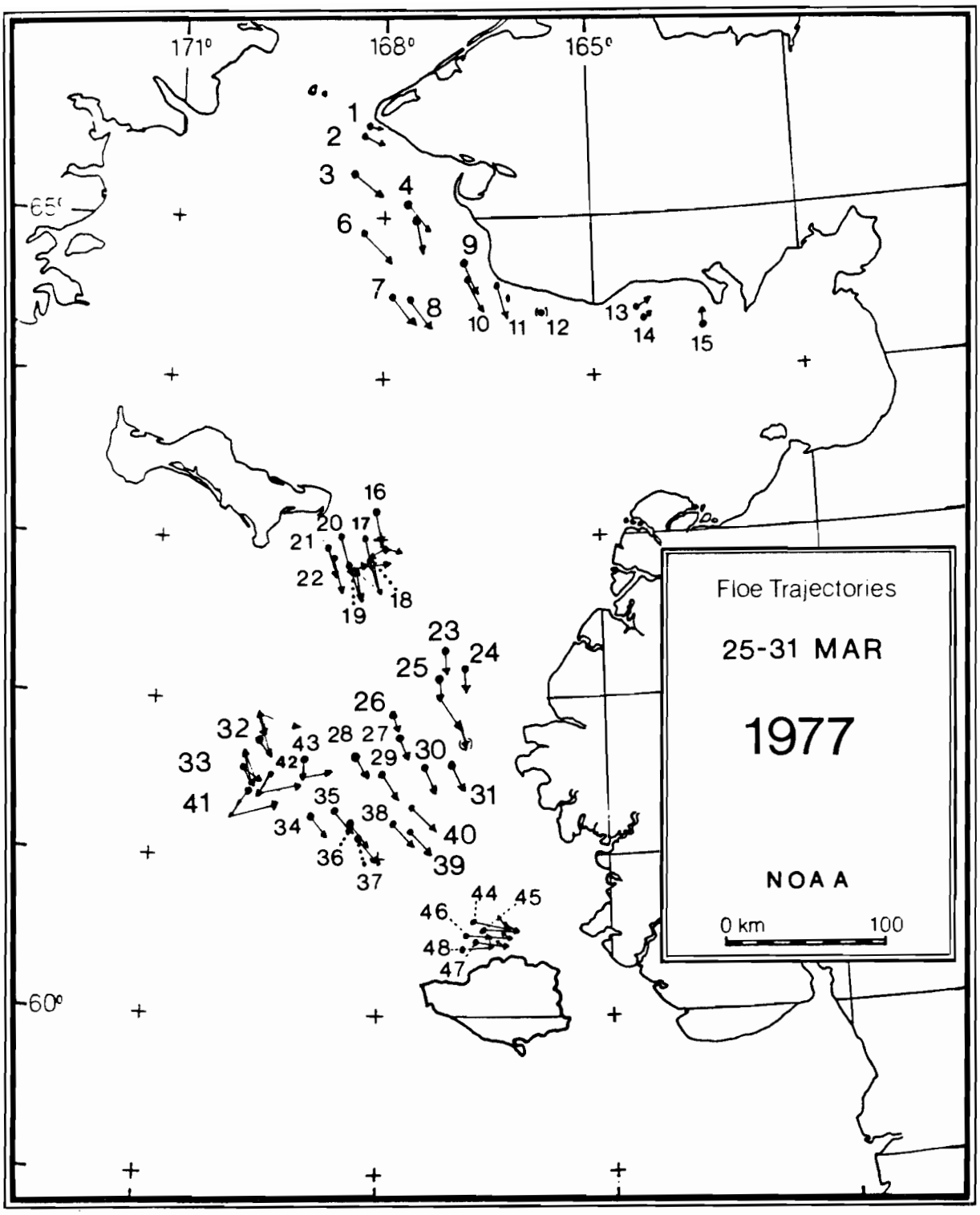
17-24 February 1979

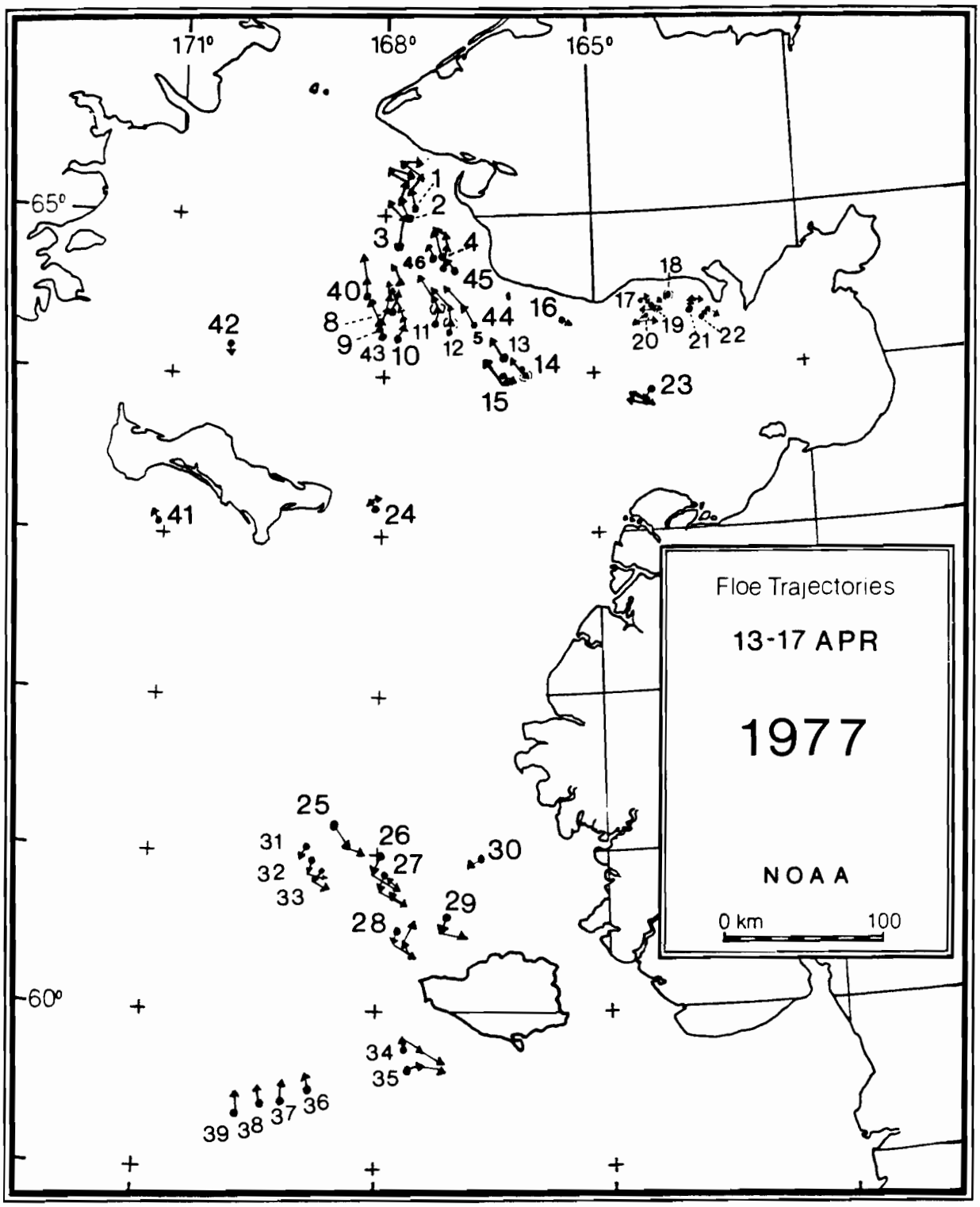
17	1
18	1
20	1,2
21	1-5
24	1-5


171°
168°
165°
65°
60°
1
2
3
4
5
Floe Trajectories
14-17 FEB
1976
NOAA
0 km
100


171°
168°
165°
65°
60°
1
2
3
4
5
6
Floe Trajectories
22-27 FEB
1976
NOAA
0 km
100


171°
168°
165°
65°
60°
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Floe Trajectories
9-29 MAR
1976
NOAA
0 km
100


171°
168°
165°
65°
60°
1
2
3
4
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
Floe Trajectories
25-31 MAR
1977
NOAA
0 km
100


171°
168°
165°
65°
60°
Floe Trajectories
13-17 APR
1977
NOAA
0 km
100

b. LANDSAT

Trajectories are plotted using floe positions found on the LANDSAT daily charts. Each floe is lettered; numbered floes correspond to those found on the NOAA floe trajectory maps in Appendix Va. The days on which each floe was plotted are found on the separate maps. The dot symbol refers to the initial location of the floe; the triangle symbol shows the next plotted position and is oriented to indicate direction of travel.

22-28 February 1976

22	A
23	B,C
25	B-H
26	C-J,2-5
27	H-Q
28	K-Q

25-31 March 1977

25	A-T,13,14
26	A-T,28,30,36-38,41,43-45
29	U-Z
30	U-Z,AA-AC
31	AA-AC

13-17 April 1977

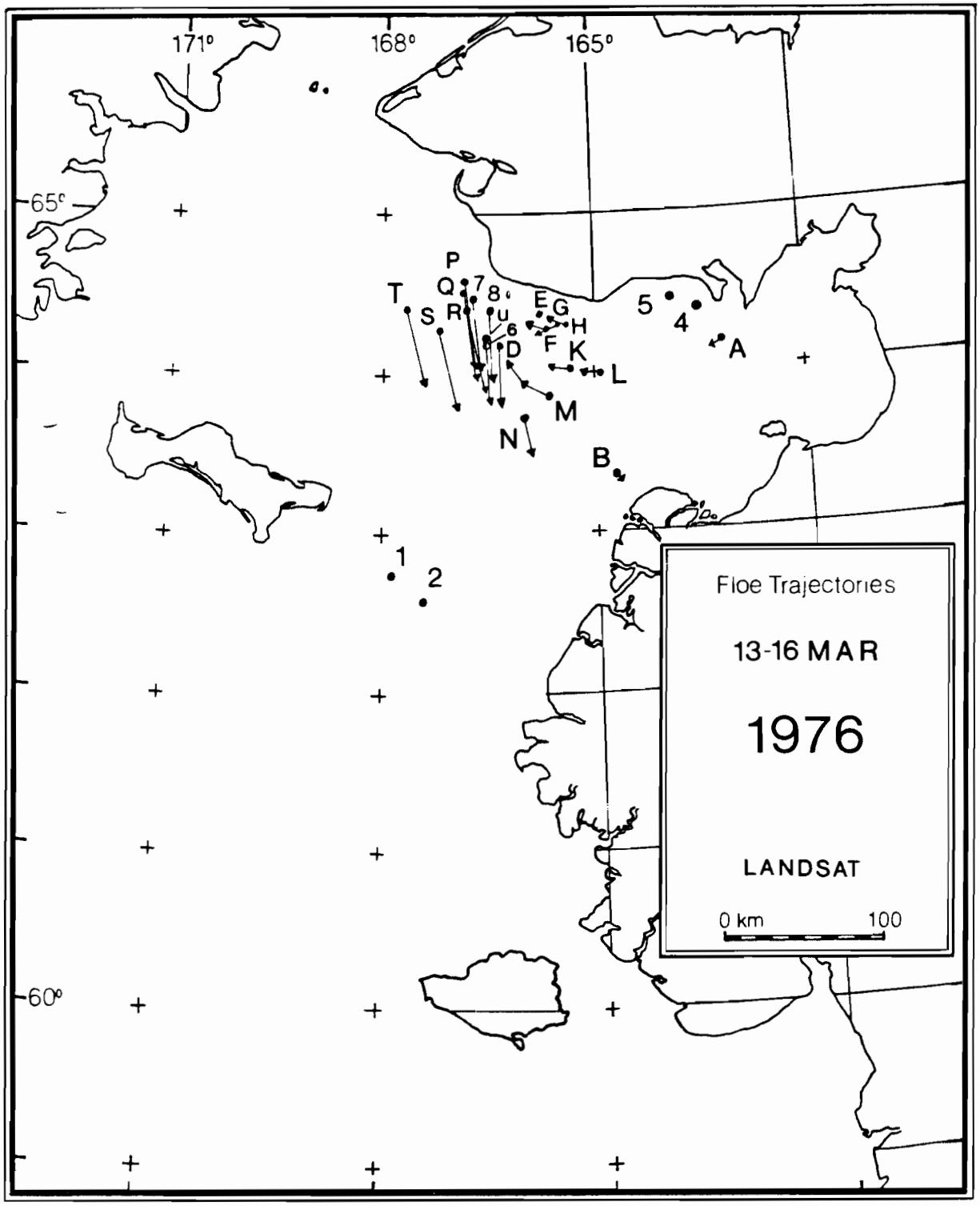
13	A-L,16-19,21-23,30,34,35
14	1-L,13-19,21,23,30
15	A,B,M,3,11,13,14,16,40,43,45,46
16	M,N,1-3,40,43,46
17	N,1-3,40

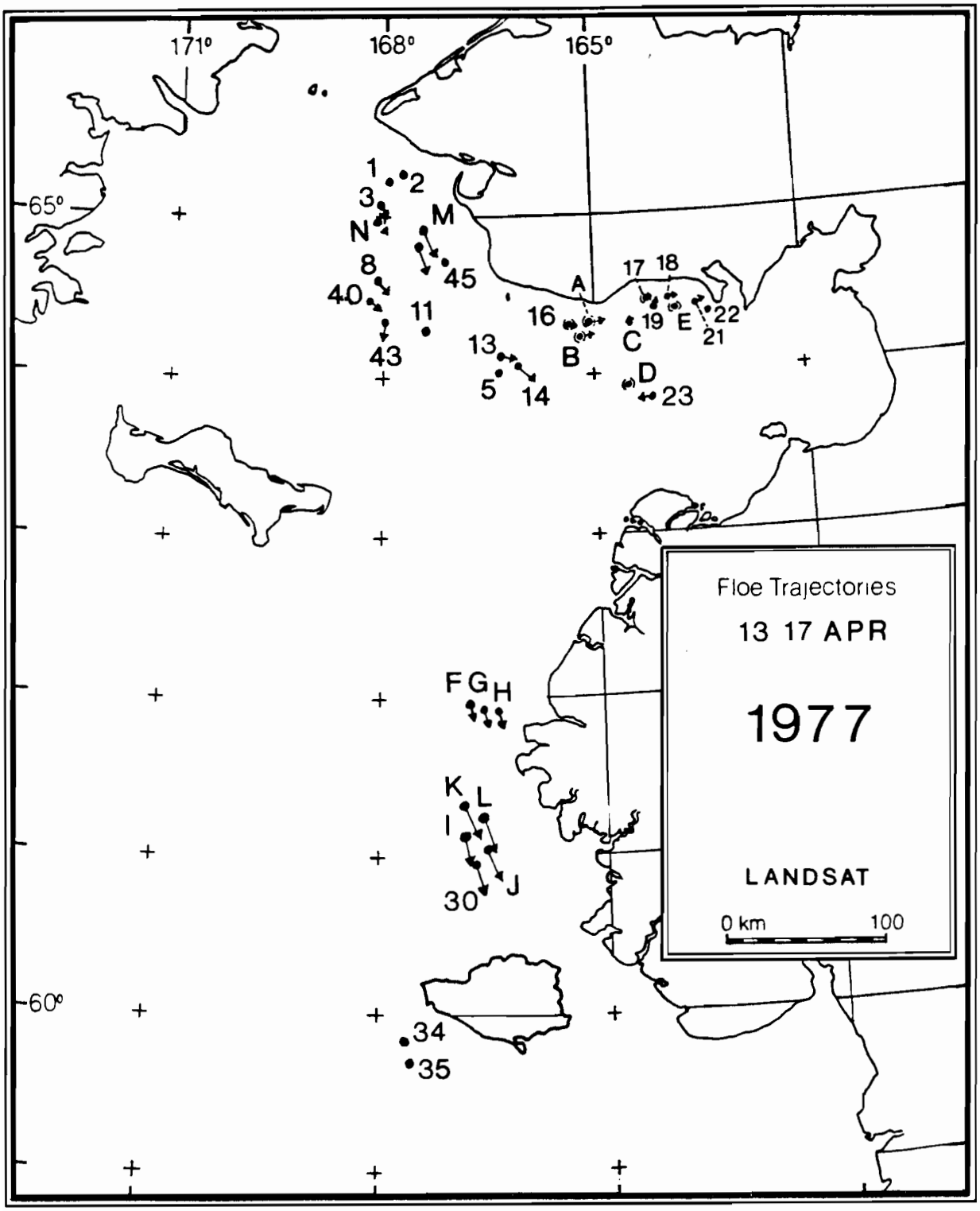
19-20 February 1979

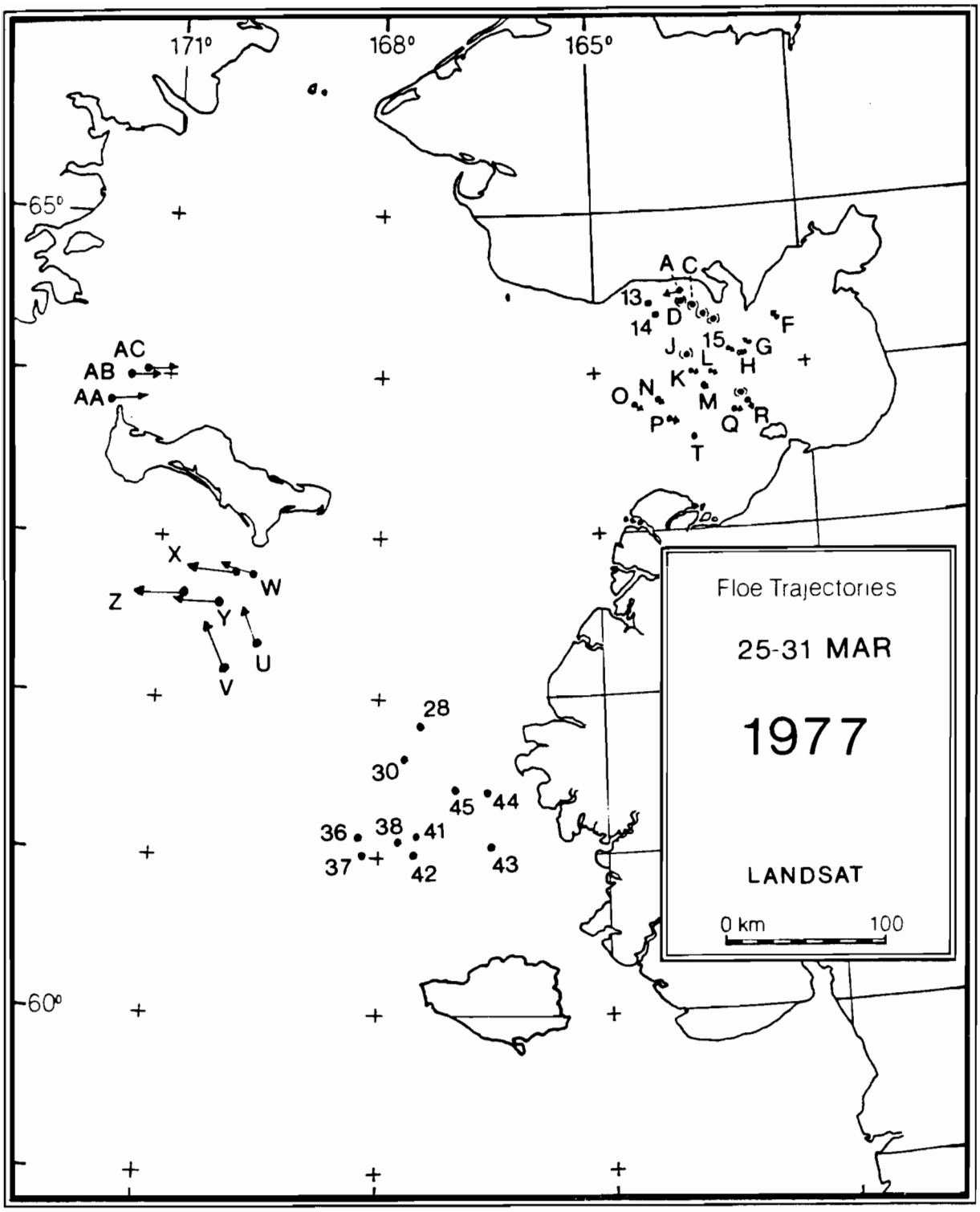
all	A-G,1

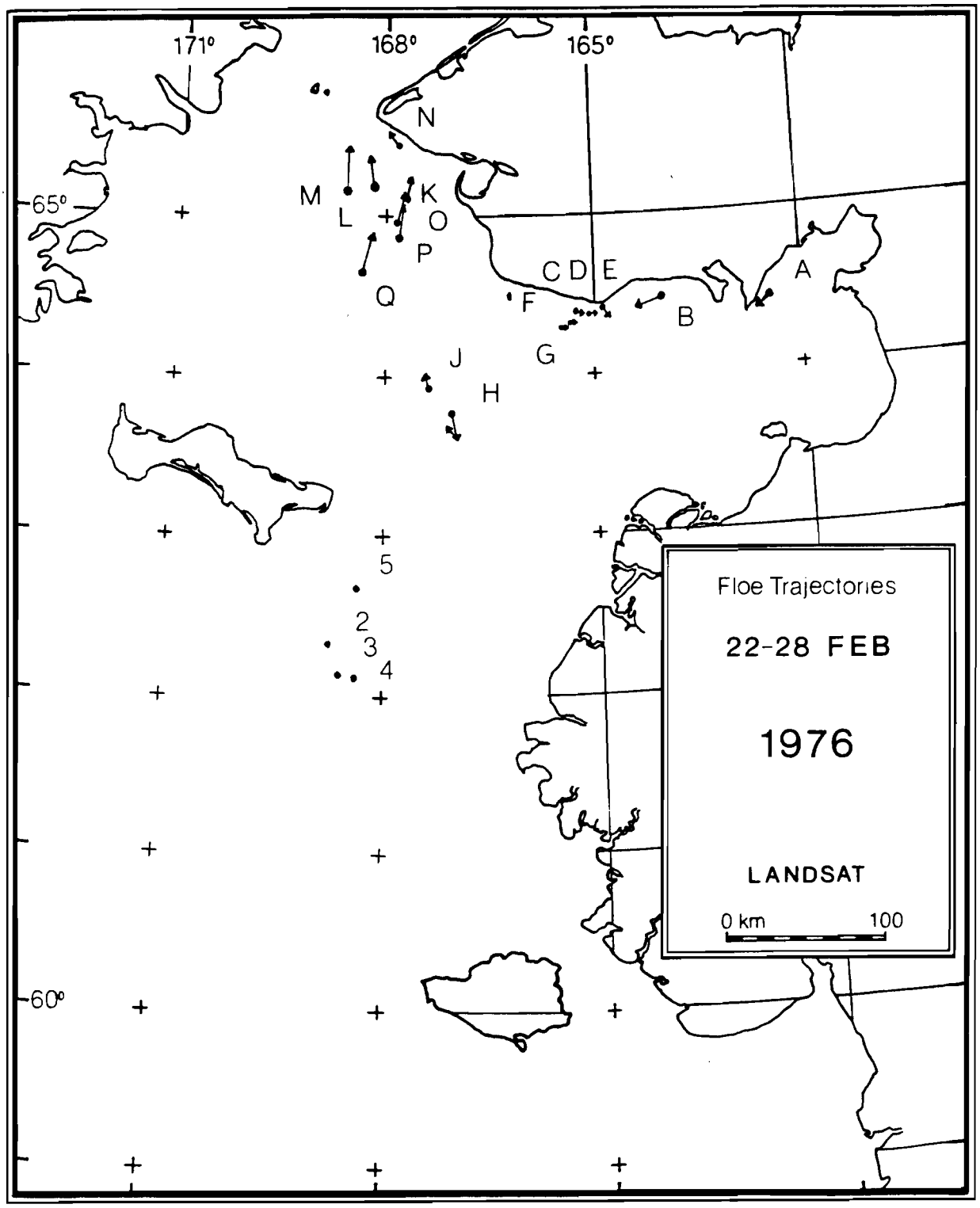
13-16 March 1976

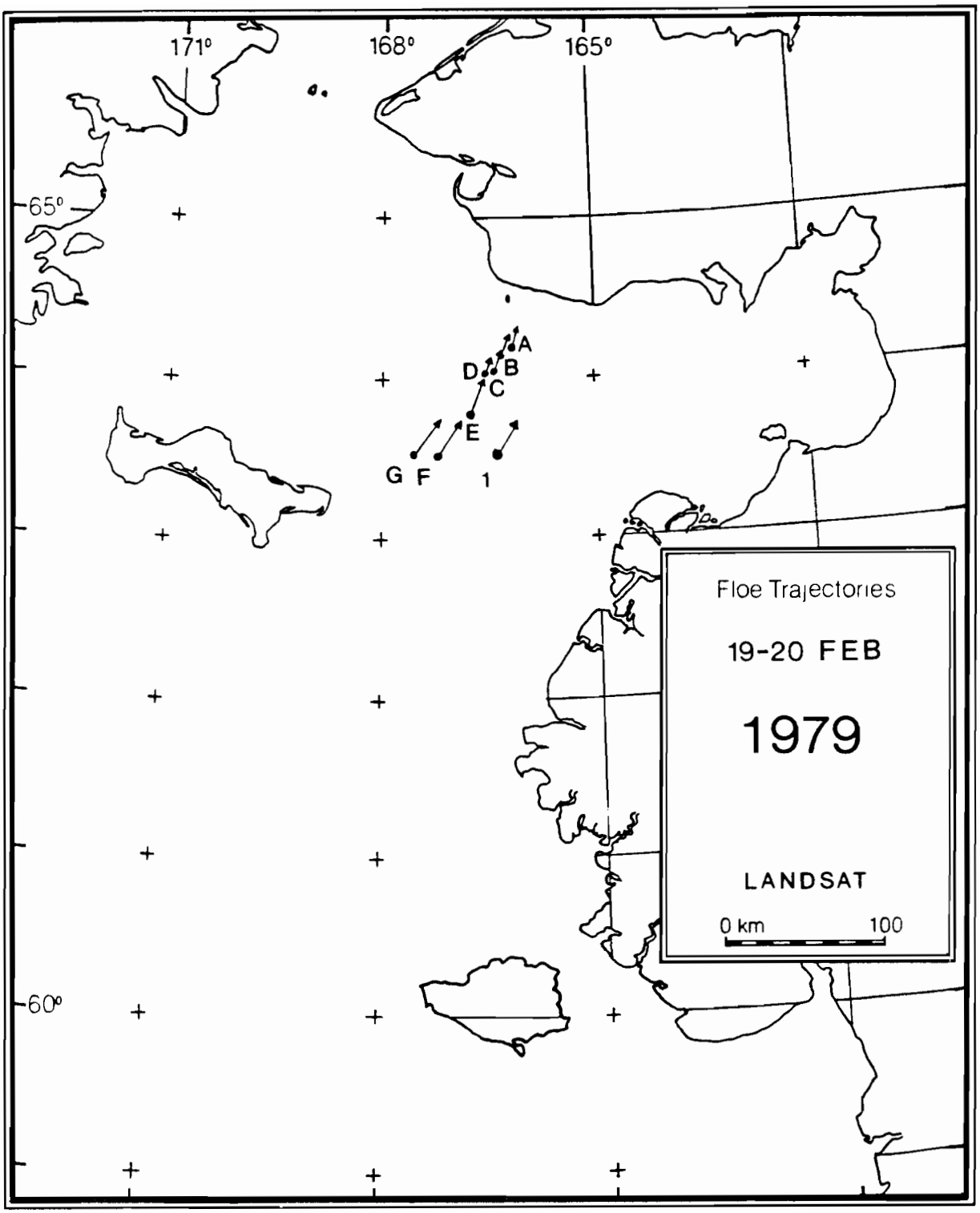
13	A,B
14	A-H,K-N,4,5,7,8
15	C,D,F-H,K-T,1,2,6-8
16	M,P-T


171°
168°
165°
65°
60°
P
Q
7
8
T
S
R
u
6
E
G
H
F
K
D
L
M
N
B
5
4
A
1
2
Floe Trajectories
13-16 MAR
1976
LANDSAT
0 km
100


171°
168°
165°
65°
60°
1
2
3
N
M
45
8
40
11
43
13
5
14
A
16
17
18
19
E
22
21
C
B
D
23
F
G
H
K
L
I
J
30
34
35
Floe Trajectories
13 17 APR
1977
LANDSAT
0 km
100

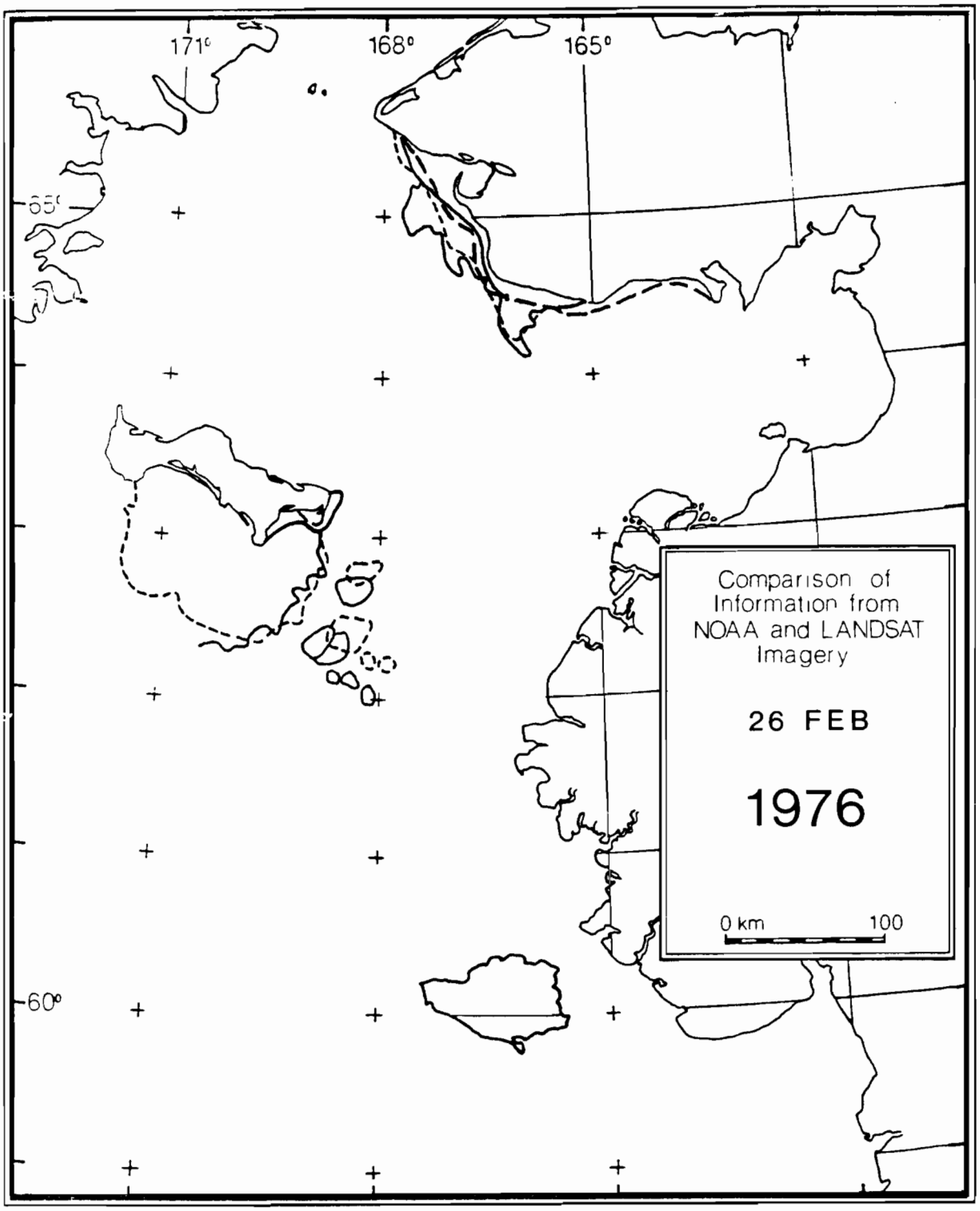

171°
168°
165°
65°
60°
AC
AB
AA
X
W
Z
Y
U
V
A C
13
D
14
F
15
G
J
L
H
K
O
N
M
P
Q
R
T
28
30
45
44
36
38
41
37
42
43
Floe Trajectories
25-31 MAR
1977
LANDSAT
0 km
100

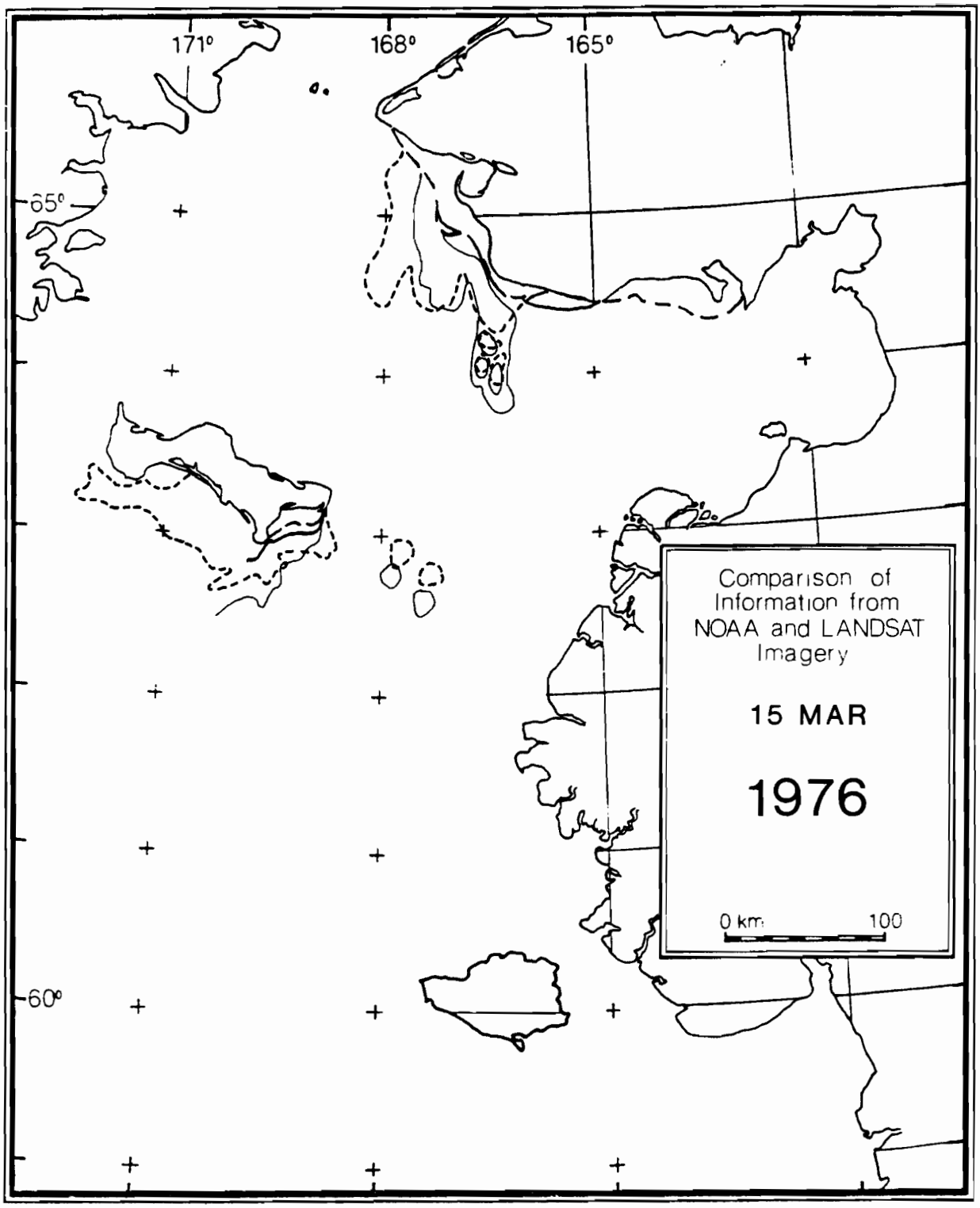

171°
168°
165°
65°
60°
N
M
L
K
O
P
Q
F
C D E
A
B
J
G
H
5
2
3
4
Floe Trajectories
22-28 FEB
1976
LANDSAT
0 km
100

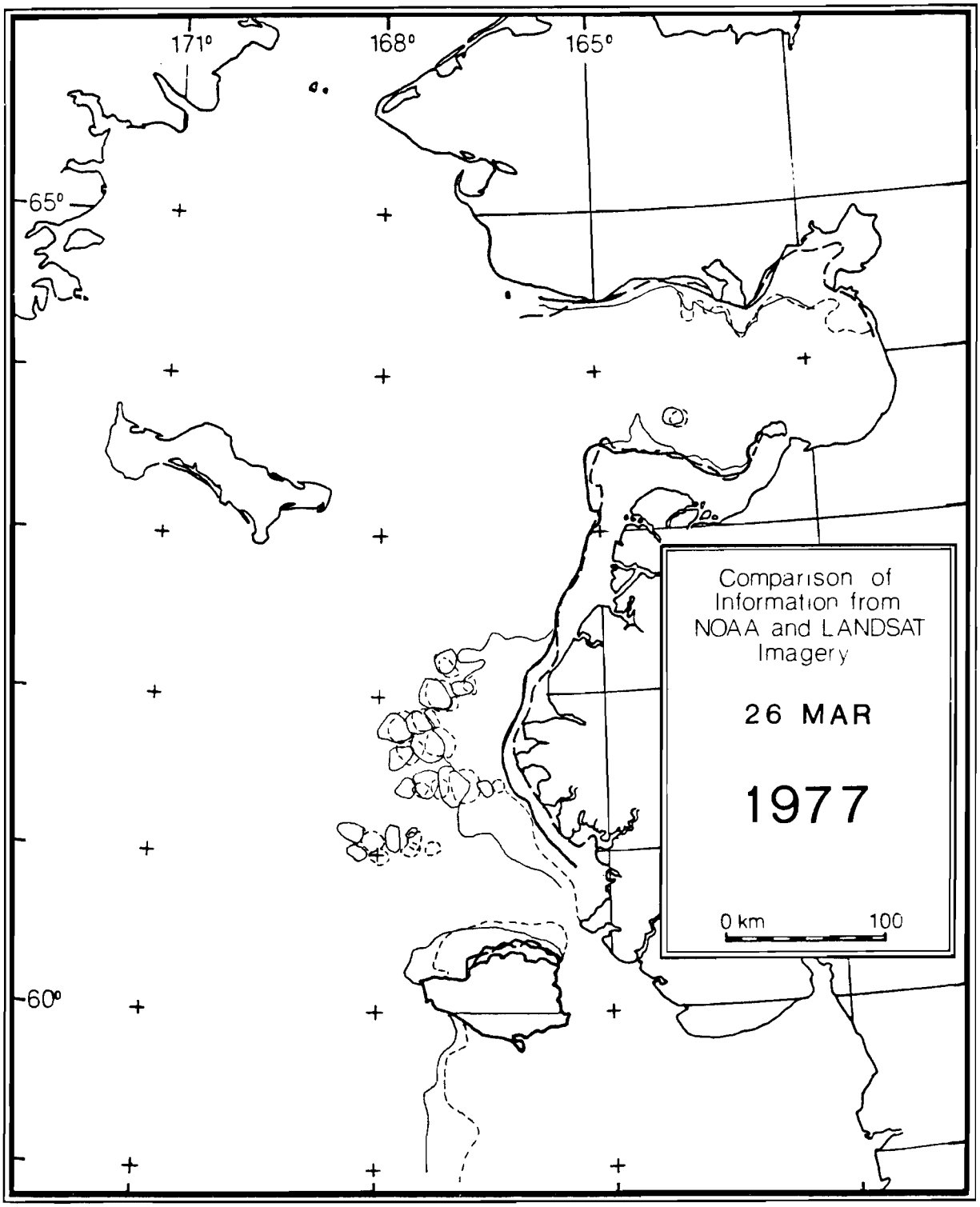

171°
168°
165°
65°
60°
A
B
C
D
E
F
G
1
Floe Trajectories
19-20 FEB
1979
LANDSAT
0 km
100

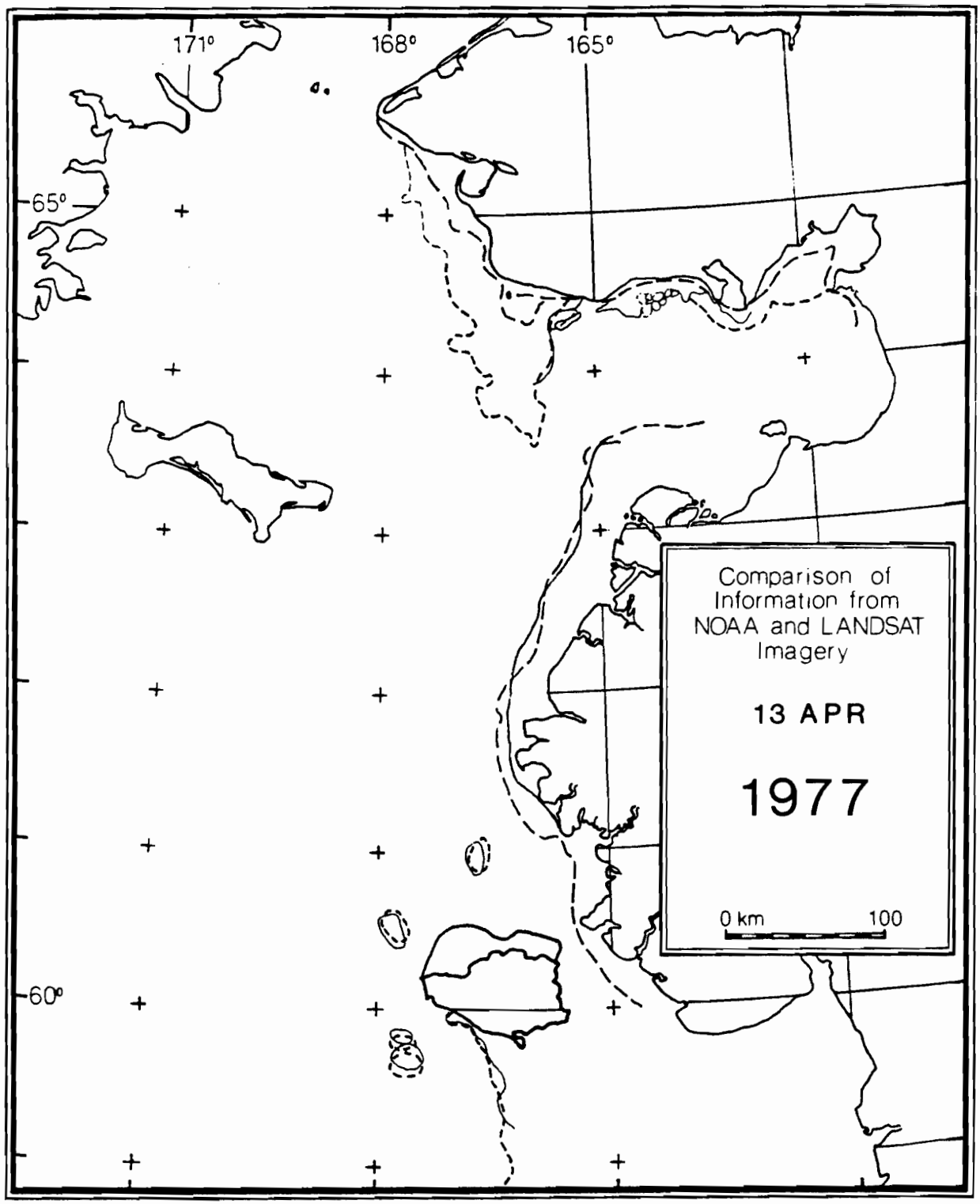
Appendix VI

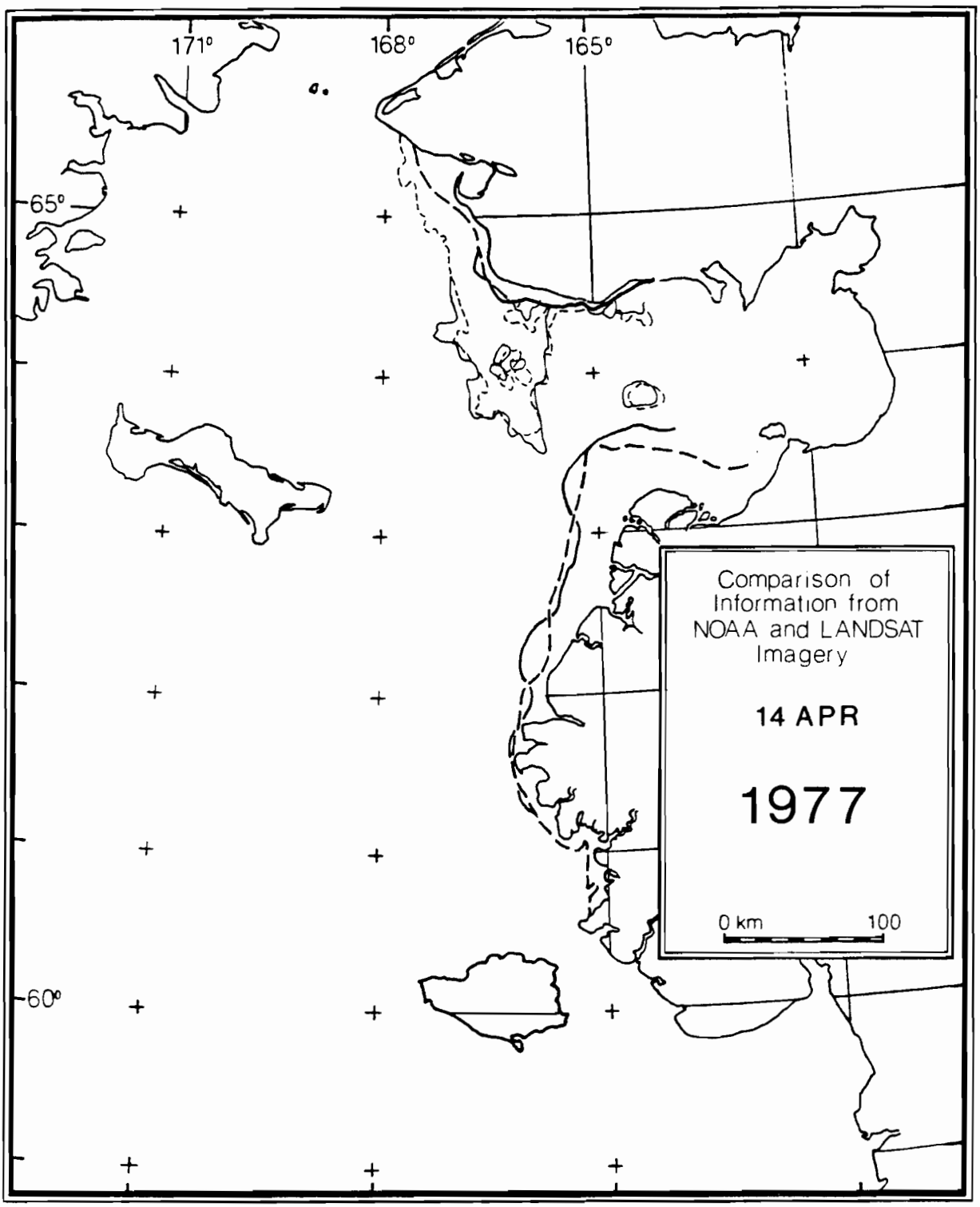
Comparisons of NOAA and LANDSAT Data

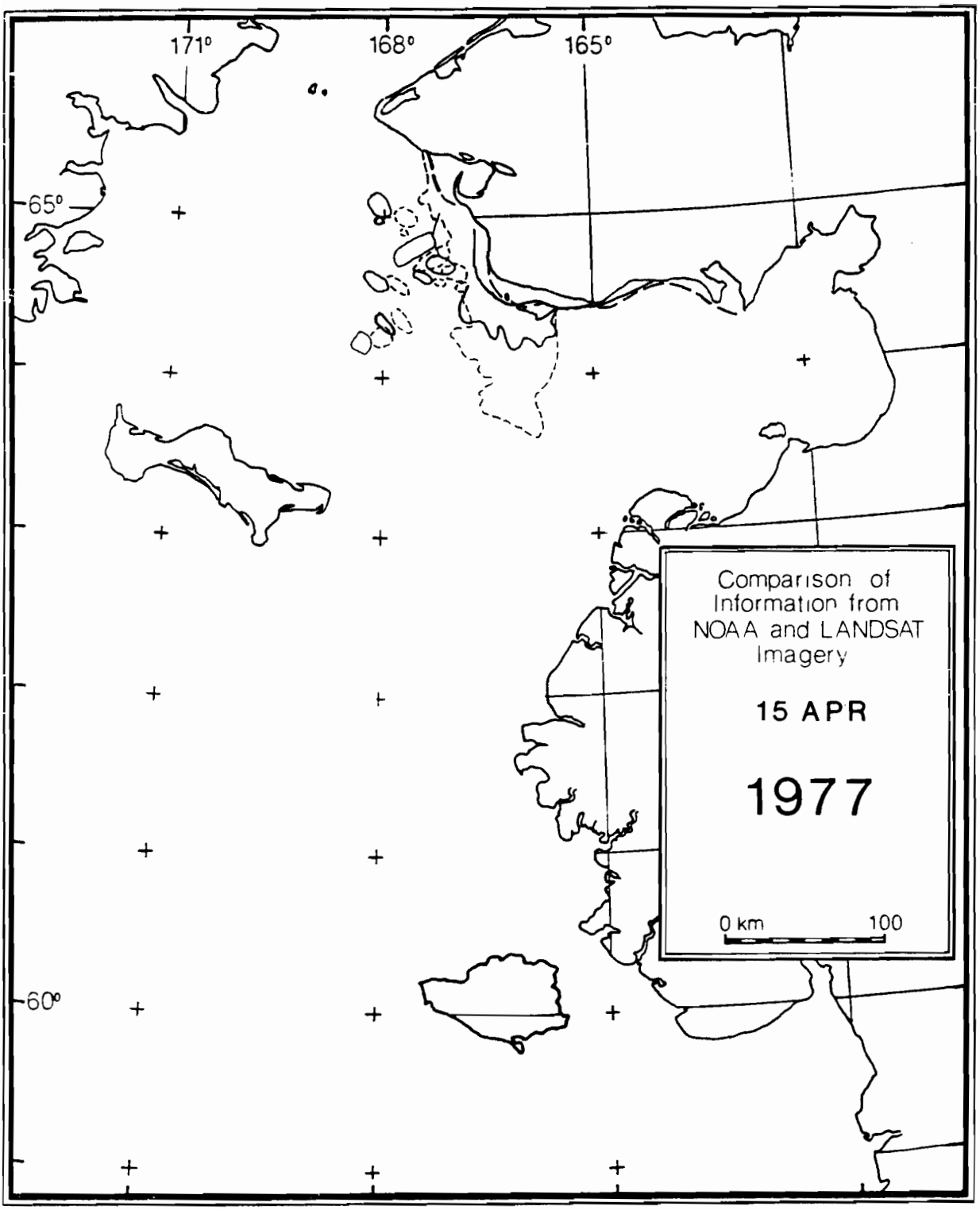

171°
168°
165°
65°
60°
Comparison of Information from NOAA and LANDSAT Imagery
26 FEB
1976
0 km
100

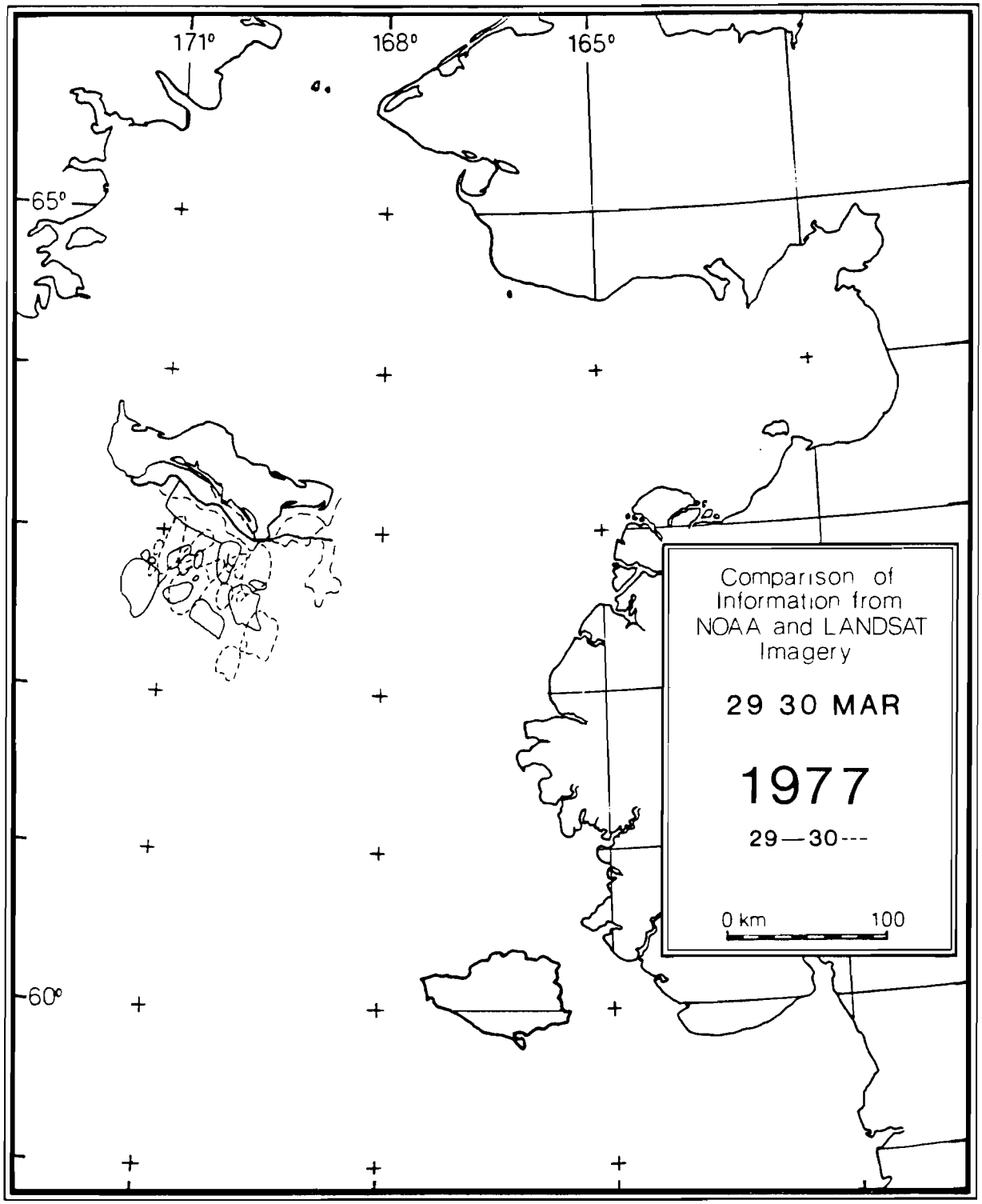

171°
168°
165°
65°
60°
Comparison of Information from NOAA and LANDSAT Imagery
15 MAR
1976
0 km
100

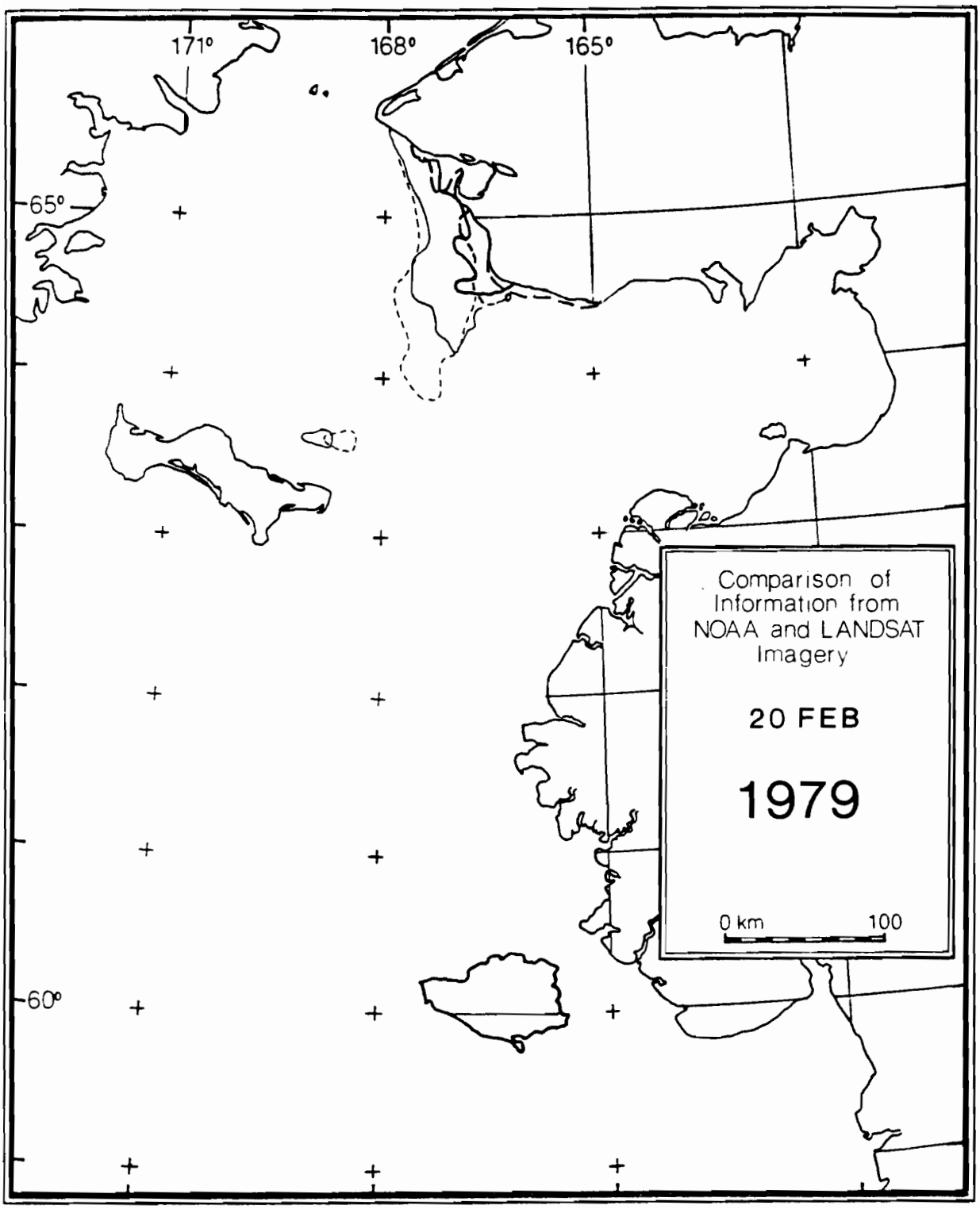

171°
168°
165°
65°
60°
Comparison of Information from NOAA and LANDSAT Imagery
26 MAR
1977
0 km
100


171°
168°
165°
65°
60°
Comparison of Information from NOAA and LANDSAT Imagery
13 APR
1977
0 km
100


171°
168°
165°
65°
60°
Comparison of
Information from
NOAA and LANDSAT
Imagery
14 APR
1977
0 km
100

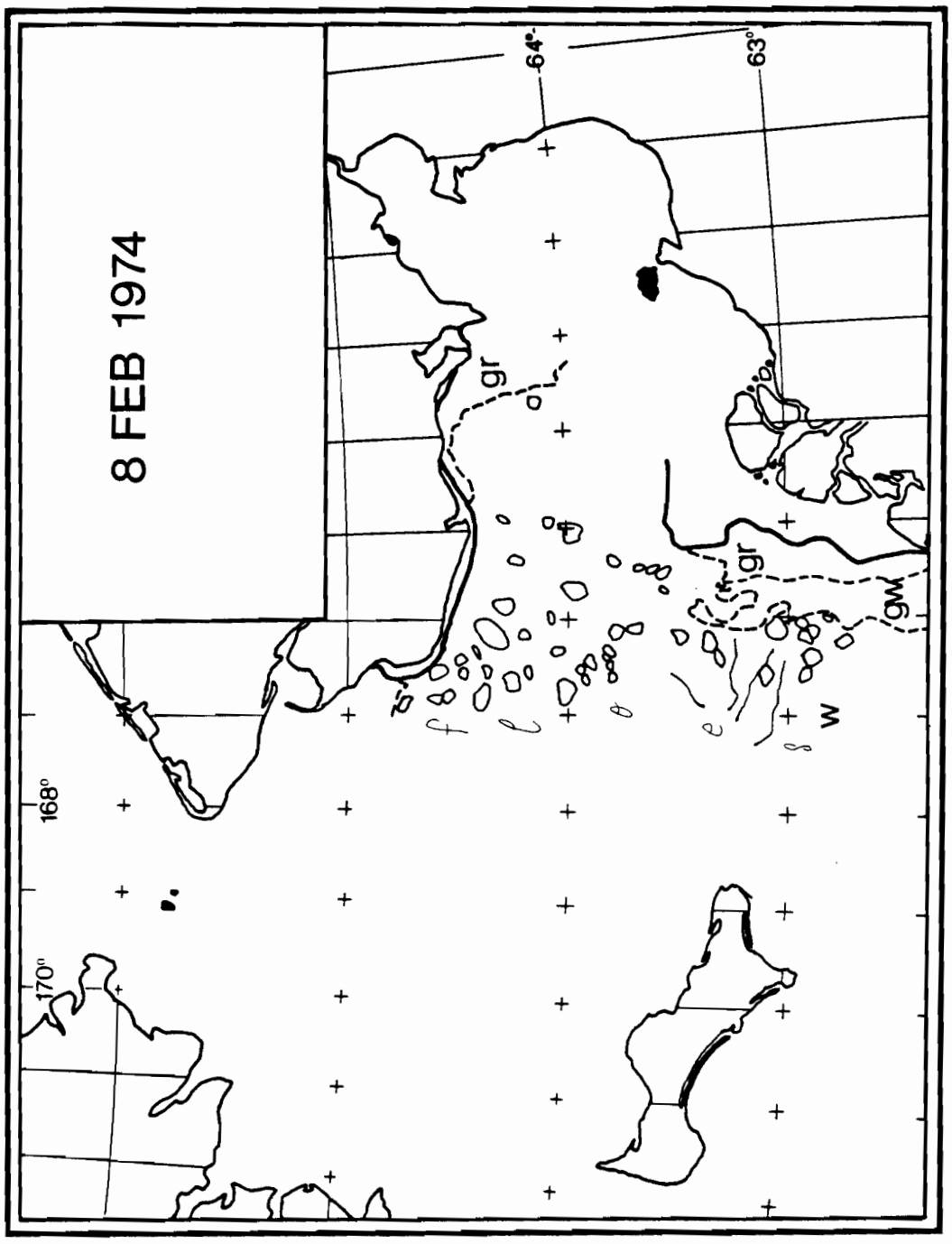

171°
168°
165°
65°
60°
Comparison of Information from NOAA and LANDSAT Imagery
15 APR
1977
0 km
100

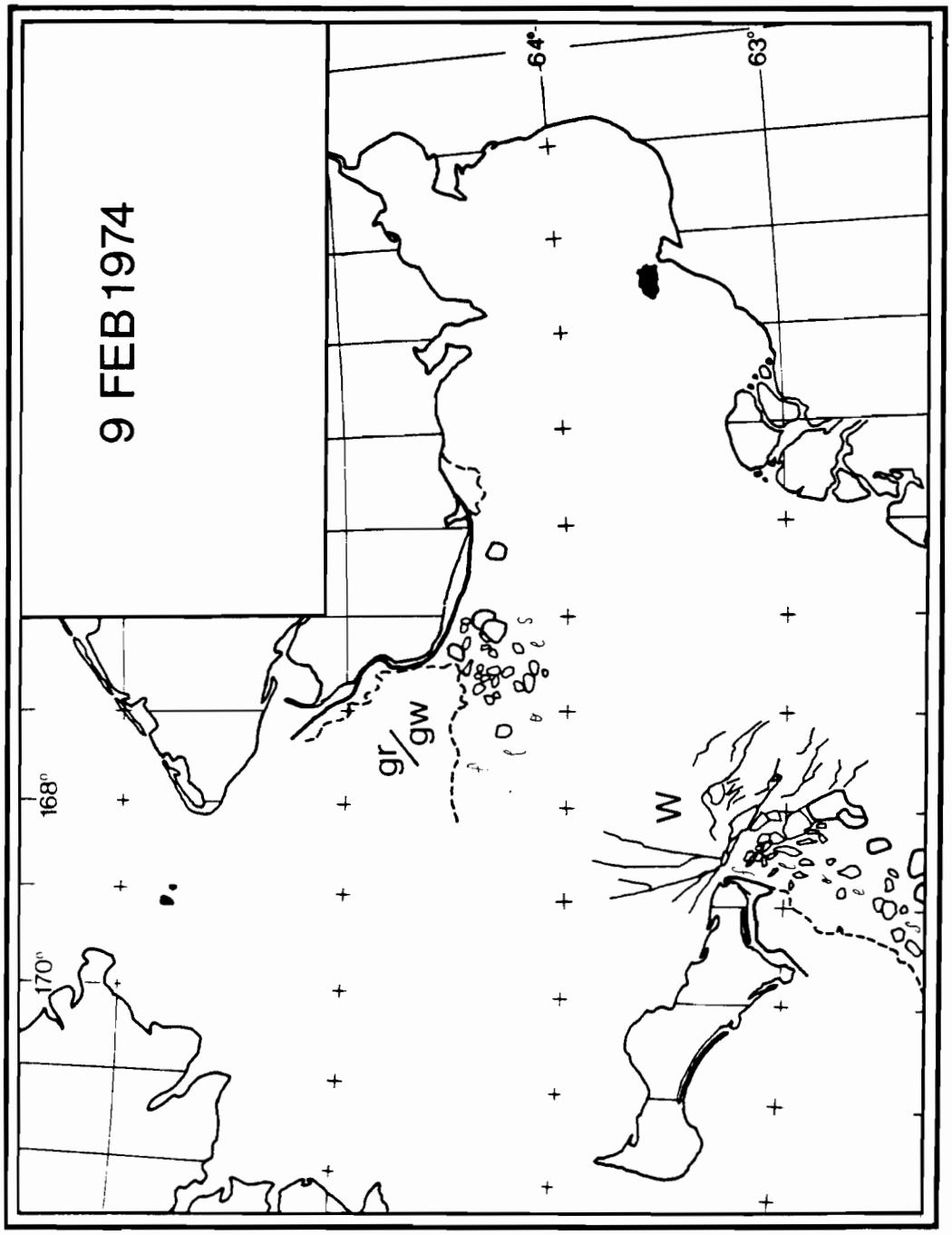

171°
168°
165°
65°
60°
Comparison of Information from NOAA and LANDSAT Imagery
29 30 MAR
1977
29—30---
0 km
100

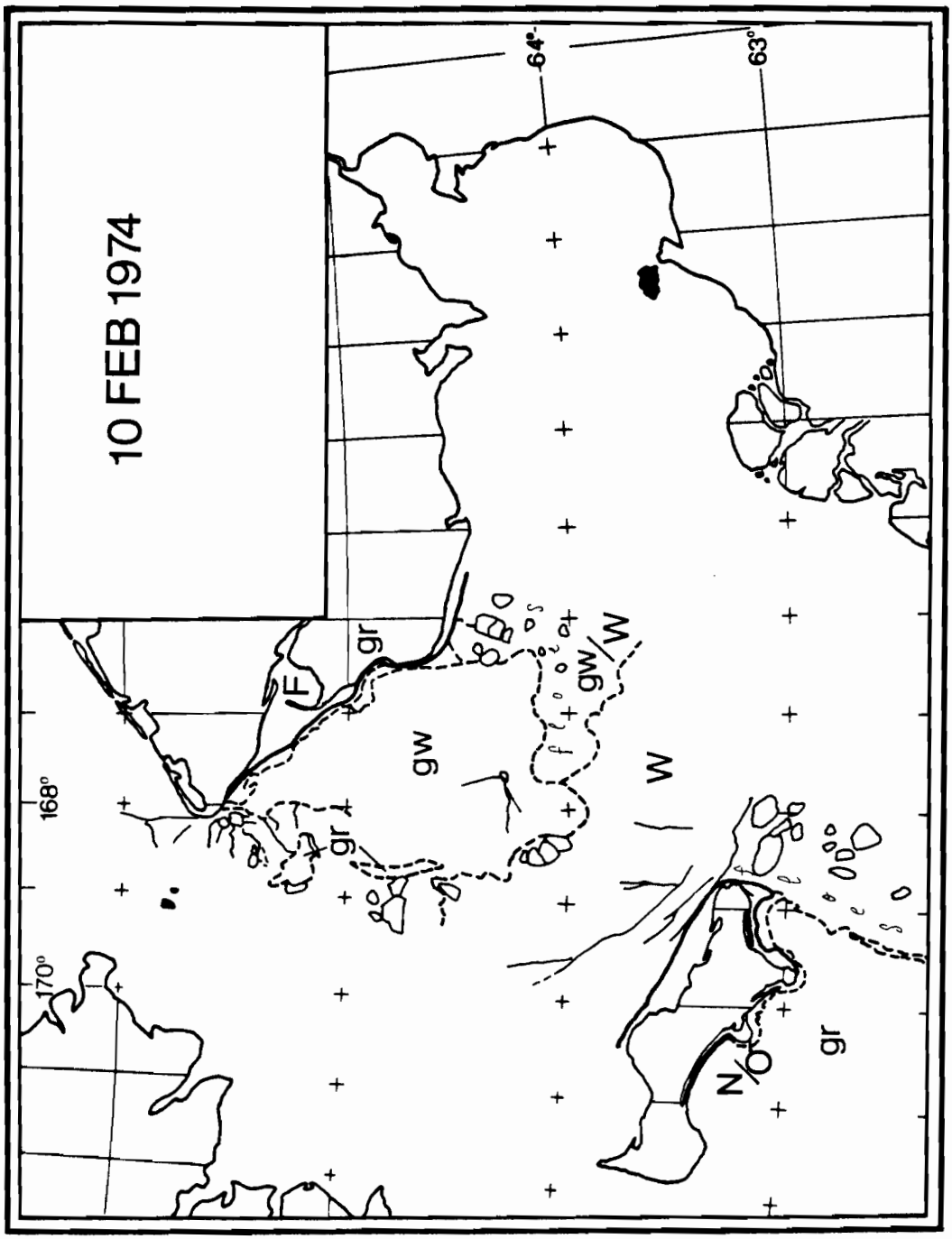

171°
168°
165°
65°
60°
Comparison of Information from NOAA and LANDSAT Imagery
20 FEB
1979
0 km
100

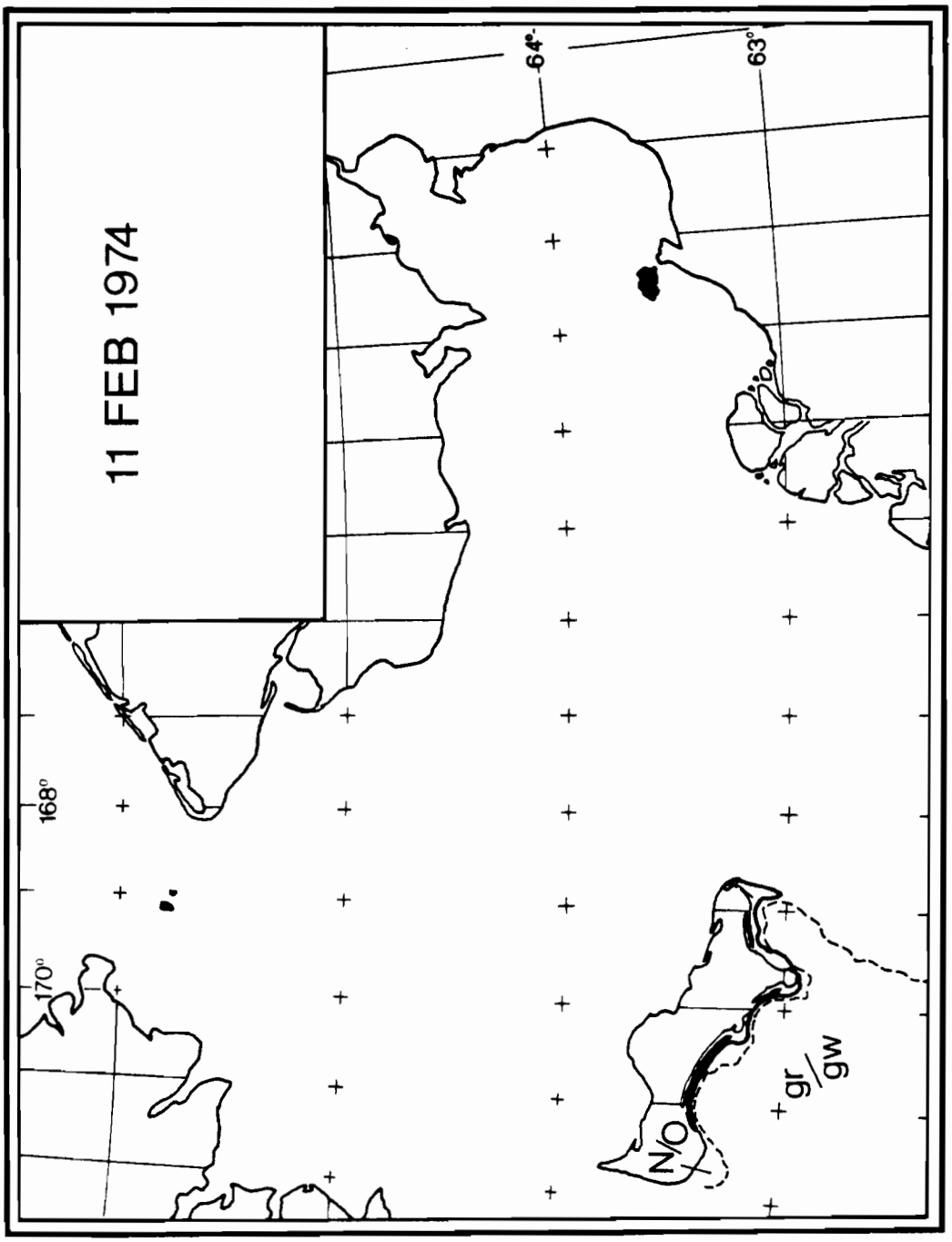
Appendix VII

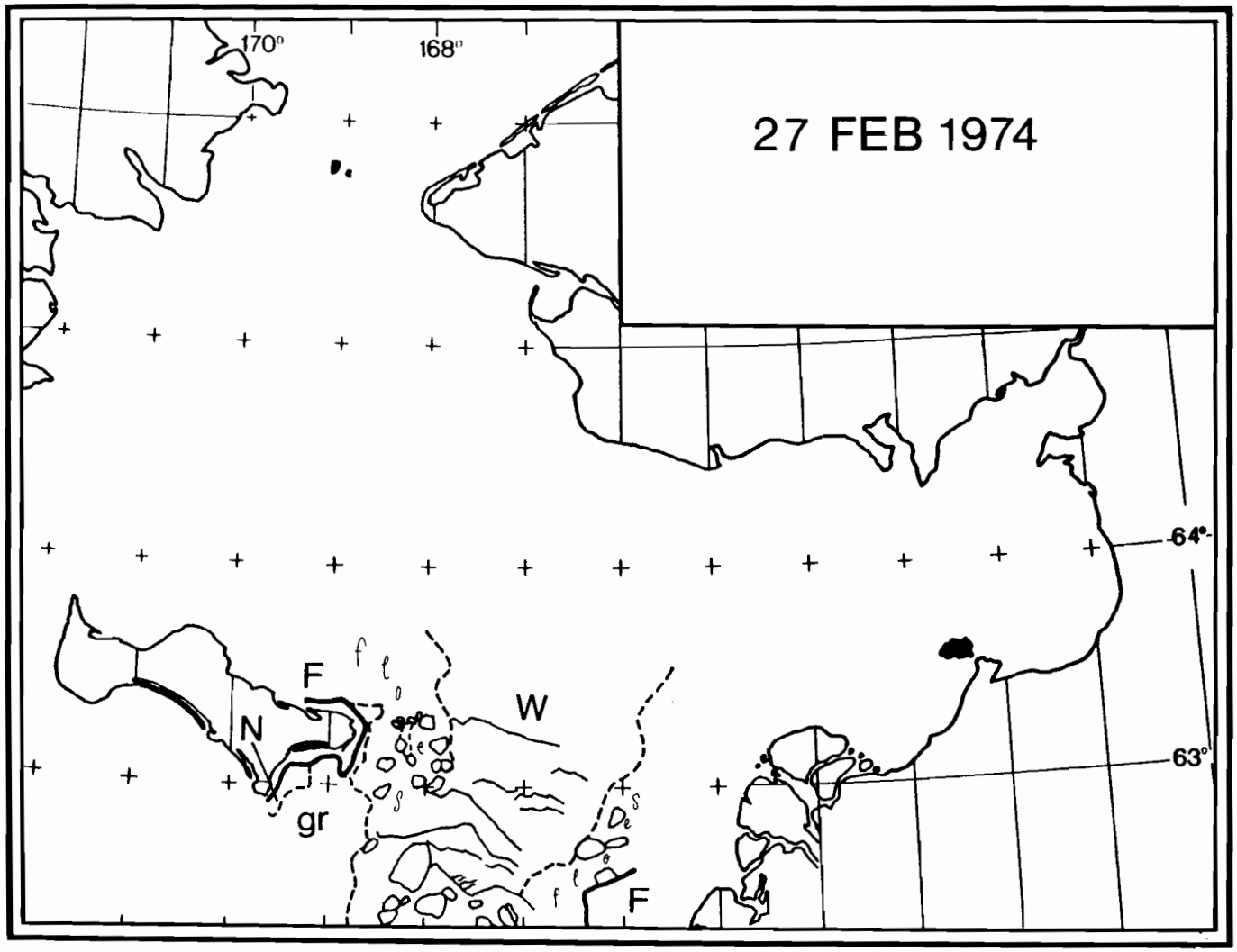
LANDSAT Charts for 1974

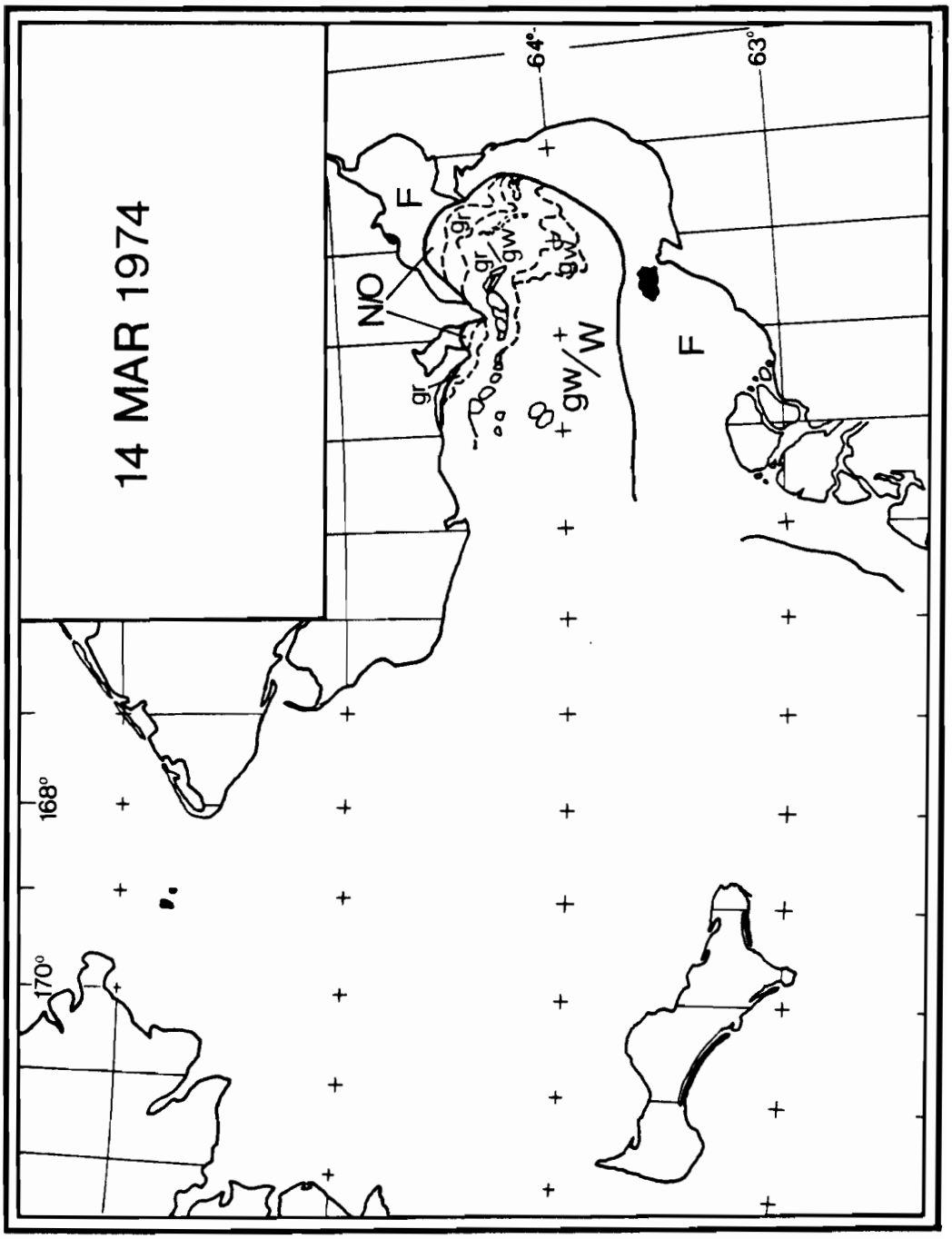

8 FEB 1974
64°
63°
gr
gr
mg
W
168°
170°

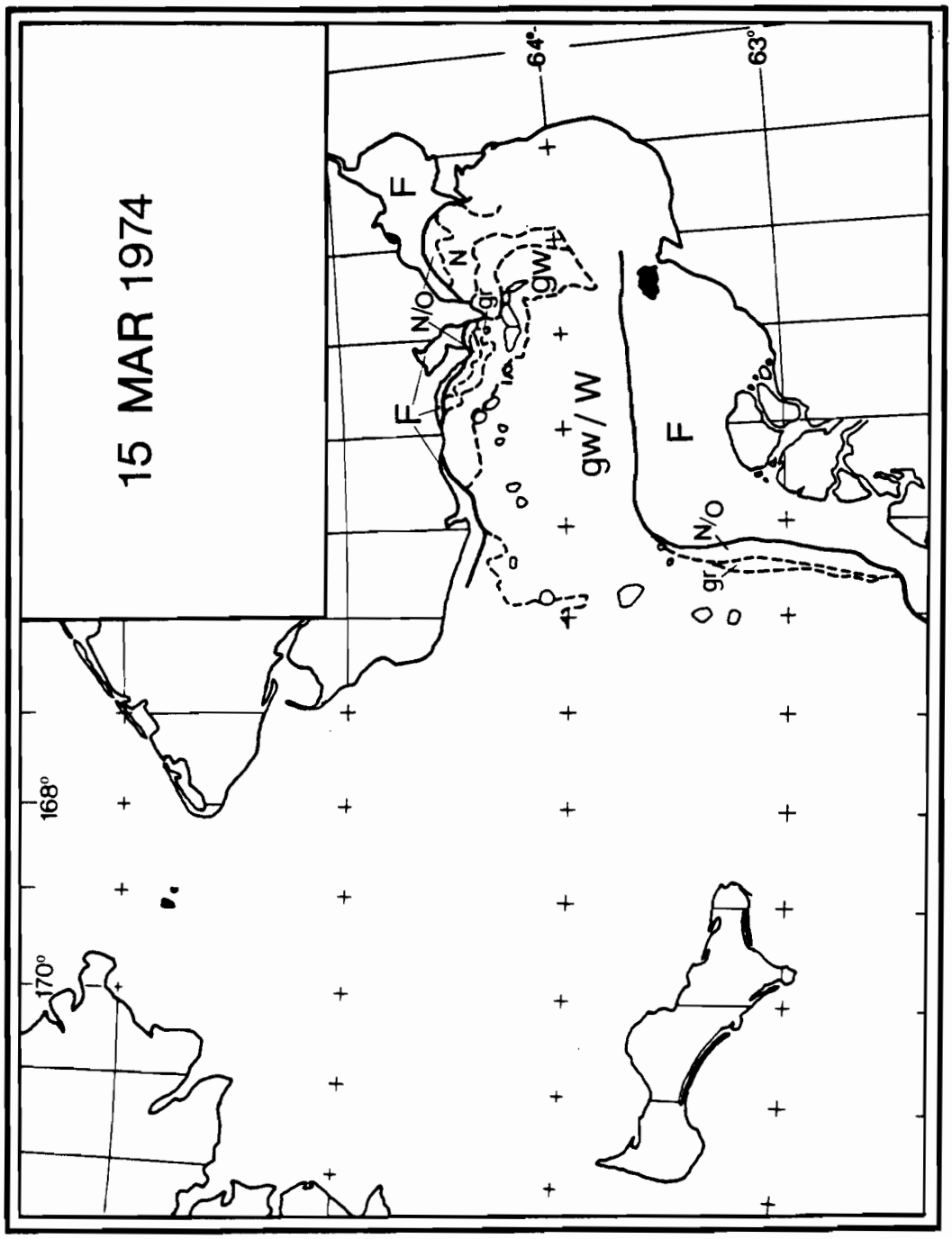

9 FEB 1974
64°
63°
168°
170°
gr/gw
W

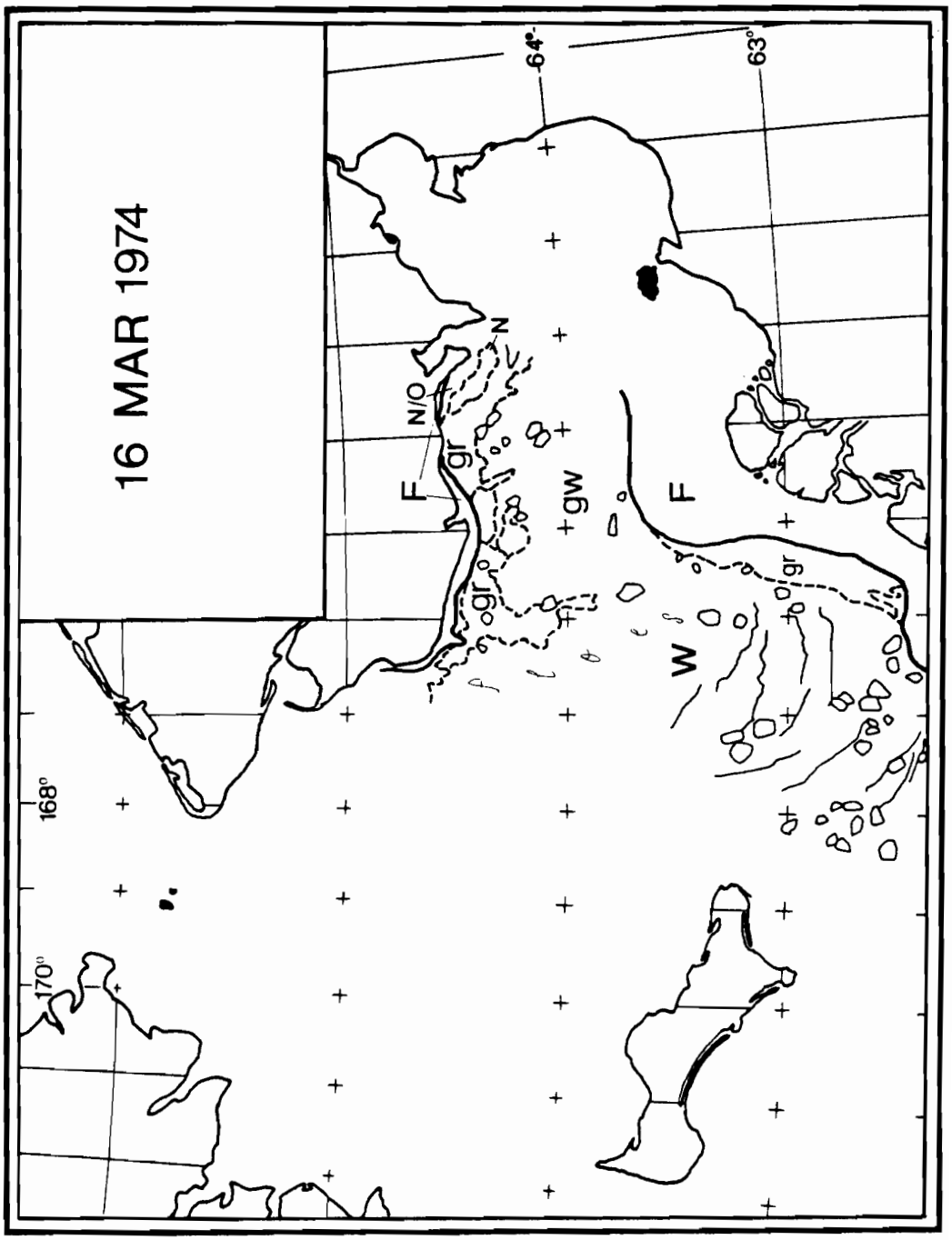

10 FEB 1974
64°
63°
168°
170°
F
gr
gw
gw/W
W
gr
N/O
gr

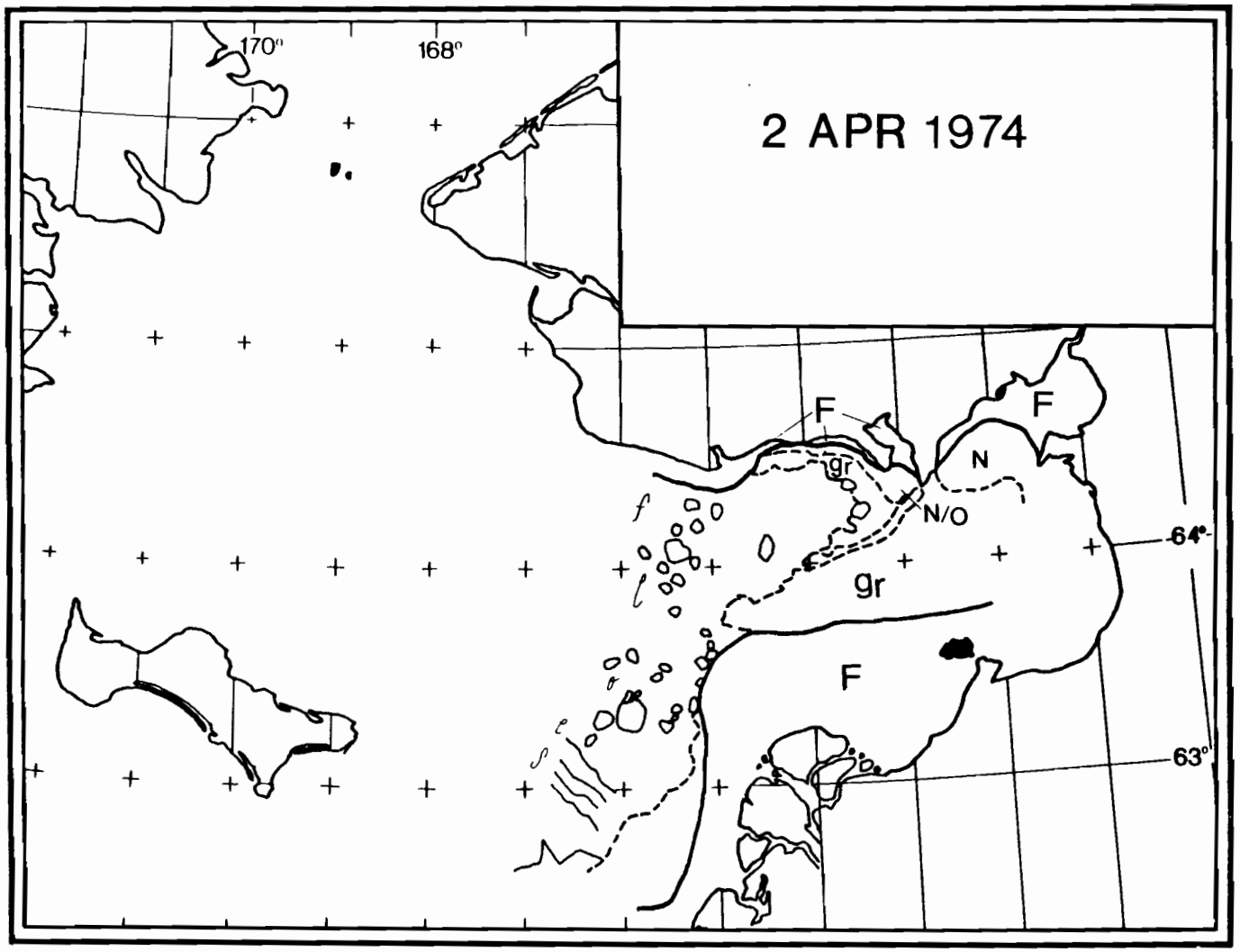

11 FEB 1974
64°
63°
168°
170°
gr/gw
N/O

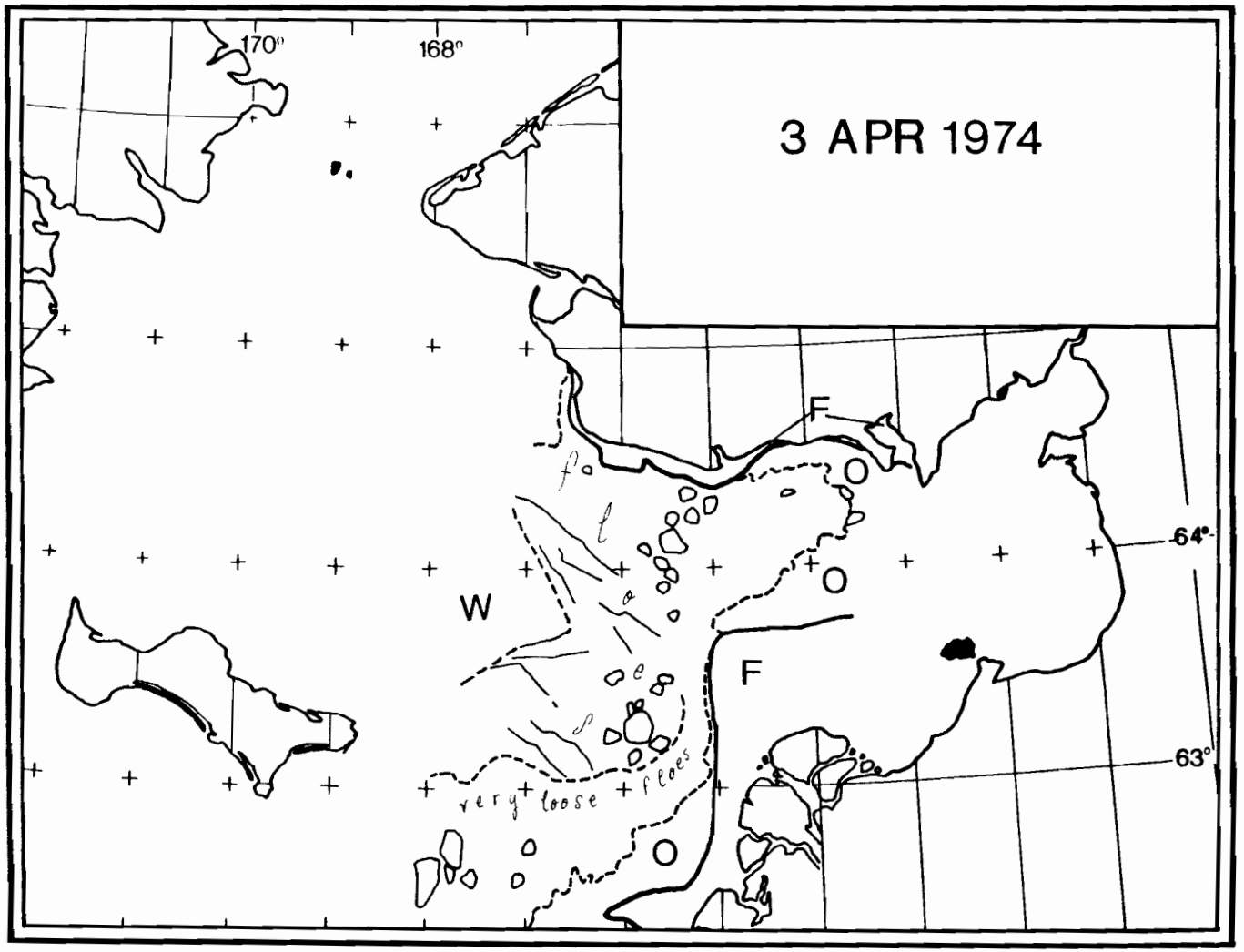

27 FEB 1974
170°
168°
64°
63°
F
N
W
gr
F

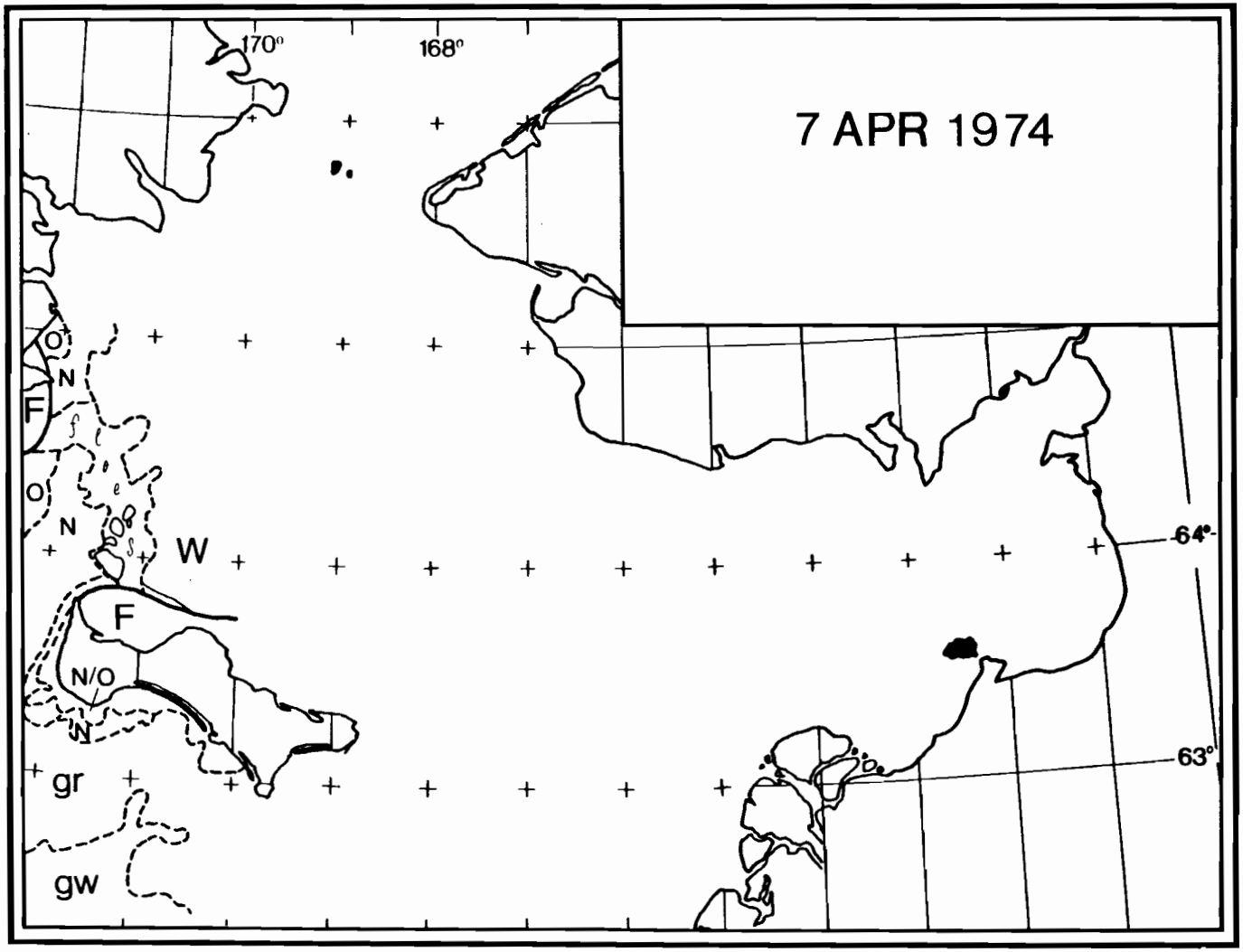

14 MAR 1974
64°
63°
F
NO
gr
gw
gw/W
F
168°
170°

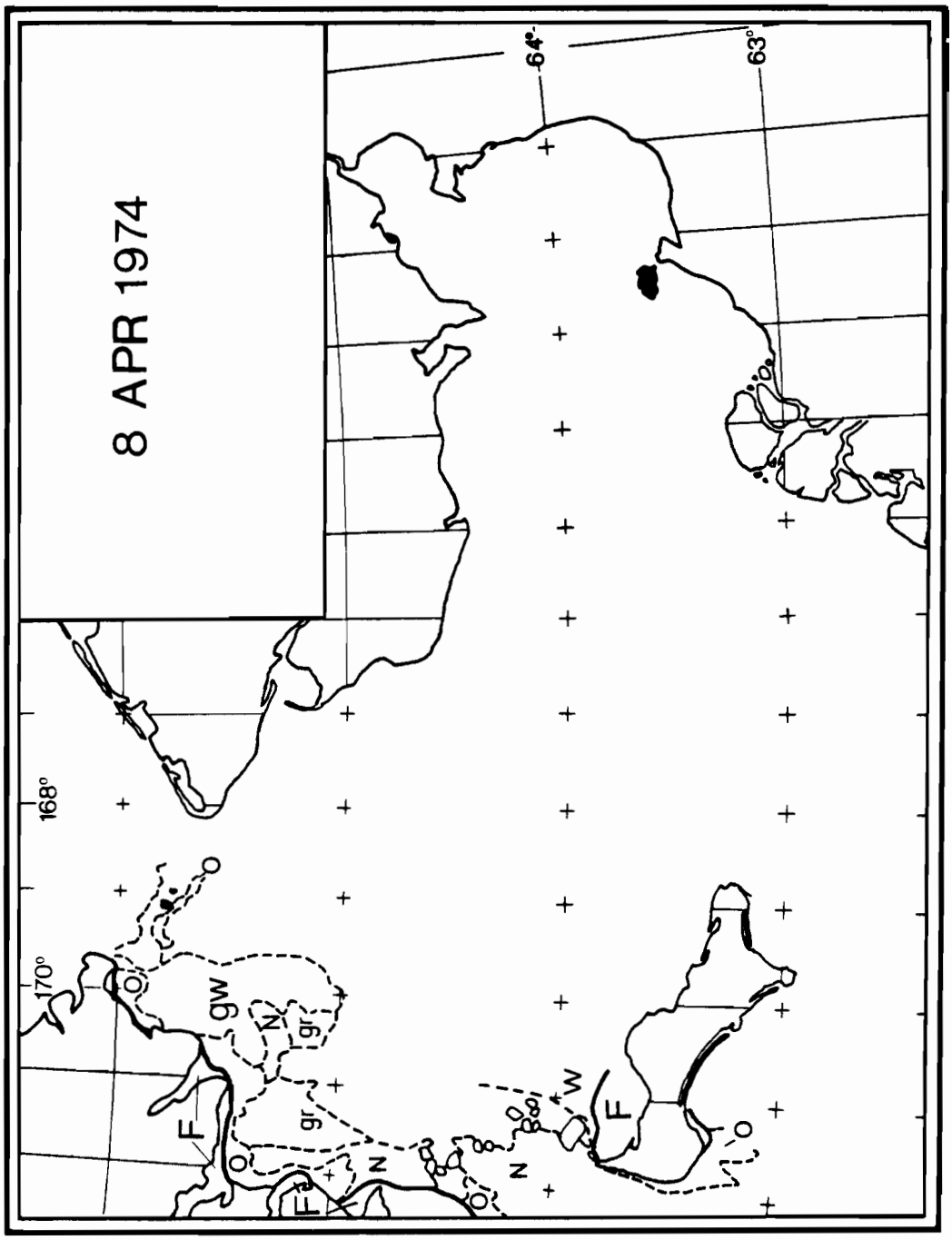

15 MAR 1974
64°
63°
F
N
N/O
gr
gw+
gw/W
F
N/O
gr
168°
170°

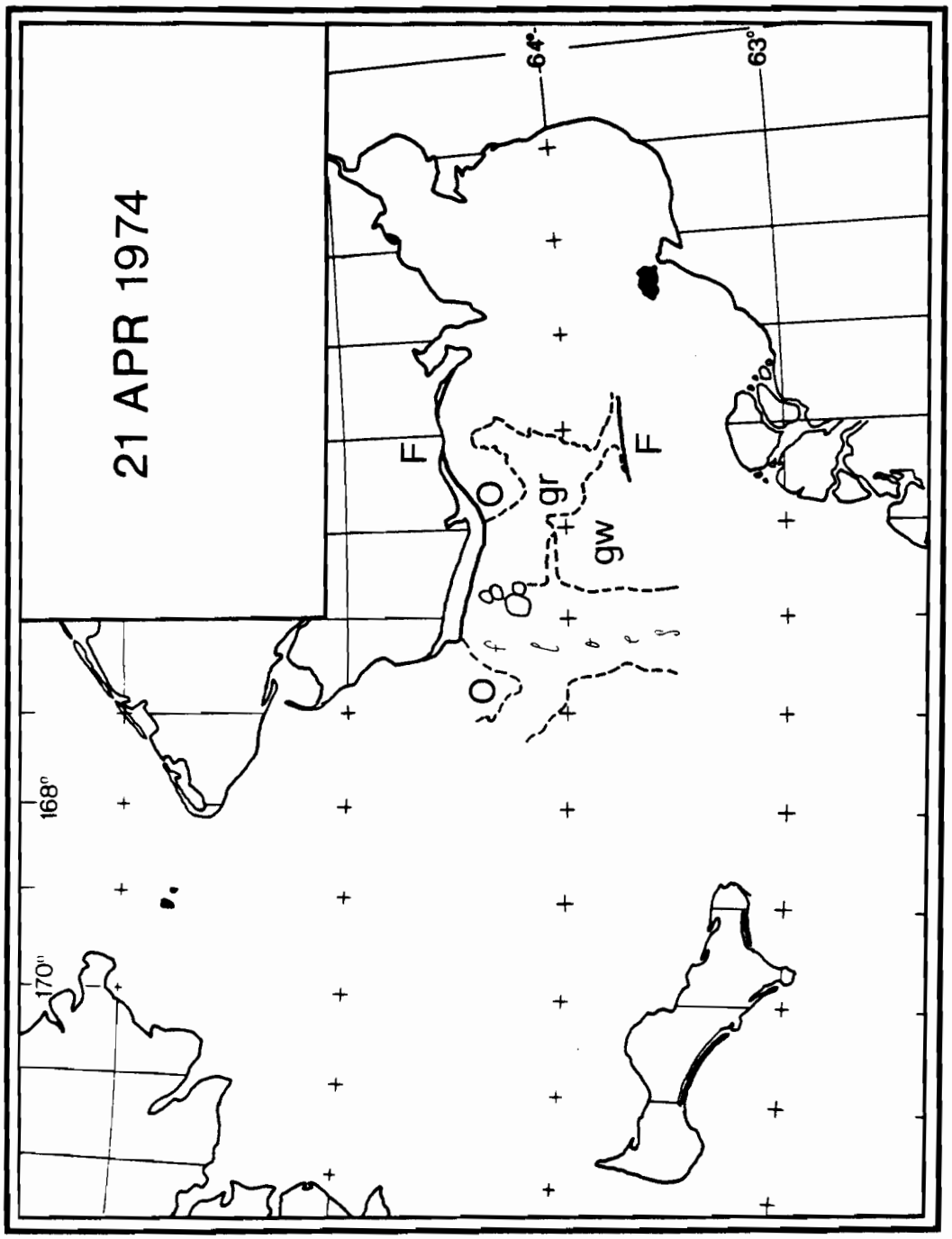

16 MAR 1974
64°
63°
168°
170°
N/O
N
F
gr
gw
F
gr
gr
W

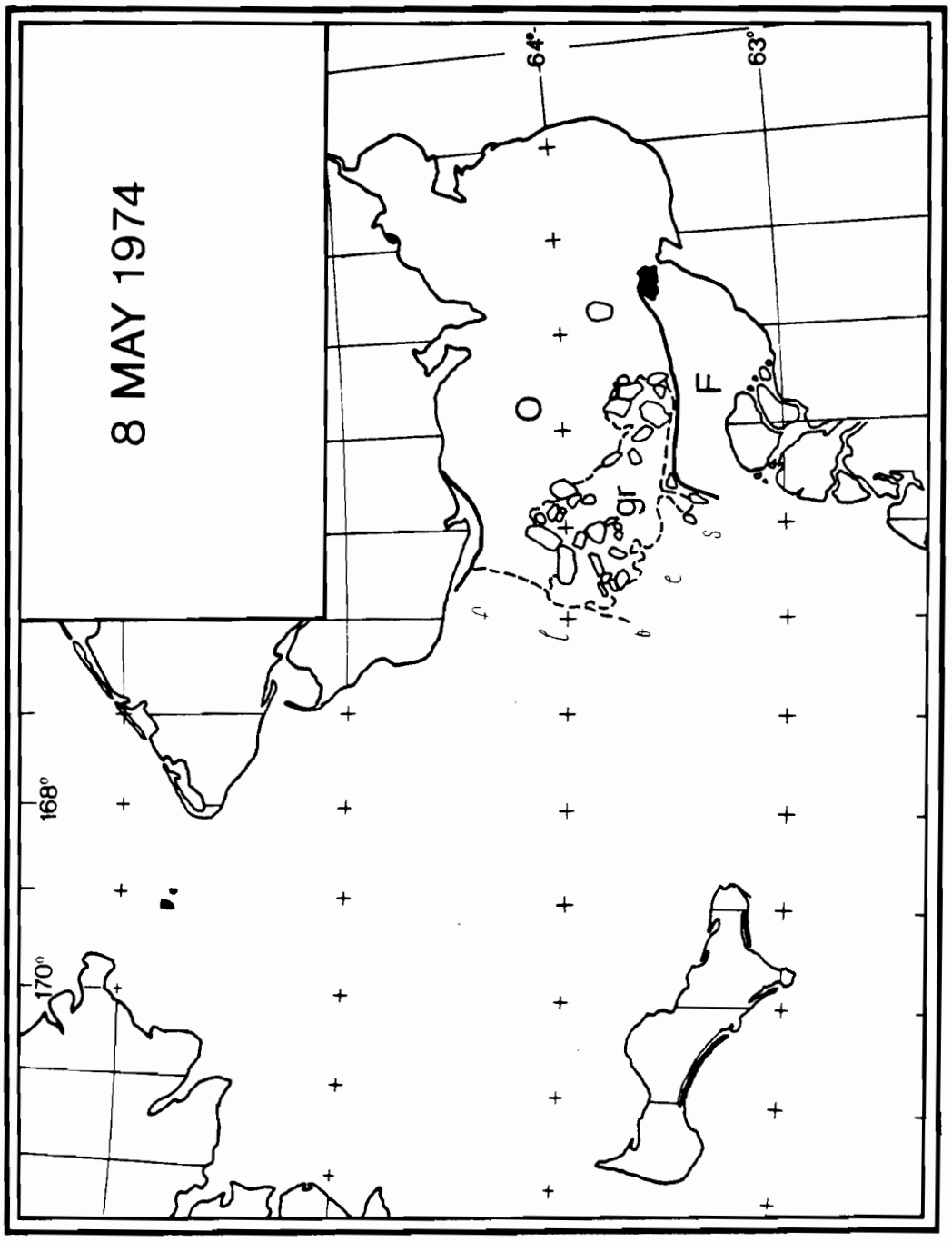

2 APR 1974
170°
168°
F
F
gr
N
N/O
64°
gr
F
63°

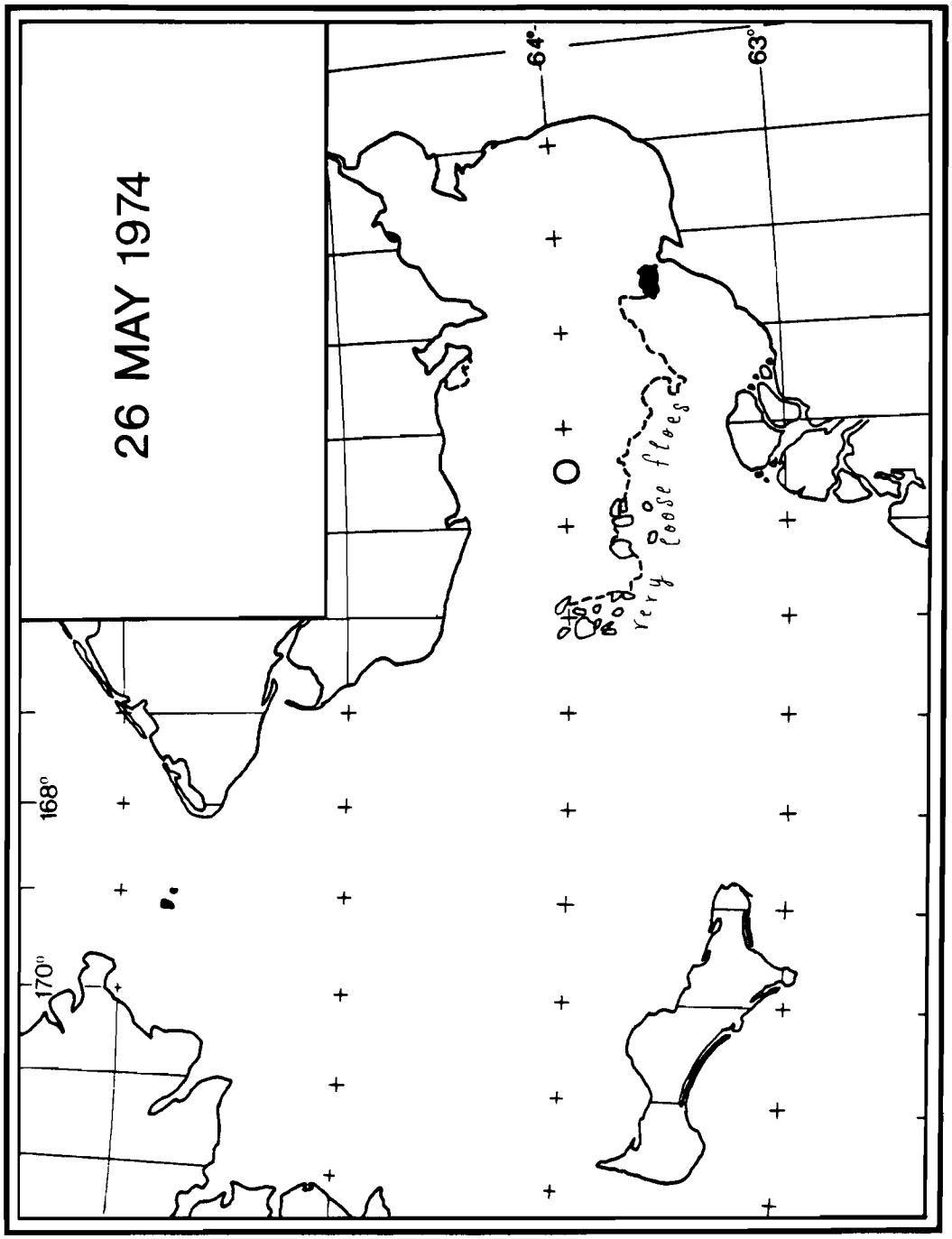

3 APR 1974
170°
168°
64°
63°
F
O
W
F
O
O
very loose floes

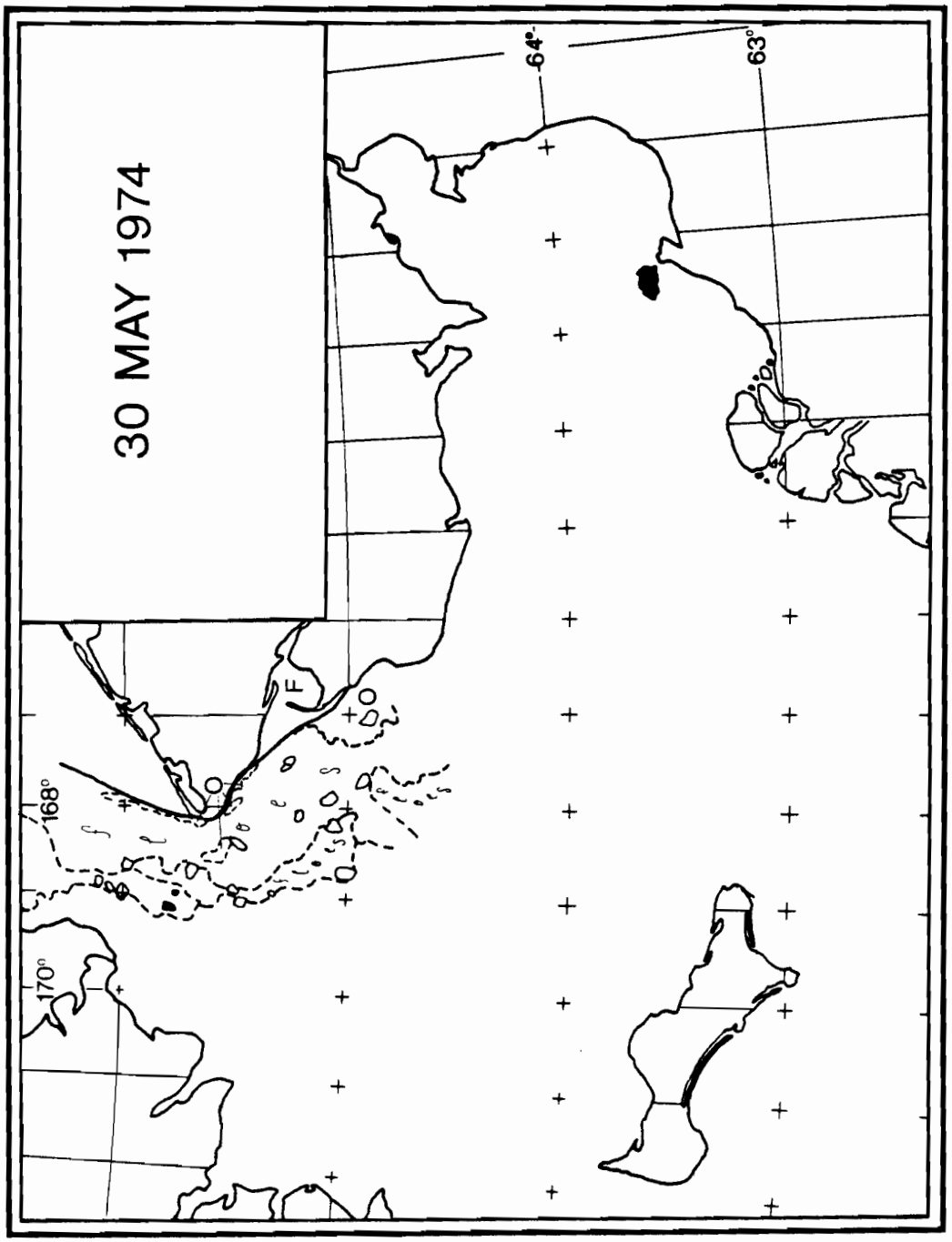

7 APR 1974
170°
168°
64°
63°
O
N
F
O
N
W
F
N/O
N
gr
gw

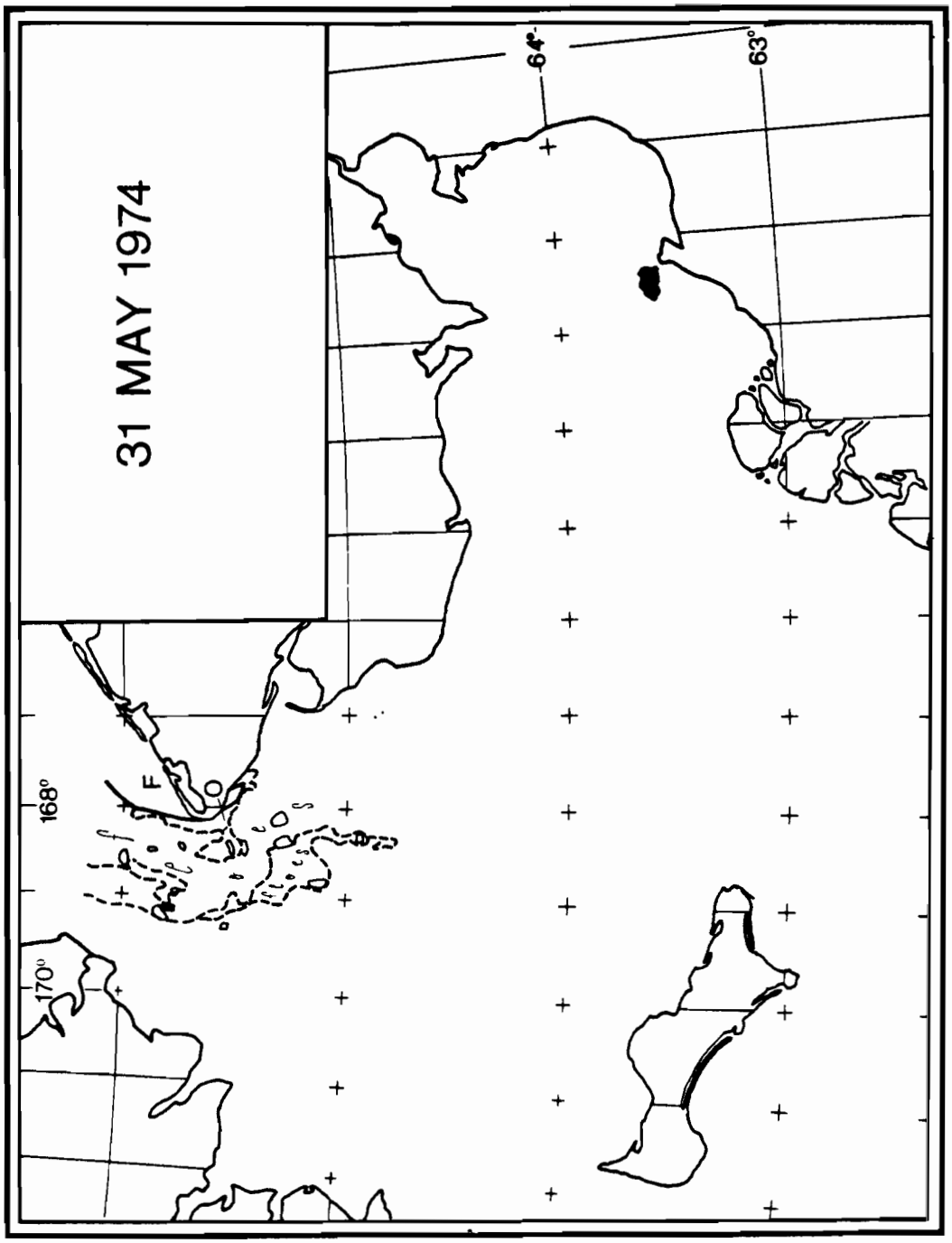

8 APR 1974
64°
63°
168°
170°
gw
gr
gr
F
F
F
N
N
W
O
O
O
O
O

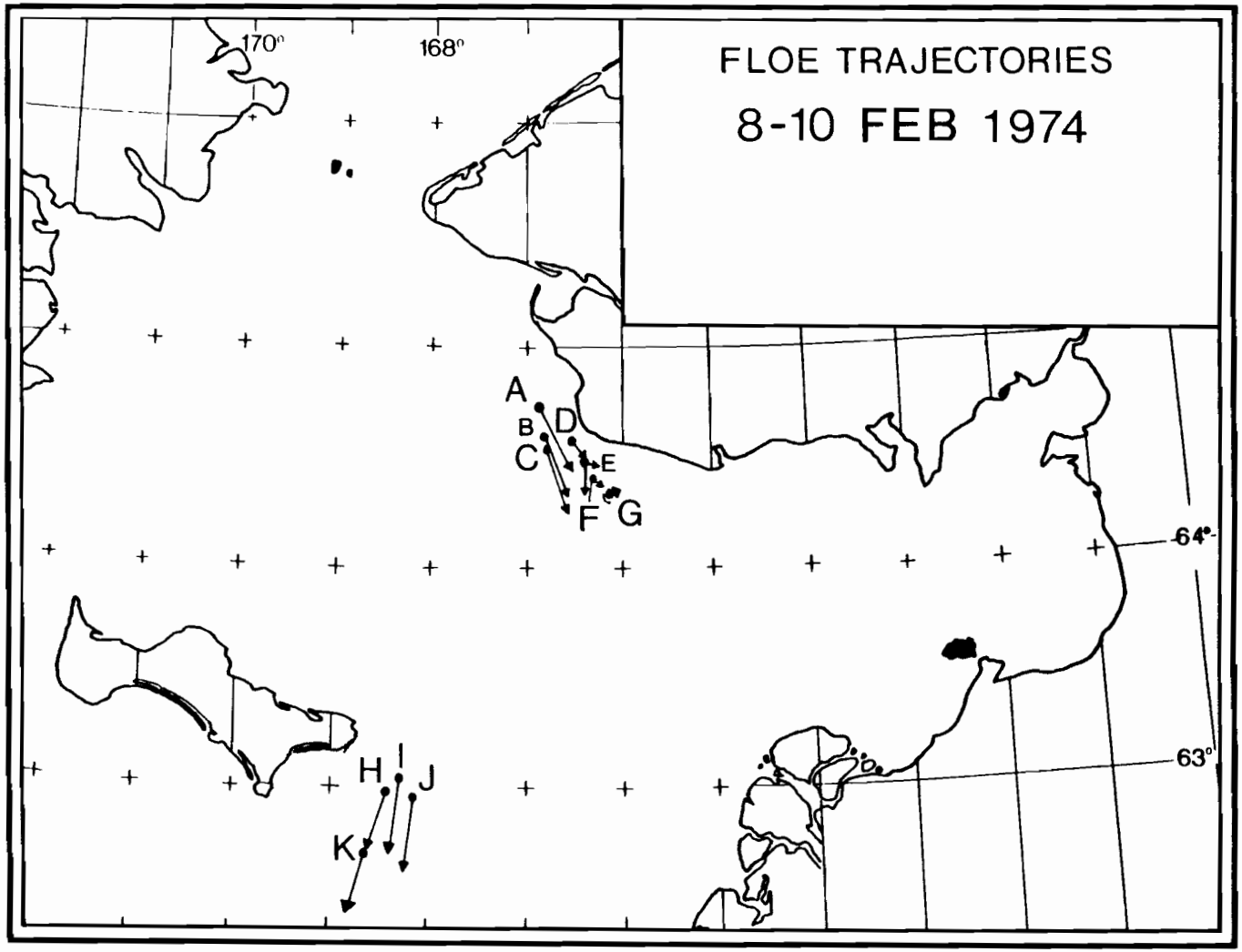

21 APR 1974
64°
63°
F
O
gr
gw
F
168°
170°

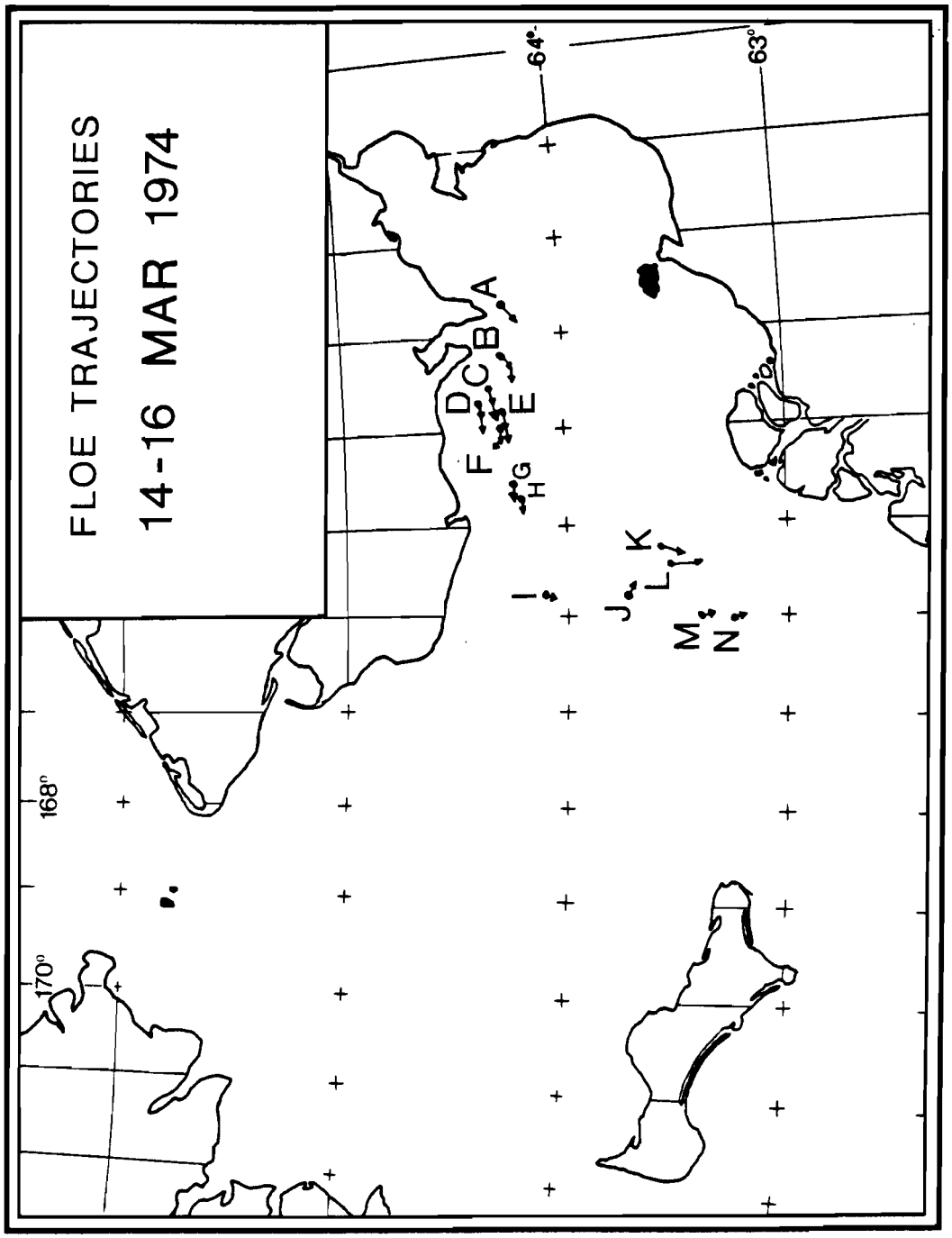

8 MAY 1974
64°
63°
168°
170°
O
O
F
gr

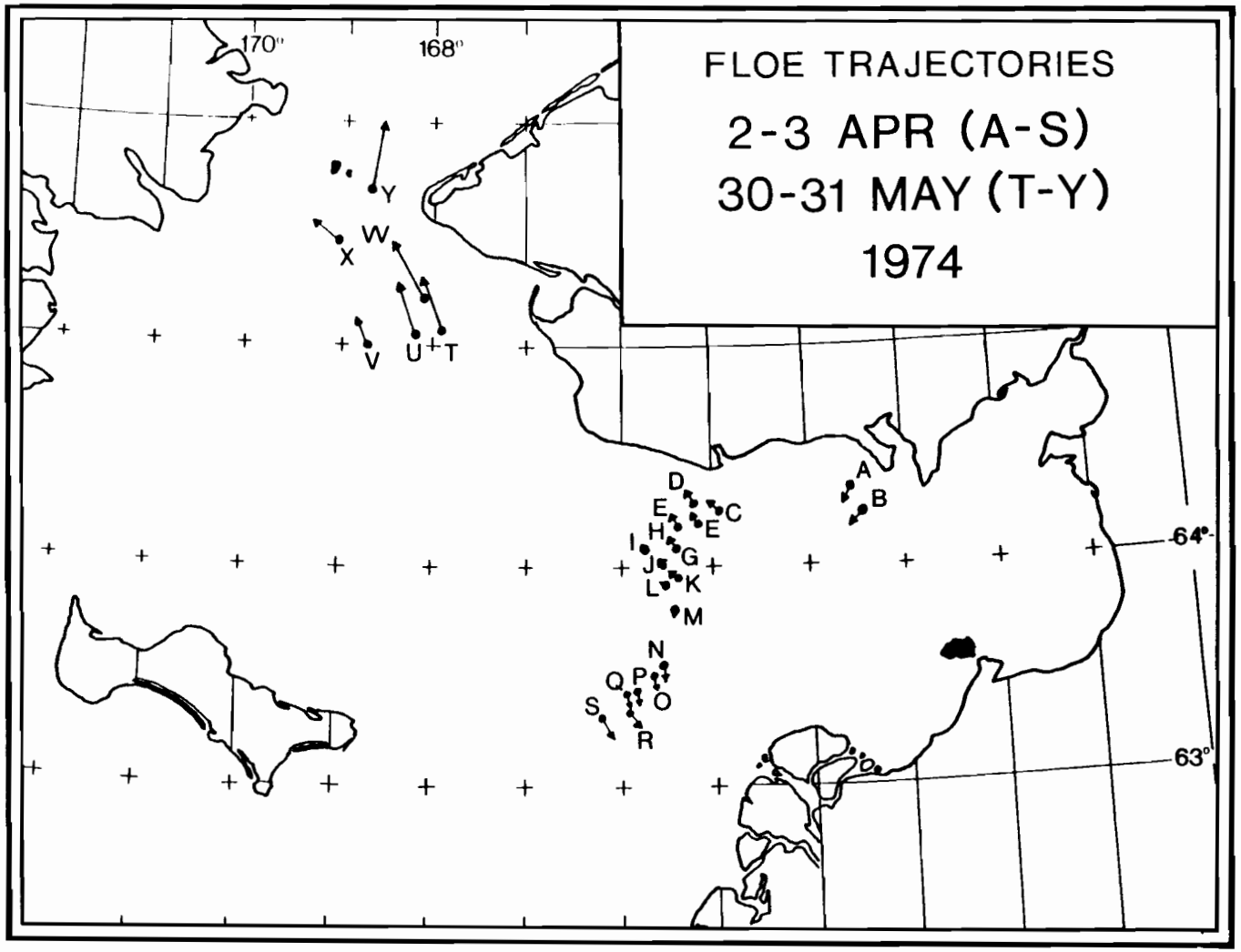

26 MAY 1974
64°
63°
168°
170°
very loose floes


30 MAY 1974
64°
63°
168°
170°
F


31 MAY 1974
64°
63°
168°
170°
F


FLOE TRAJECTORIES
8-10 FEB 1974
170°
168°
64°
63°
A
B
C
D
E
F
G
H
I
J
K


FLOE TRAJECTORIES
14-16 MAR 1974
64°
63°
168°
170°
A
B
C
D
E
F
G
H
I
J
K
L
M
N


FLOE TRAJECTORIES
2-3 APR (A-S)
30-31 MAY (T-Y)
1974
170°
168°
64°
63°
A
B
C
D
E
E
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y