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SEA ICE STUDIES IN THE SPITSBERGEN-GREENLAND AREA

Investigation No 28 540

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The overall objective of this investigation is to utilize LANDSAT data to study sea ice in general and in the Svalbard-Greenland area in particular and to compare the usefulness of LANDSAT and weather satellite data (NOAA-2, ESSA-8, etc.) for studying sea ice. The specific objectives are as follows:

1. To develop a technique for forecasting changes in the position and concentration of sea ice in the Svalbard area due to the influence of weather (primarily wind) and ocean currents.
2. To determine the physical characteristics of sea ice and ice boundaries, including statistical data on the dimensions and form of ice floes.
3. To determine ice drift velocities in the East Greenland Current, and thereby obtain an estimate of the outflow of ice from the Arctic Basin.

TECHNIQUES

MSS 7 of all the negatives received have been copied in BW at 1:1 mill scale. An extra copy has been sent to the co-investigator. MSS 4 has been used for several scenes for a closer study of special features on bare land and open sea.

From BW MSS 7 a great number of ice floes have been traced from day to day. Where land can be seen on the imageries, correct position can be determined, otherwise the drift estimations are influenced by position errors 1-2 km, which are found in the Landsat positioning system (NYE 1974). For velocities greater than 10cm S^{-1} the maximum error will decrease to less than 4% after a period of 5 days.

The frequency distribution of the size of the floes have been determined from BW (1: 500 000 scale) by a semiautomatic planimeter.

A parameter which has been used for the form of the floe is the quotient of the greatest width and length. This is read directly from the (1: 1 mill.) scenes, together with the orientation of the longer axis.

/is/ The contrast, sea-glacier ice is high making excellent condition for the survey of glacier fronts terminating in sea. Even when the sea/ice-covered, the shadow from the vertical ice cliff makes it possible to find and map the front. The glaciers terminating on land often have more diffuse borders as the front is partly moraine covered. The transfer to maps are made by directly projecting the images on to the maps by enlargement to the same scale.

The edge enhancement method (Matsuno, et al. 1975) has been used for extraction of various geological lineaments from satellite images. Positive and negative images are placed one above another and the upper one is slightly removed from the exact-fit position in any suitable direction; thus the edges of all dark and bright patterns will be exaggerated.

ACCOMPLISHMENTS

Drift velocities, direction and divergence

From the very comprehensive material received, it has been possible to obtain unique information on the ice drift condition in a remote area of difficult access. The results are shown in Fig. 1. It has been possible to follow some of the floes over periods as long as 15 days, i.e. only one day less than the total coverage period of Fig. 1.

During the first part of the period there was a prevailing northerly wind in the area. The last part, however, was calm with fair weather caused by a high pressure area extending eastward from Greenland. The drift speed therefore generally decreases towards the end of the period. In the north-west of the Svalbard archipelago, the effect of the Vest-Spitsbergen current is evident.

The numerous ice drift estimations in the East Greenland Sea make it possible for the first time to determine the drift speed simultaneously at various location across the Fram Strait. From Fig. 2. it is seen that a maximum speed of about 25 cm S^{-1} is observed between 2°E and 4°W in the area between 80 and 81°N . The average speed across the strait is 20.5 cm S^{-1} during the period. As the width of the drift ice stream is 330 km , and the average thickness of the ice is around 3 m thick, the outflow of ice from the Polar Ocean during the period 21. - 27. April equals 0.2 Sv ($1 \text{ Sverdrup} = 10^6 \text{ m}^3 \text{ S}^{-1}$). During the following

period, 27. April-2. May, the observations, though fewer in number, indicate that the outflow had decreased considerably to about 0,1 Sv, with an average speed of the outflow of about 10 cm s^{-1} . The wind stress is relatively low in the area as well as over the Polar Ocean during the latter period, and the observed drift speeds may therefore indicate the velocity of the surface current.

A Nimbus - 6 located automatic station was placed on an ice flow at 81°N and 0°W the 19. April. During the period 21.-27. April this station drifted approximately along the meridian at an average speed of $23,5 \text{ cm s}^{-1}$. This is very close to the Landsat drift observations as represented in Fig. 2. Thus these two independent methods mutually confirm each other. The present material indicates that there may be great variations in the drift speed from floe to floe within a given area. On one occasion a certain floe became relatively isolated from other floes with comparable dimensions. This floe, indicated by IF in Fig. 1, is seen to move very different from the others in that area. The average speed for this particular floe during the period 21.-27. April, is 31 cm s^{-1} while the speed of the other floes is 22 cm s^{-1} . The reason for this may in part be that the ice floe had an exceptional shape both above and below the water surface.

When the drift ice in the Trans Polar Current passes into the East Greenland Sea considerable acceleration takes place. For the period 27. April to 2. May the observation in the central area ($80-81^{\circ}\text{N}$, $0-4^{\circ}\text{W}$) noted in Fig. 2, shows that the average speed increased from $11,1 \text{ cm s}^{-1}$ at $80,8^{\circ}\text{N}$ to $21,4 \text{ cm s}^{-1}$ at $80,1^{\circ}\text{N}$. The divergence in this area was $2,7 \times 10^{-7} \text{ s}^{-1}$ for the five-day period. This corresponds to an opening up of as much as 10-12% of a given area over the period mentioned. At this time of the year open water at these latitudes may refreeze. Because of this effect it becomes important to carefully select the best measuring line when the outflow is to be estimated.

Fig. 3 gives a unique overview and detailed information on the drift speeds which may be encountered in the eastern part of the archipelago. The highest speed, 54 cm s^{-1} , is for a floe moving along the local ice edge (cf. Fig. 4). A considerable acceleration is seen to take place when the ice flow passes between Kvitøya and Storøya.

A few hours after the image (Fig.3) was registered, a flight was made along the northern side of Nordaustlandet and across to Kvitøya for deployment of a Nimbus station on the latter. This scene will therefore be studied closer for comparison with surface observations of various phenomena.

Form and dimensions of ice floes

The Landsat imagery represented in Fig. 4 shows an area in the eastern part of the archipelago when a transport of drift ice occurred between the islands caused by a north-north-westerly wind. The figure reveals a lead pattern which is predominant in the area. Leads are seen to run from the maximum pressure zone along the islands towards the core of the ice flow. The direction of these leads is assumed to be perpendicular to the resultant force of the friction along the boundaries of the flow, and the wind stress. Should the patterns formed on each side of the core now and then overlap each other due to changes in direction of wind and sea currents, floes may form with the parallelogram like shape such as seen in great number in Fig.4. The mentioned floe shape is also illustrated by Fig.5 where the direction of the ice flow is south-southwestwards along the continental slope north of Spitsbergen.

For the area represented by Fig. 4 the length and the width of a number of floes have been estimated. The relationship between these two lengths is shown in Fig. 6. The average quotient is seen to be close to 0.5.

In Fig. 7 are given some examples of the frequency distribution of the acreage at the floes. Three images from the central area of the East-Greenland Current and another three images which includes the ice border, have been considered. As can be seen there is no special difference in the distribution between the two locations in the ice flow. A possible difference caused by swells for instance, may in case be found between floes with average less than 10 km^2 .

Land map improvements

The shape of Kvitøya has been further corrected from the image copied in Fig.4. A new map is now under preparation.

Glaciology

The tracing of the so-called surging glaciers is of special interest in Spitsbergen as this is a frequent phenomenon here. By a surge the glacier may advance many km within a year and is thus easily detected on a LANDSAT image. During a surge the glacier surface is also heavily crevassed and would appear with a different brightness. Fig. 8.

With the frequent passages over Spitsbergen it is possible to get a rough idea of the mass balance in different areas. The large change in albedo between snow and glacier ice is used to follow the snowline as it shifts upwards during the ablation season. There is a good correlation between the net mass balance figures and the height of the equilibrium line. On the subarctic glaciers the snowline and the equilibrium line are, however, not identical. The thick layer of superimposed ice on the surface separates the two lines by more than 100 m vertical height. Efforts are now being made to find means to separate the superimposed ice from the normal glacier ice on the images. Fig. 9.

Fig. 10 shows the variation in the height of the snow line in Southern Spitsbergen July 18th. The pattern of the iso-lines for the snow line heights fits well in to the known picture of the glaciation limit.

Geology

The Edge Enhancement method (Matsuno, et al., 1975) has been applied to analyse the fracture systems of NW Spitsbergen, using the MSS-7 band monochromatic image (E-2467-12374, date: 3, May, 1976), enlarged into 1:420,000 in scale. Fig. 11. Although most nunataks are covered by snow in this time of the year, many important geologic structures are distinguished on the image. Major lithologic borders between the Caledonian metamorphics and the middle Paleozoic sedimentary rocks are represented by the areas of different ridge-patterns. The diagonal faults and main joint systems are well seen as small scale patterns on the image. The predominant gneissosity is also shown very well in the whole area. There is a good possibility to distinguish the borders of different lithologic units in the Caledonian metamorphics by careful examinations of the edge enhanced pattern from the snow-free time of the year. This study will be extended to cover whole Svalbard.

DATA QUALITY AND DELIVERY

The quality of data received is generally excellent. Since October 1st, about 340 scenes have arrived. These are now being investigated with respect to phenomena within a series of disciplines. The ^{x/}amount of data received and the repetitive coverage has led to progress on all objectives of this investigation.

SIGNIFICANT RESULTS

Detailed information on the outflow through the Fram Strait of ice from the Polar Ocean over shorter periods have been obtained. It is found that the speed of the outflow may vary about 100% over periods of a few days. The core of the East Greenland Current is found between 2°E and 4°W. The speed of the surface water at 81°N is for a calm period estimated to be about 10cm s⁻¹.

A new surging glacier has been discovered and new fronts of several glaciers have been determined. The variation of the snow line with respect to distance from the coast has for the first time been determined for the southern part of Spitsbergen. Great variations was observed, from 200 m in east to 550 m in the central area of the island.

ACKNOWLEDGEMENT

This report has been prepared in co-operation with Mr. O. Liestøl (glaciology) and dr. Y. Ohta (geology) at the Norwegian Polar Research Institute while Mr. Ø. Finnekåsa has prepared the necessary photo products and produced the necessary back ground material for the investigation.

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Nye, J.F., 1974, AIDJEX BULLETIN No. 27

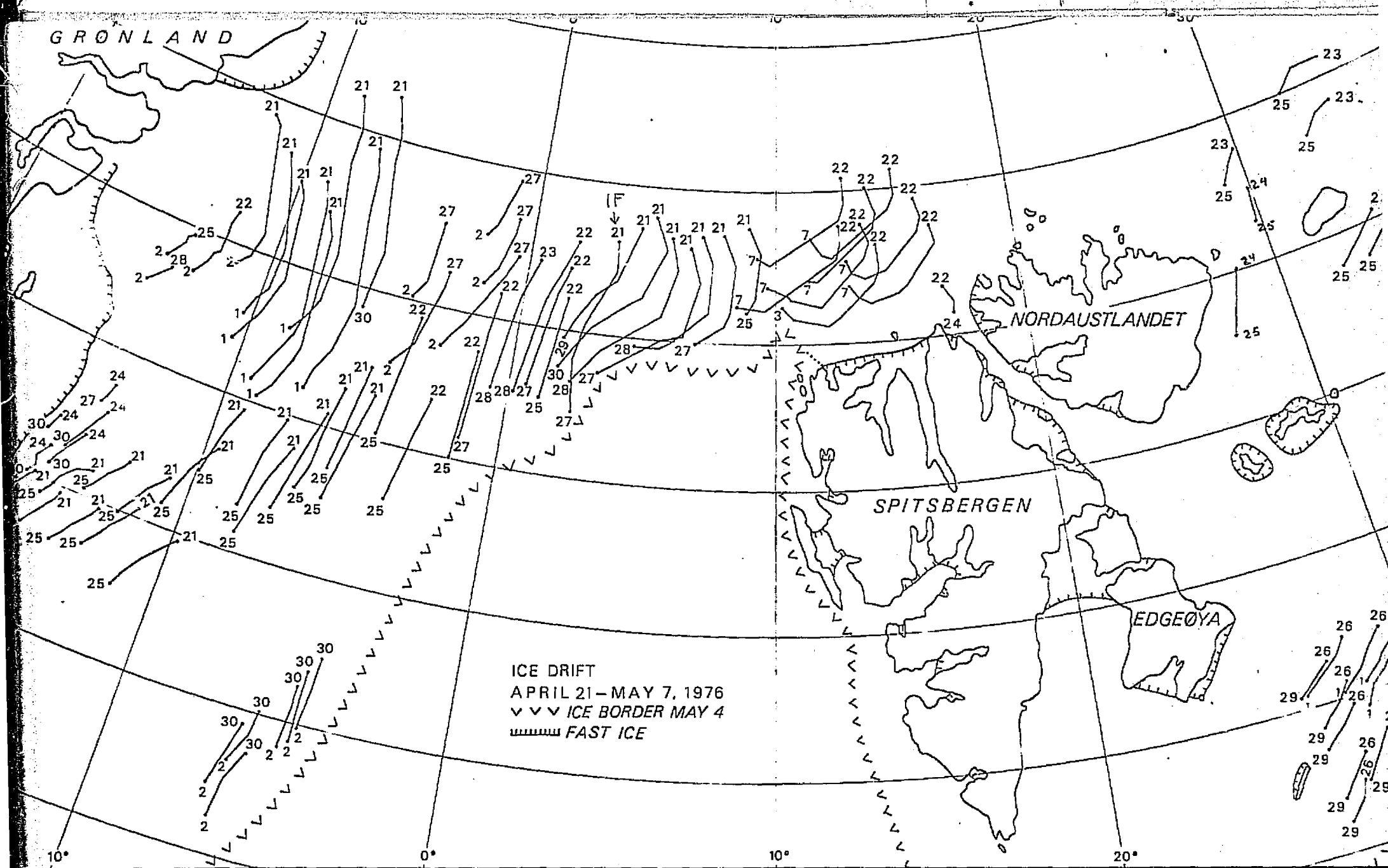


Fig.1

Displacements of ice floes as observed between 21 April and 7 May 1976. The first and last day of the observing period for an individual floe are indicated.

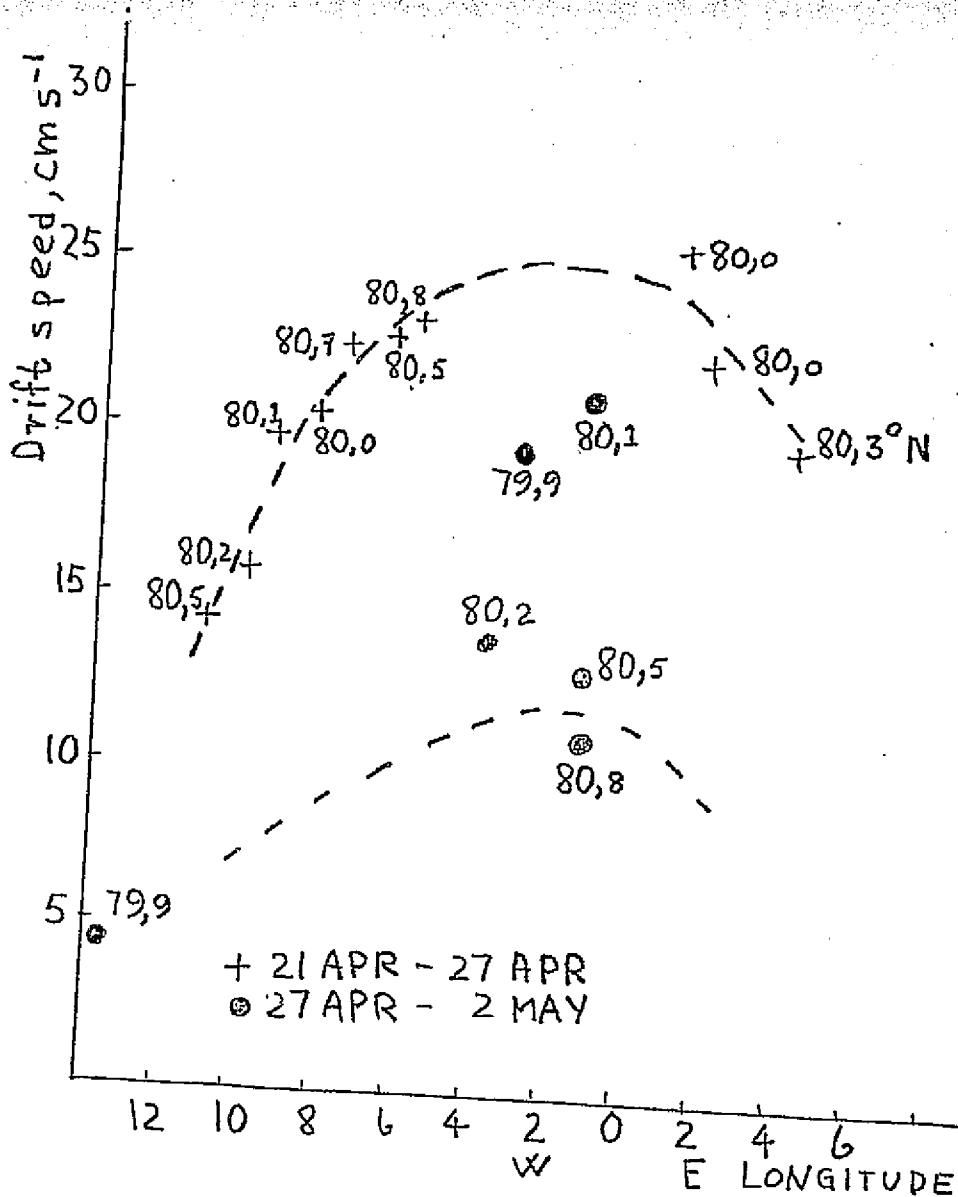


Fig.2

Drift speeds of floes in the Fram Strait during the period 21 April-2 May 1976. The latitude is given at the observed averages.

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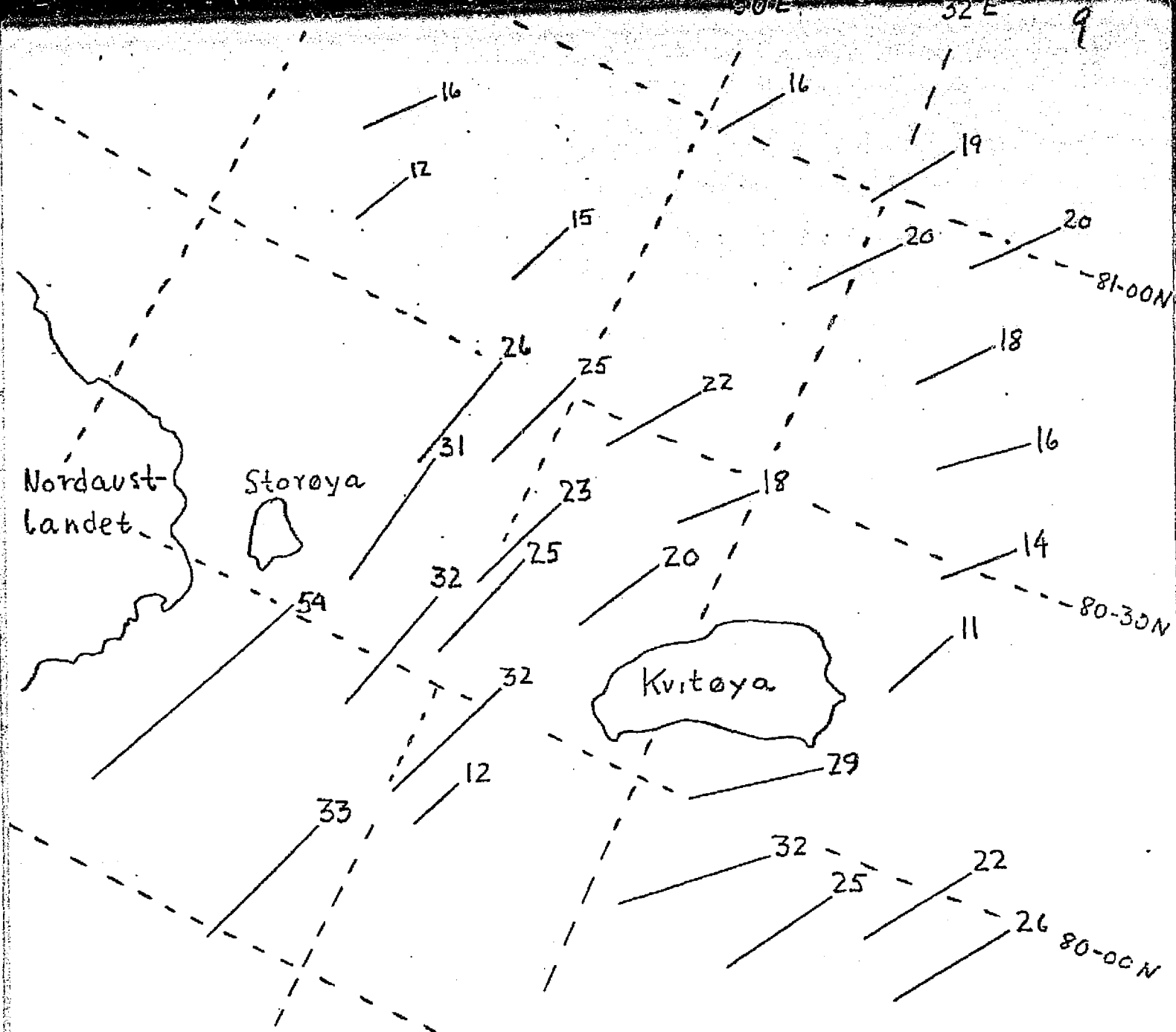


Fig.3

Drift speed (cm s^{-1}) of floes from 24 to 25 April 1976 in the area represented by Fig.4.

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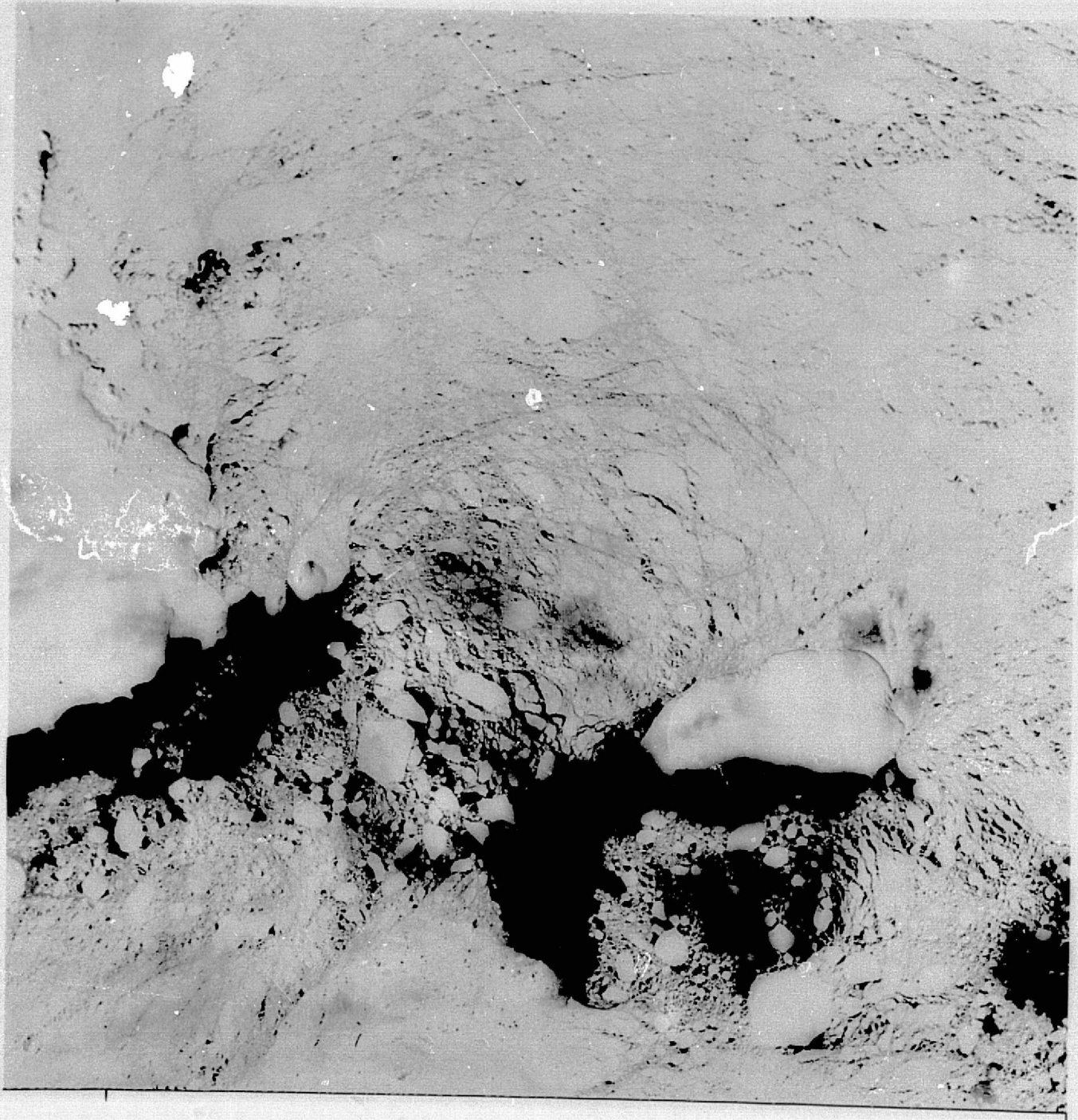


Fig.4

Imagery obtained in the eastern part of the Svalbard archipelago. There is a strong drift of ice from north-northeast through the passage between Kvitøya and Nordaustlandet(cf.Fig.3).Note the lead pattern in the ice flow as well as the great quantity of floes with a parallelogram-like shape.

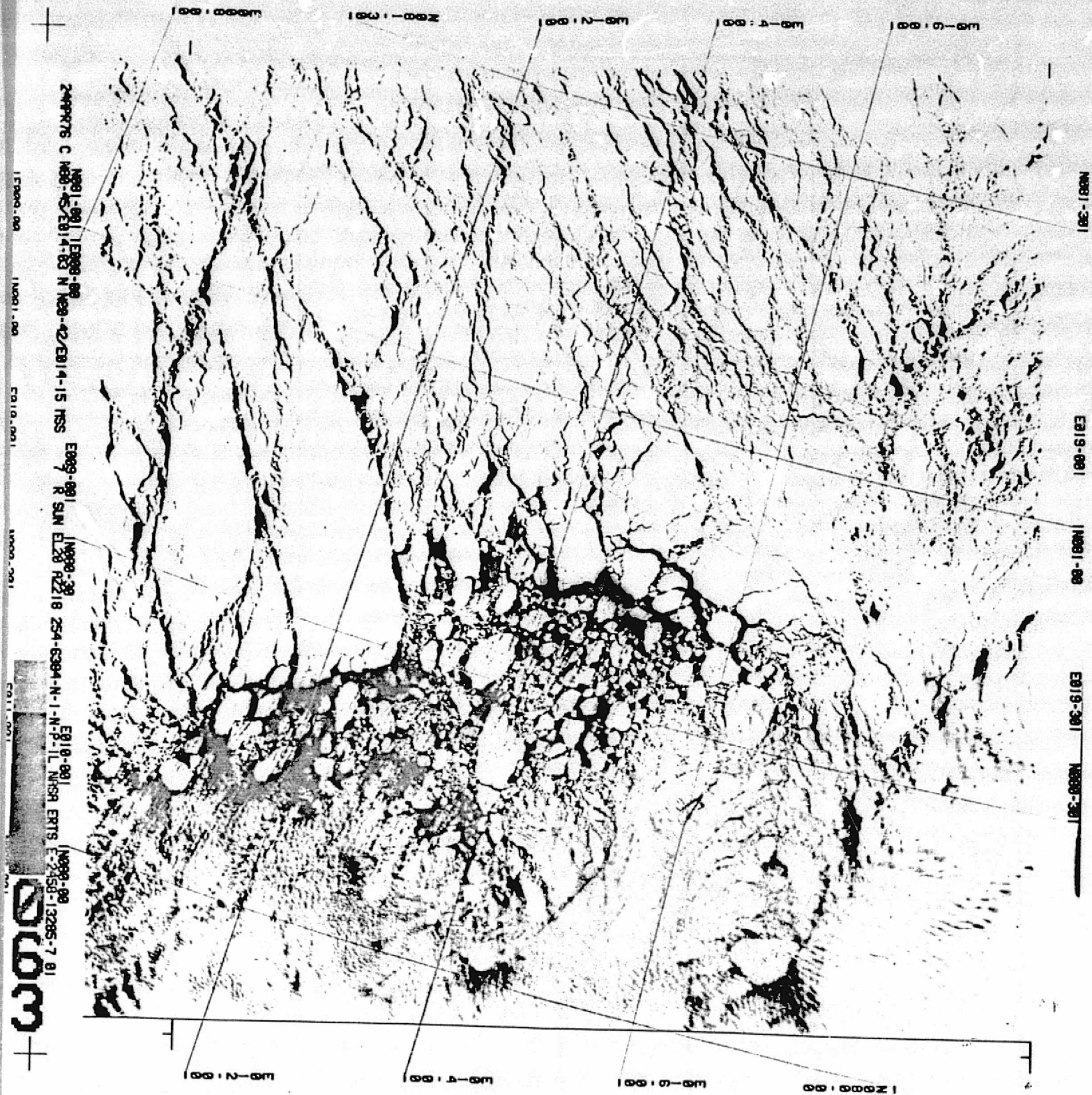


Fig.5

Floes with a parallelogram like shape north-west of Spitsbergen .

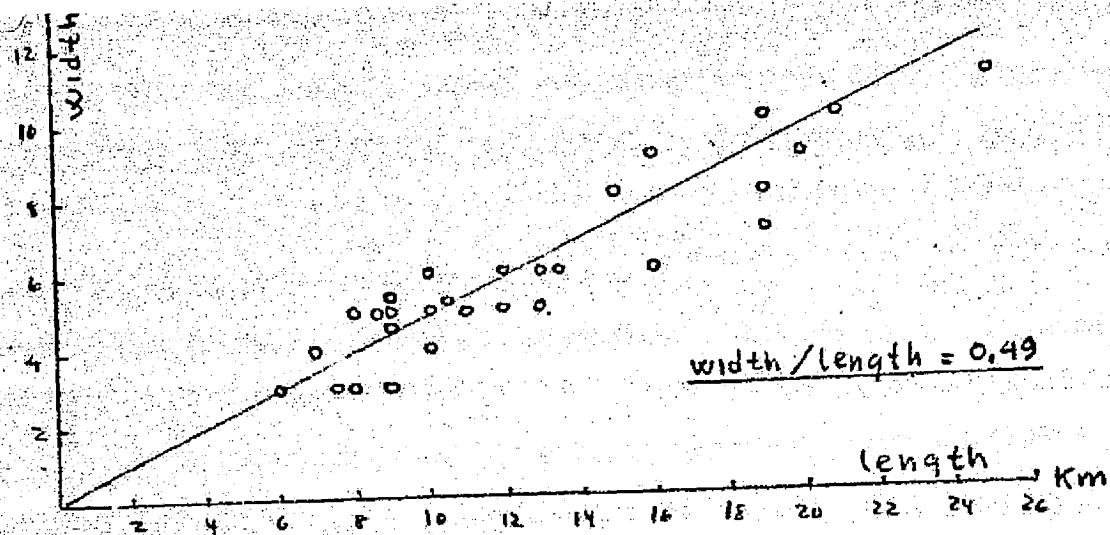


Fig.6

Relationship between length and width of ice floes in an area of outflow represented in Fig.4.

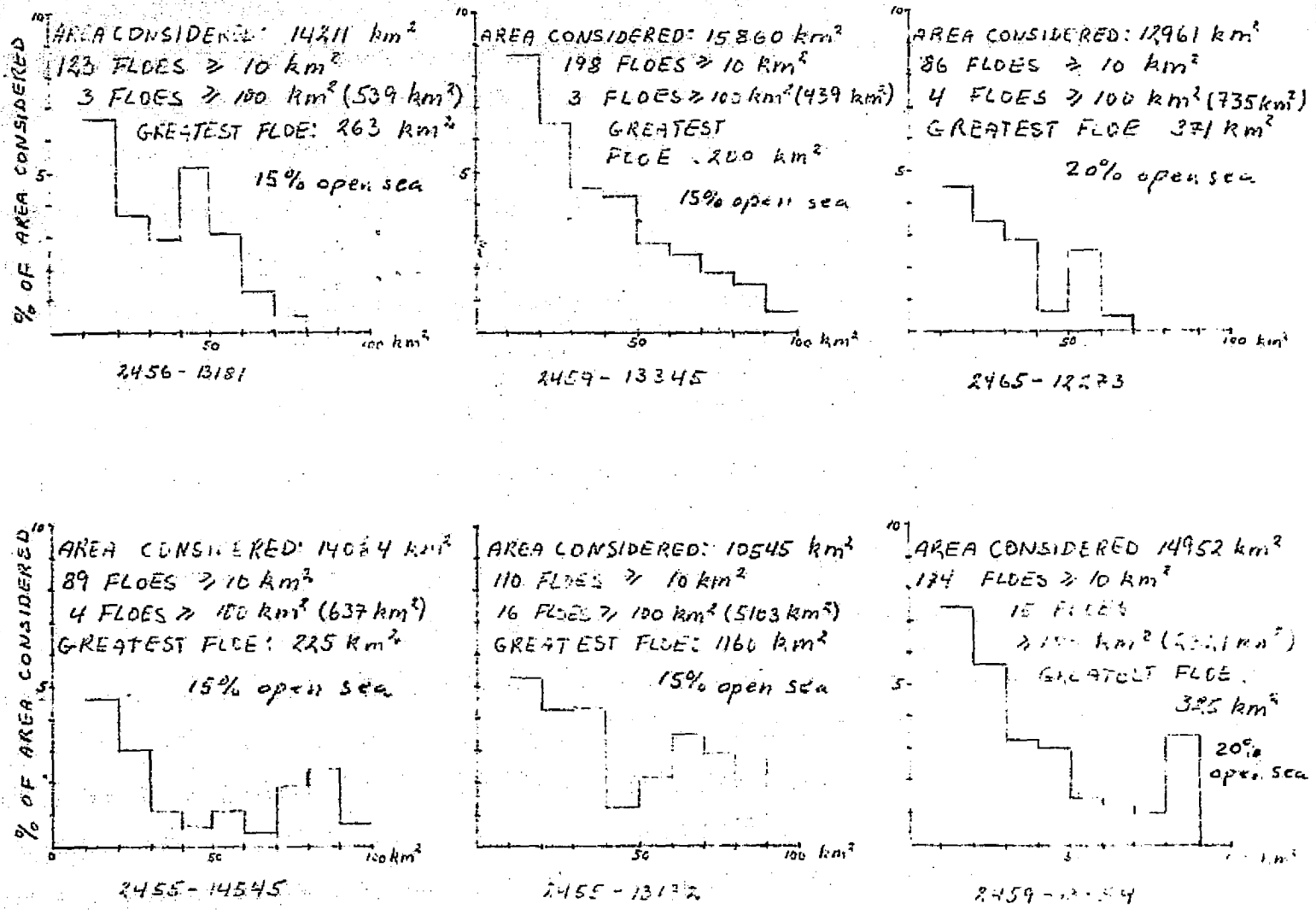


Fig.7

Graphs showing the frequency distribution of floes with different acreage. The upper row is from the central area, and the lower row is from the border area in the East-Greenland Current.

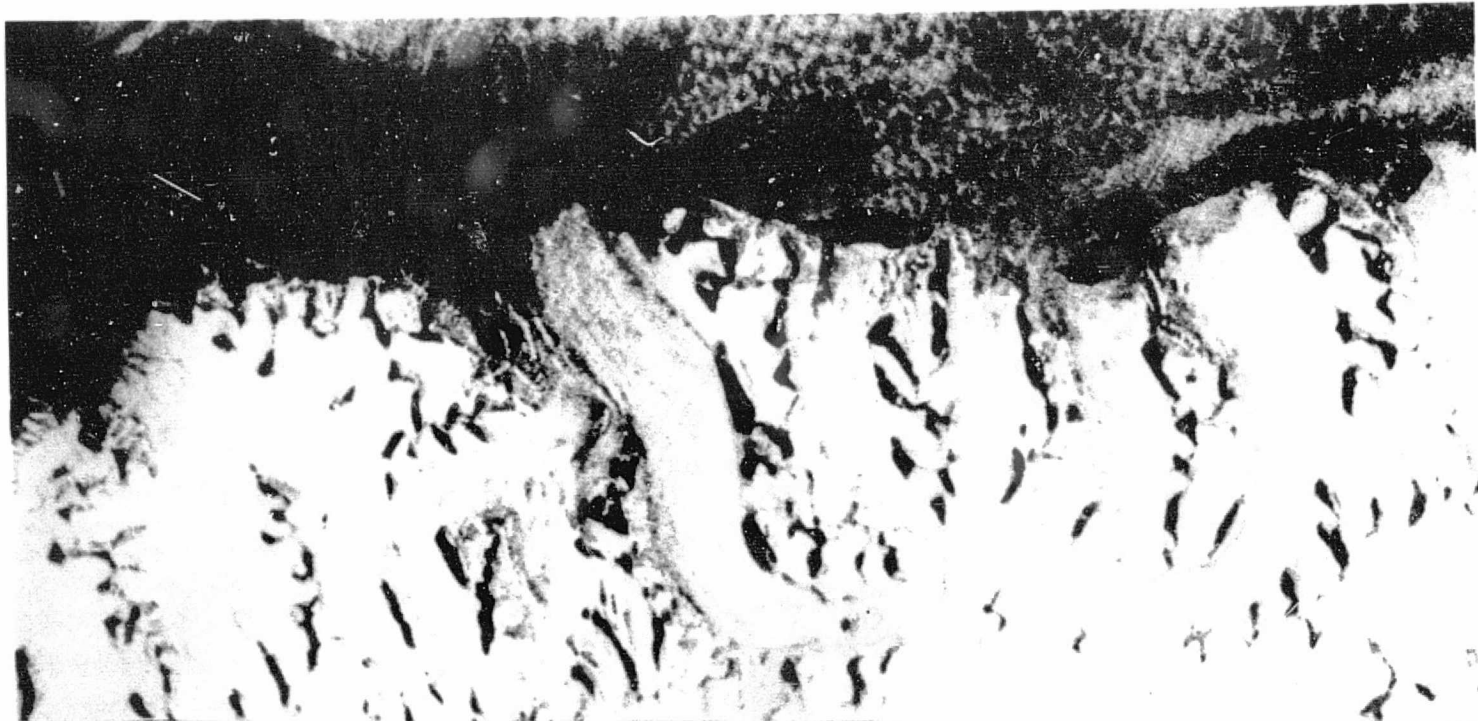


Fig.8 above shows the surging glacier Jemelianov, marked J in Fig.10. Fig.9 below: The glacier marked F is the Finsterwalderbreen where mass balance studies have been carried out by Norsk Polarinstitut since 1950. The snow line is clearly seen. The somewhat brighter gray area below this line is perhaps superimposed ice. The glacier is marked F in Fig.10.

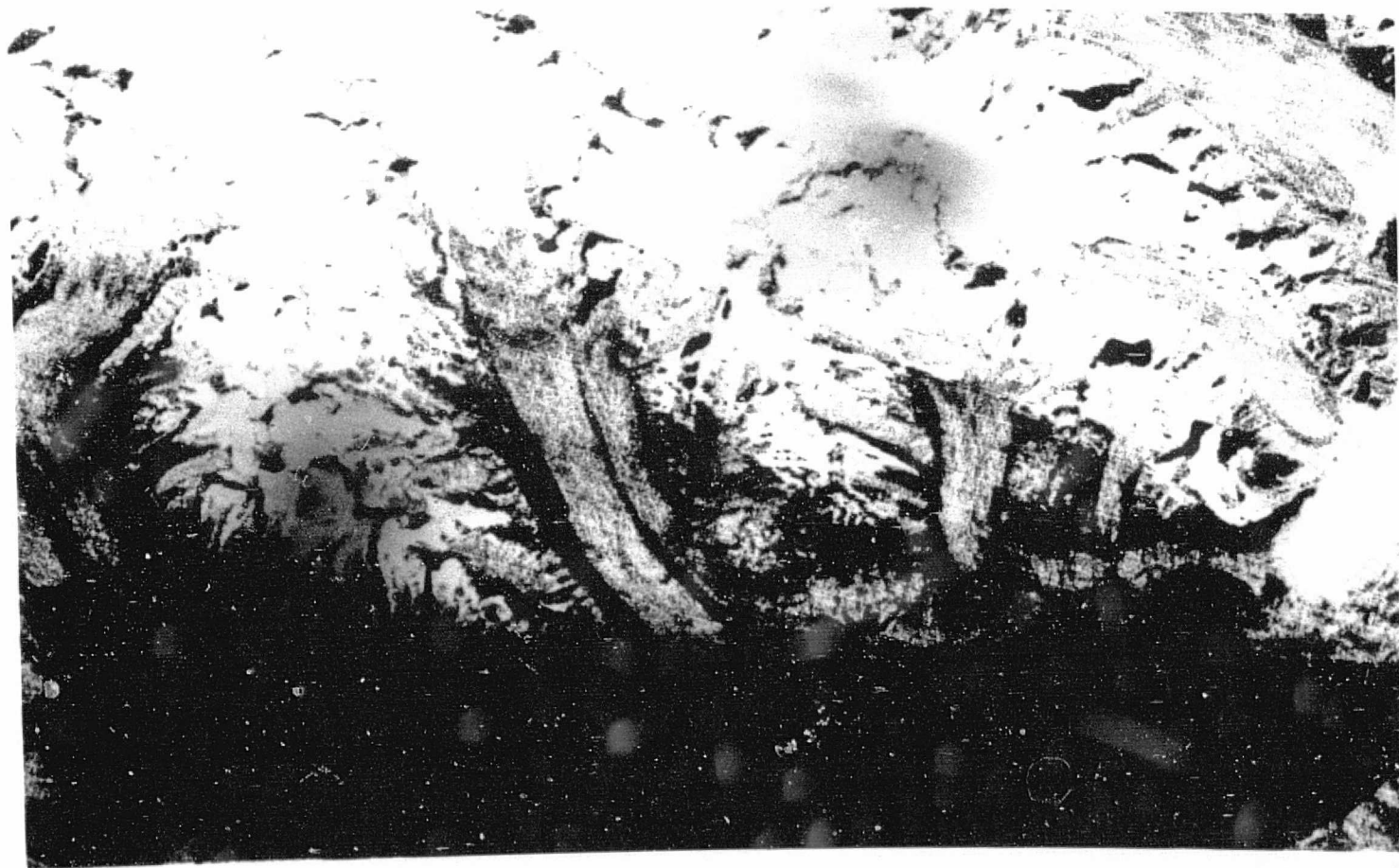


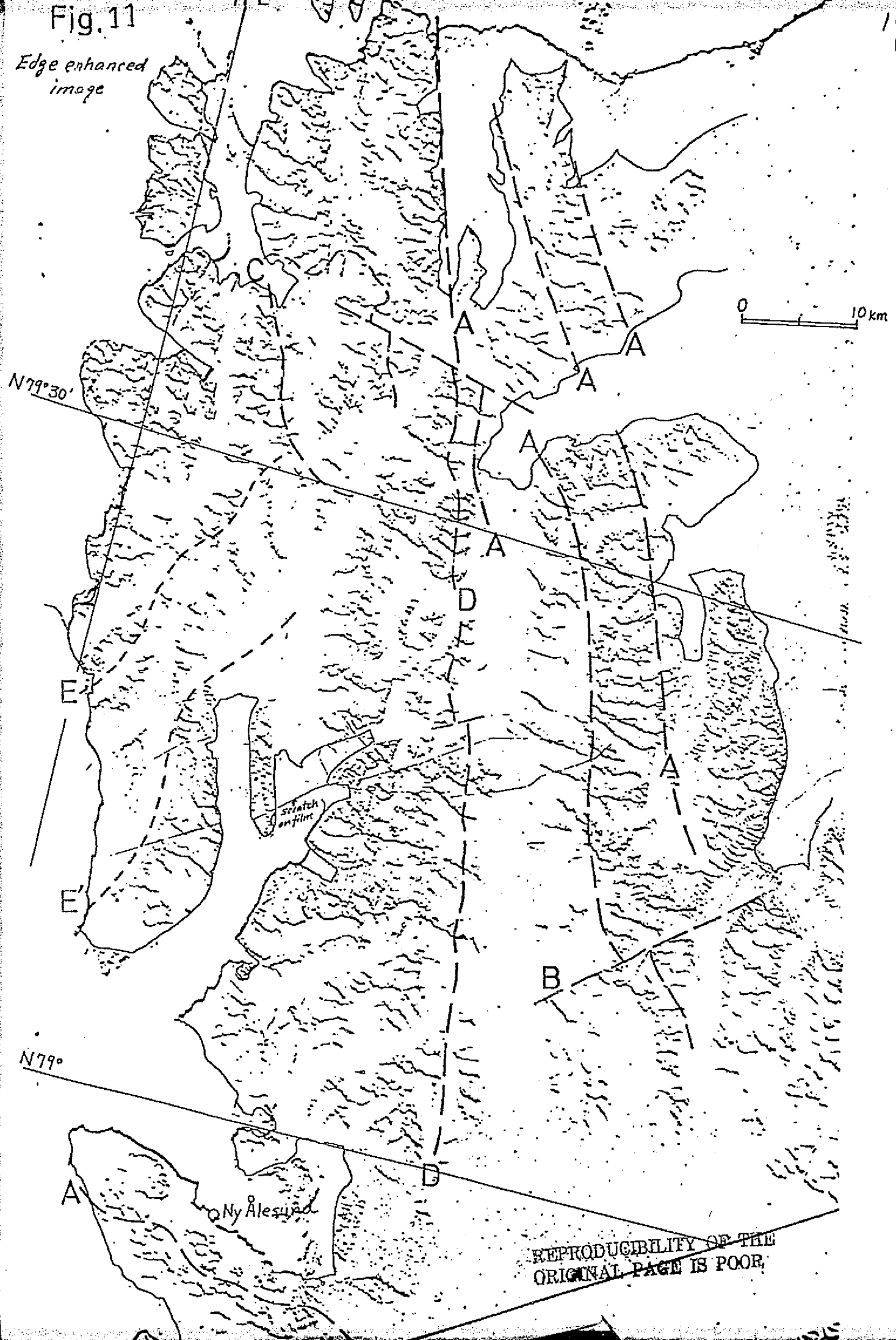


Fig. 10

Iso-lines for the height of the snow line on glaciers in the southern part of Spitsbergen, 7 July 1976.

Fig. 11

Edge enhanced image



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