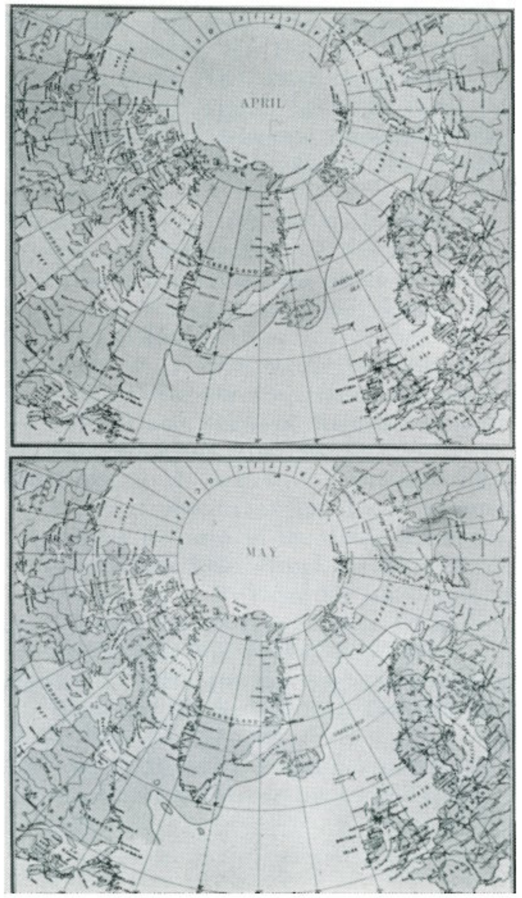
Sea Ice in Satellite Pictures

BORGTHÓR H. JÓNSSON,
THE ICELANDIC METEOROLOGICAL OFFICE, KEFLAVÍK, ICELAND

ABSTRACT

The outflow of ice from the Polar basin through the gap between Spitsbergen and Greenland has been investigated with the aid of satellite pictures and monthly surface pressure maps. An attempt has been made to classify the types of sea ice which occur in the coastal waters of northern Iceland. It is suggested that persistent northerly winds over the area east of Greenland will cause greater amount of ice to drift into that area, and consequently enhance the chances that the ice-pack will drift all the way to the north coast of Iceland. A suggestion is made that by using Zubov's empirical rule a 10 to 15 days ice forecast may be prepared, once the exact position of the ice edge has been mapped by the aid of satellite pictures.



Observation of sea ice conditions by weather satellites is a new and valuable aid in charting and following the movement of the ice edge. The purpose of this article is to show that variations in the extent of the ice tongue, that reaches southward between Spitsbergen and East-Greenland, are probably caused by changes in the circulation of the atmosphere.

The drift of the ice island Arlis II from Point Barrow in Alaska (1961–1965) to the Denmark Strait seems to indicate that perhaps there is a greater and more erratic outflow of sea ice from the Beaufort sea into the North-Atlantic than was generally believed up to present time.

The estimate 10,000 km^3 of ice, that the East-Greenland current is supposed to carry from the Arctic into the North-Atlantic Ocean must be a rather crude one, since the satellite pictures indicate large variations in the amount of the annual coverage of ice in this area.

Fig. 1. Extreme ice limits in April and May. "The enormous year to year variations from the conditions defined as "average" cannot be overemphasized. In this connection, particular attention is called to the series of charts, which show the extreme limits of ice in the North Atlantic region in the period 1898–1938. "As in the case of weather data, averages cannot be used to determine the precise nature of conditions for any specific time in the future. The average can only serve as a record expectancy in very general terms." (From *Iceatlas of the Northern Hemisphere*. Published by the Hydrographic Office, United States Navy.)

Information on sea ice is now compiled from observations and reports from ground stations, ships, aircraft and pictures from weather satellites. For brevity these pictures will henceforth be called APT pictures (Automatic Picture Transmission).

Up to the present the APT pictures received at Keflavik Airport have come from the ESSA Satellites. They orbit the earth approximately from pole to pole at heights between 1400 and 1500 km. The gridding of areas north of 60 degrees latitude demands great precision, and even so, some adjustments are usually necessary. Pictures can yet only be taken over the daylight zone of the earth. This means that we can only get pictures of the ice edge from February to November. (For further technical information see: APT Users Guide, published by U. S. Dept. of Commerce.) The area under discussion lies between 60° N and 80° N. It is bounded by the east coast of Greenland in the West and 10° E in the East.

Sea ice conditions off and at the north coast of Iceland are here divided into three categories. When this classification was made three primary factors were considered as most important, namely the amount of ice coverage, the difficulty for shipping and finally the estimated cooling effect on the sea off the north coast (this factor affects the fishing).

The three categories are:

1. New ice less than 1 year old formed by freezing of the surface waters at and off the north coast of Iceland, sometimes mixed with a few icefloes that may have been broken off the main icefield by intense storms. This ice coverage amounts usually to 1/10 or less and normally causes small difficulties for shipping except into certain harbours. Cooling effect of the sea is negligible. These conditions are not unusual for the north coast.

2. The icefield has been driven by persistent northeasterly winds southwards along the east coast of Greenland. When the wind turns to prevailing westerly direction f. ex. for a month or so, the icefield breaks up and drifts rapidly east wards. The coverage is usually 1 to 3 tenths and can cause difficulties for shipping along the north coast. The cooling effect is considerable, but depends on the duration of the ice. This kind of ice usually disappears rapidly once the wind direction becomes east or southerly. The year 1965 is a case in point.

3. The ice tongue between Spitsbergen and East-Greenland has been driven by northerly winds all the way from Shannon Island to the north coast of Iceland. When seen on the APT picture the coverage is 10/10 and seems to reach all the way from the North Pole to Iceland. This is usually caused by a combination of a strong north-wind along the east coast of Greenland for several months and a prevailing easterly wind over the southern Denmark Strait.

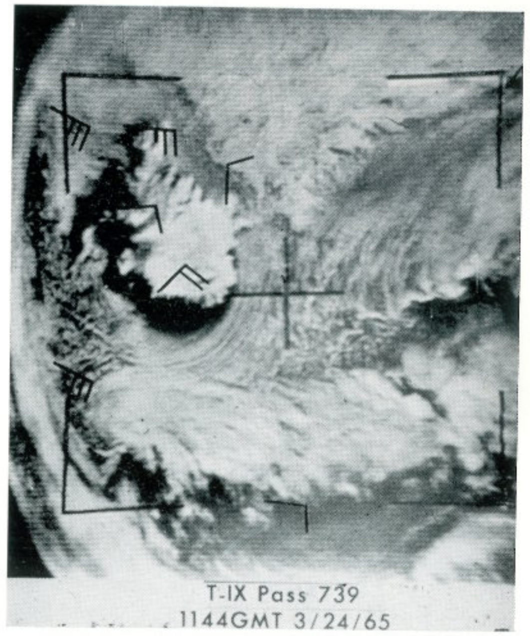


Fig. 2. March 24, 1965. Persistent and rather strong north and northeasterly winds from the beginning of November 1964 to the end of January 1965 drove the ice-pack southward. In the beginning of February 1965 the wind direction changed to westerly. This caused the ice-pack to break up somewhat and drift rapidly eastward. A northerly wind prevailing during the month of March drove this broken icefield to the north coast of Iceland.

This will slow down the outflow of ice through the Denmark Strait and consequently increase the ice drift to the north coast of Iceland. These conditions will make shipping almost impossible along the north coast and the cooling effect is considerable, probably causing dearth of herring in these waters the following summer.

It is the last category that will be discussed in the following:

The question that we must ask ourselves is: Why are there such great variations in the extension of the arctic icepack? This icepack covers most of the Arctic and extends towards Alaska and Siberia and also southward to Iceland.

The popular narrative of the Ivan Papanin expedition is that the camp was built on a floe at the North Pole and the floe began to drift immediately. This was late in May 1937. It

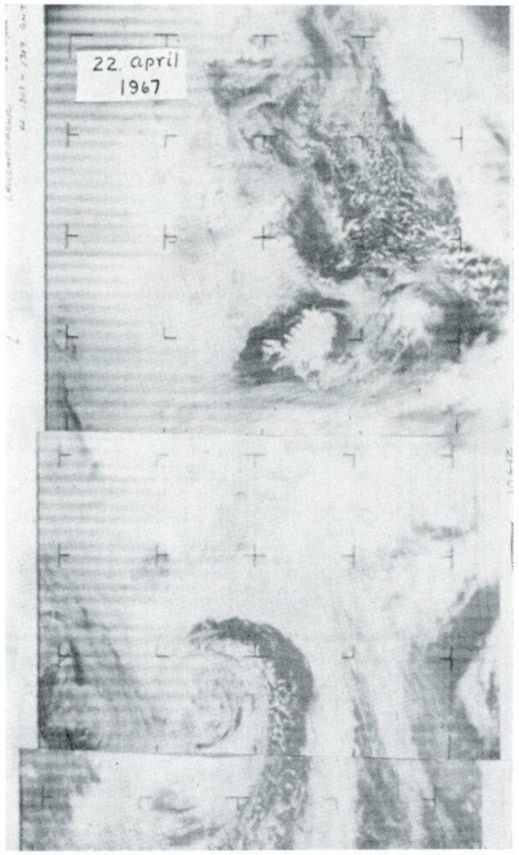


Fig. 3. April 22, 1967. The first APT picture received in Iceland gave us a jolt. The main ice-pack is much closer to Iceland than we had anticipated from other reports. However changeable wind direction over this area kept the ice-pack away from the coast so it never became a serious hindrance to shipping. This ice-pack on other hand cooled the surface waters very much and paved the road, so to speak, for the ice-pack in 1968. The strange cloud formations that curve around Iceland from the north coast, east and then southward along the east coast are probably due to the fact, that a cold and heavy airmass tends to flow around an obstacle rather than over it. This will cause a convergence and condensation in the airmass.

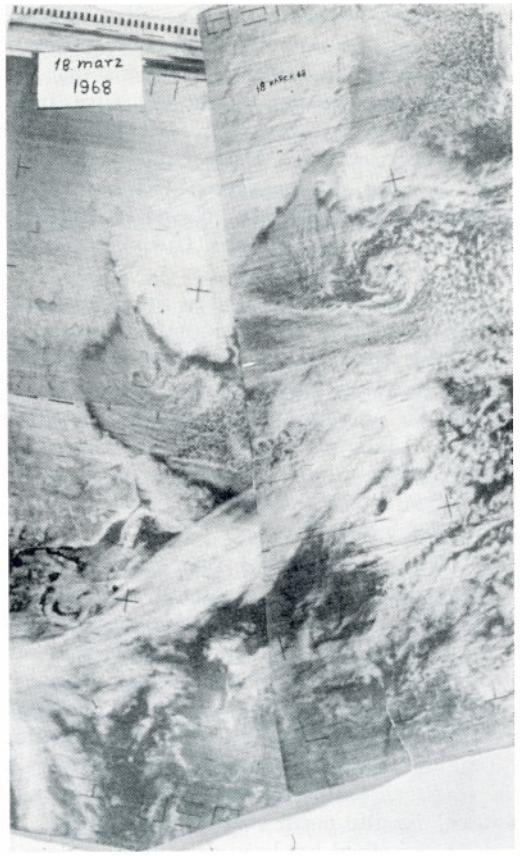


Fig. 4. March 18, 1968. The ice-pack is approaching the north coast. The cloud formation shows that very strong northerly winds are blowing over this area.

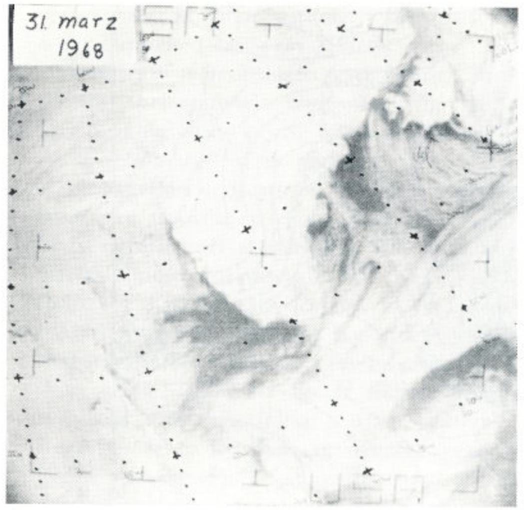


Fig. 5. March 31, 1968. Now there is no escape. The main ice-pack is just off the coast.

drifted in the direction of the gap between Greenland and Spitsbergen. At first they drifted with an average speed of 3—5 km per day. The direction of the drift was frequently changed, or even reversed, by the wind; but still the average was 5 km per day in the direction of Greenland. They gradually gained speed until by the time they passed Northwest Foreland they were averaging 8 to 10 km per day. They continued drifting south till they got to the vicinity of Scoresby Sund, then they were getting so near the open water that it became dangerous and the Russians sent a ship to pick them up in February 1938, near Scoresby Sund.

It is interesting to note that adverse winds were able to reverse the drift of the floe and presumably then a great portion of the Arctic icefield. The drift however was on the average 5 to 10 km per day. It would not be wise to take this as conclusive proof that ocean currents are the dominant factor of the ice drift as the following episode shows:

„Roald Amundsen undertook in 1919 to repeat Nansen's drift on the *Fram*, embarking on the same course aboard the schooner *Maud*. But whereas it had taken Nansen only 40 days to drift from Novaya Zemlya to the New Siberian Islands, it took Amundsen more than a year to complete the same journey. Amundsen had assumed that the climatic and oceanic processes of the Arctic follow a regular cycle year after year. Actually they are subject to great and irregular fluctuations that yield a predictable pattern only in ultimate correlation with the cycles of solar activity. By chance Amundsen had chosen the worst possible time for this voyage" (*Gordienko* 1951).

The accounts of these three expeditions seem to indicate that direction and speed of the wind is a large and sometimes even a decisive factor in the ice drift. It is suggested by the author of this article that prevailing (for several months) northerly winds will cause unusual amount of ice to drift through the gap between Greenland and Spitsbergen. This outflow of ice from the Polar basin into the Greenland Sea can at all times be observed in the APT pictures, when they are obtainable

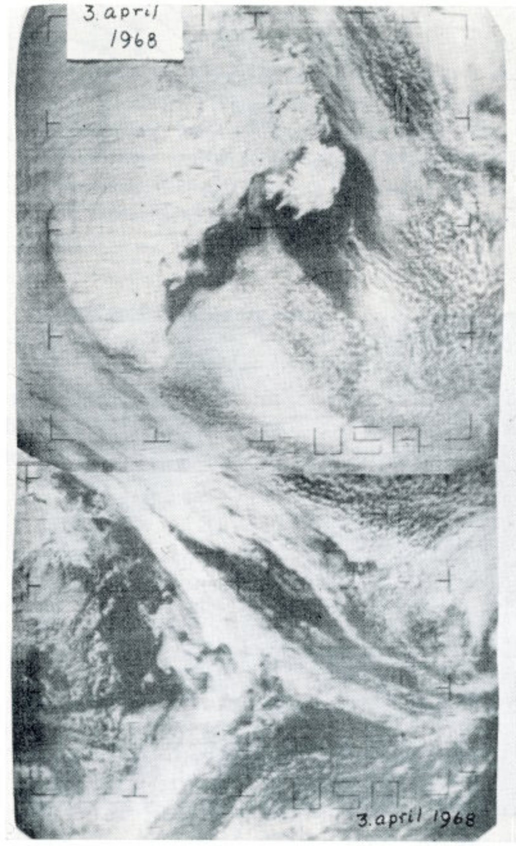


Fig. 6. April 3, 1968. The main ice-pack has reached the coast. Polar bears have been sighted.

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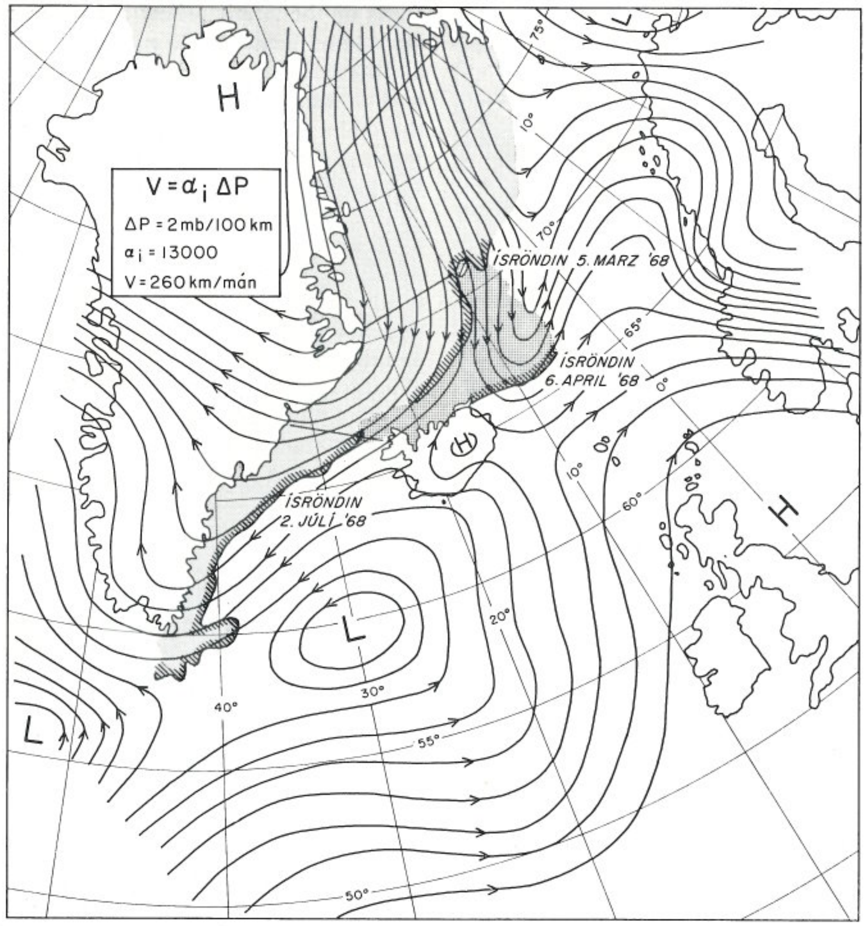

Fig. 7. The average monthly surface pressure map for February 1968. From March 5, 1968 to April 6 the ice edge has moved southward about 260 km (about 160 miles). The strong northerly winds east of Greenland, and the easterly winds over the southern Denmark Strait may by observed.

from this area. This outflow has two possible directions of movement, depending on the prevailing weather conditions.

First: The icefield stagnates in the area between Jan Mayen, Scoresby Sund and Spitsbergen, while the normal outflow (10,000 km^3 per year) drifts through the Denmark Strait and the melting and breaking up of the icefield prevents it from reaching Iceland, except where it skirts the northwest coast on its way southward. This is referred to as a normal situation.

Second: The icefield continues towards Iceland, mainly because of two factors, namely prevailing and rather strong north and even northwesterly winds over the area between Jan Mayen, Scoresby Sund and Iceland, while prevailing easterly winds over the Southern Denmark Strait hamper the normal outflow of the ice there. This is an unusual situation and causes the main icefield to drift rather rapidly – driven by the strong northerly winds and the East Greenland current – to the north coast of Iceland, hindering all shipping in that area and cooling the surface water to such an extent that one can expect but a short herring

season, if any, that summer. This is exactly what happened last year (1968).

American meteorologists are using infrared sensing thermometers and measuring the surface heat radiation of the water of Hudson Bay. As a result they were generally able to reinforce previous indications that the melt water from the thawing pack-ice remains a distinct body significantly colder than the surrounding waters almost until the autumn freeze up. This indicates that once the icepack has reached the coastal waters of northern Iceland the chances that the following winter will bring ice into these same waters are better than even, since the cold and less saline surface waters will freeze more easily than in average years (see Fig. 3 and Fig. 8). To stop this trend a radical change in the atmospheric circulation is necessary.

The ice-pack has pressure ridges reaching a height of about 8 meters, while corresponding pendants go to three to five times the height of the ridges, below the normal bottom of the ice-pack. These ridges and pendants tend to increase the effects of the wind and the currents respectively.

It is evident that a great force is needed to move an icemass of about 10,000 km^3 several hundreds of kilometers. A single low, even an intense one, only breaks up the ice edge, but does not move the ice-pack much. To move such a mass a longterm circulation in a prevailing direction is needed. Once the ice-pack has started to move and gathered momentum it will neither be easily stopped nor diverted from its course. The author has analysed over 30 maps depicting the average monthly surface pressure, selected from November 1964 to January 1969, and the correlation between the prevailing wind direction and the extent and the position of the ice edge is quite striking.

There are several difficulties in mapping the ice edge by the use of APT pictures. It is very difficult to distinguish between ice and clouds from a single picture; clouds move however 20 to 2000 times faster than the ice-pack, and with several pictures in chronological order it becomes easy. The land in high latitude is only clearly visible when it is covered with snow, otherwise it is almost impossible to be sure whether a dark area is sea or land. Melting

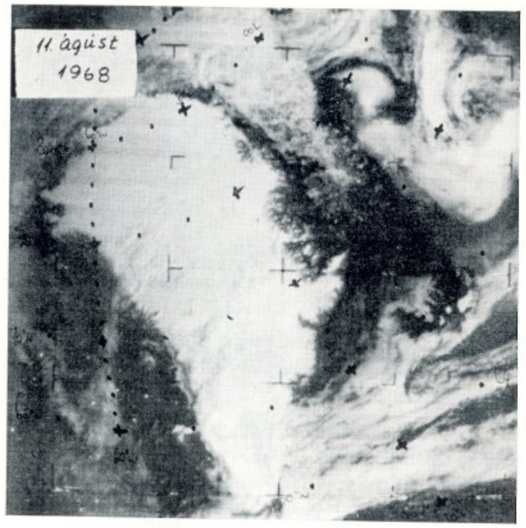

Fig. 8. August 11, 1968. The unusually cold surface waters surrounding Iceland have cooled the air to its condensation temperature; the resulting fog over the coastal waters shows off the dark land area quite distinctly. The glaciers of Iceland are easily seen. The ice tongue has withdrawn to the north and is seen extending through the gap between Spitsbergen and Greenland reaching well south of Shannon Island.

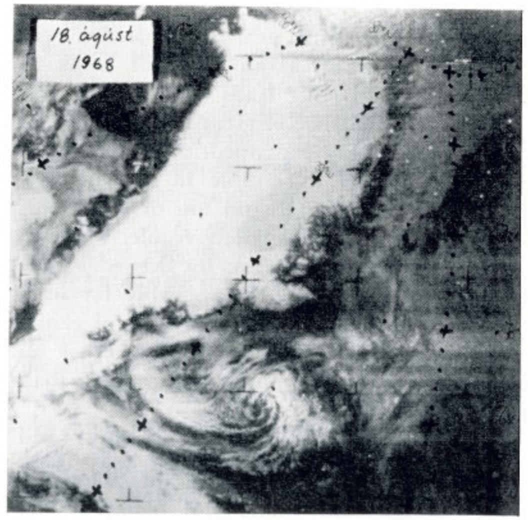

Fig. 9. August 18, 1968. In the evening sunlight the extent of the ice-pack along the east coast of Greenland is easily observed.

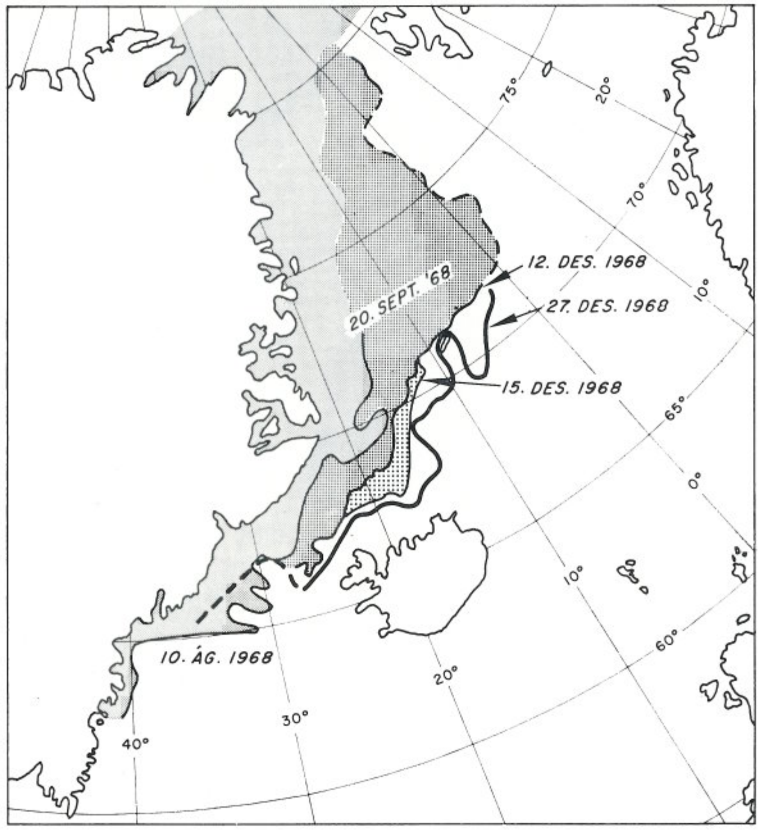

Fig. 10. The position of the ice edge is shown at several dates from August 10 to December 27, 1968. This composite picture is compiled from APT pictures and aircraft reports. The question is: will we be able to forecast the movement of the ice edge in the future?

snow from the land near the coastline will frequently show up as an apparent break in the icefield, while big leads (polynyas) in the ice-pack give evidence of great internal stresses, that are not easily explained. New and transparent ice is not discernible in the pictures. However snow that falls on top of ice of this kind will make it immediately visible. This can cause some confusion since the ice edge may seem to have advanced inexplicably far in a short time, and quite rapidly in spite of gentle wind speed. This kind of ice tends to break up easily and moves then much more rapidly than the main ice-pack.

Conclusion: By using APT pictures and mapping the position of the ice edge, whenever possible, and also using average monthly surface pressure maps, revised every 10 days or so, it should be possible to forecast the movement of the icefield 10 to 15 days ahead. These forecasts would be based upon Zubov's rule:

$$V = \alpha_1 \Delta p$$

where V is the drift of the ice in kilometers per month.

Δp is the pressure gradient in millibars per kilometer, calculated from an average monthly surface pressure map, and

α_1 is called the isobaric coefficient.

The rule is based on an empirical approach so one would probably have to find a new value for α_1. In the preliminary studies the value 13,000 was used.

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Winds and Ice Drift North of Iceland, Especially in the Year 1965

JÓNAS JAKOBSSON,
THE ICELANDIC METEOROLOGICAL OFFICE, REYKJAVÍK, ICELAND

ABSTRACT

The aim of the work presented here was to investigate whether the onrush of drift ice to the north coast of Iceland in February 1965 was caused chiefly by winds, and to study the correlation between the movement of the ice edge east of Greenland and the winds in these tracts.

Secondly it was the purpose to follow the movements of the ice in Icelandic waters after it had arrived and to find how its drift was related to winds.

INTRODUCTION

In the 19th century is was believed in northern Iceland that westerly winds increased the danger of ice. British meteorologists came to the same conclusion after their experience in Iceland during World War II, especially in the spring of 1944. *(British Hydrographic Dept.* 1946). Their research included seven years of the period 1931 to 1945 and showed that when southwesterly winds between Iceland and Greenland had lasted one to two weeks, one could expect drift ice near Straumnes, and after a duration of three weeks it would have passed Horn. The months August to November were excluded, because in these months drift ice near the Icelandic coasts is an exception.

In the years 1951 to 1956 the author kept a record of wind components between Northwest Iceland and the Greenland coast. In these years no considerable ice occurred in Icelandic waters, so these observations were discontinued. They showed, however, that a few days of southwesterly winds always preceded ice occurrence at the coast of Vestfirðir.

It may seem more natural that northwesterly winds would bring ice to the coast. But due to the effect of Greenland northwesterly winds are an unstable phenomenon at the northwest coast of Iceland. Southwesterly winds can, however, last there for days, even weeks. Therefore, it becomes their role to bring in the ice to Vestfirðir, at least when the ice belt along Greenland is relatively narrow.

After a few days of unusually strong southwesterlies off the northwest coast, ice came in the proximity of Straumnes and Horn on the 9th and 10th of January, 1952. It was apparent from trawler reports that the ice edge had moved 80 miles* towards the coast. By assuming the surface wind to be 70% of the geostrophic one, it appears that the ice has drifted with the speed of 4–5% of the surface wind. This is about twice the speed *H. U. Sverdrup* (1942) reports from the Arctic. There he found that the thick April ice drifts with 1.4% of the wind velocity against 2.4% for the thinner August ice. Here off the northwest coast of Iceland, we have altogether different conditions. The floes at the ice edge are thin and will, therefore, drift with a higher percentage of the wind velocity than thicker ice. Secondly, in a southwesterly wind over the Greenland Sea in winter the air is in an unstable state, so the velocity of the air above is easily carried down to the surface. Such turbulence effect causing transport of momentum is always present over the partly open waters at an ice edge when the wind blows out from the solid or nearly solid, cold, main drift ice. This turbulence is probably the greatest factor in forming a belt of open drift and scattered floes along the edge of major drifts.

*) Nautical miles are used throughout.