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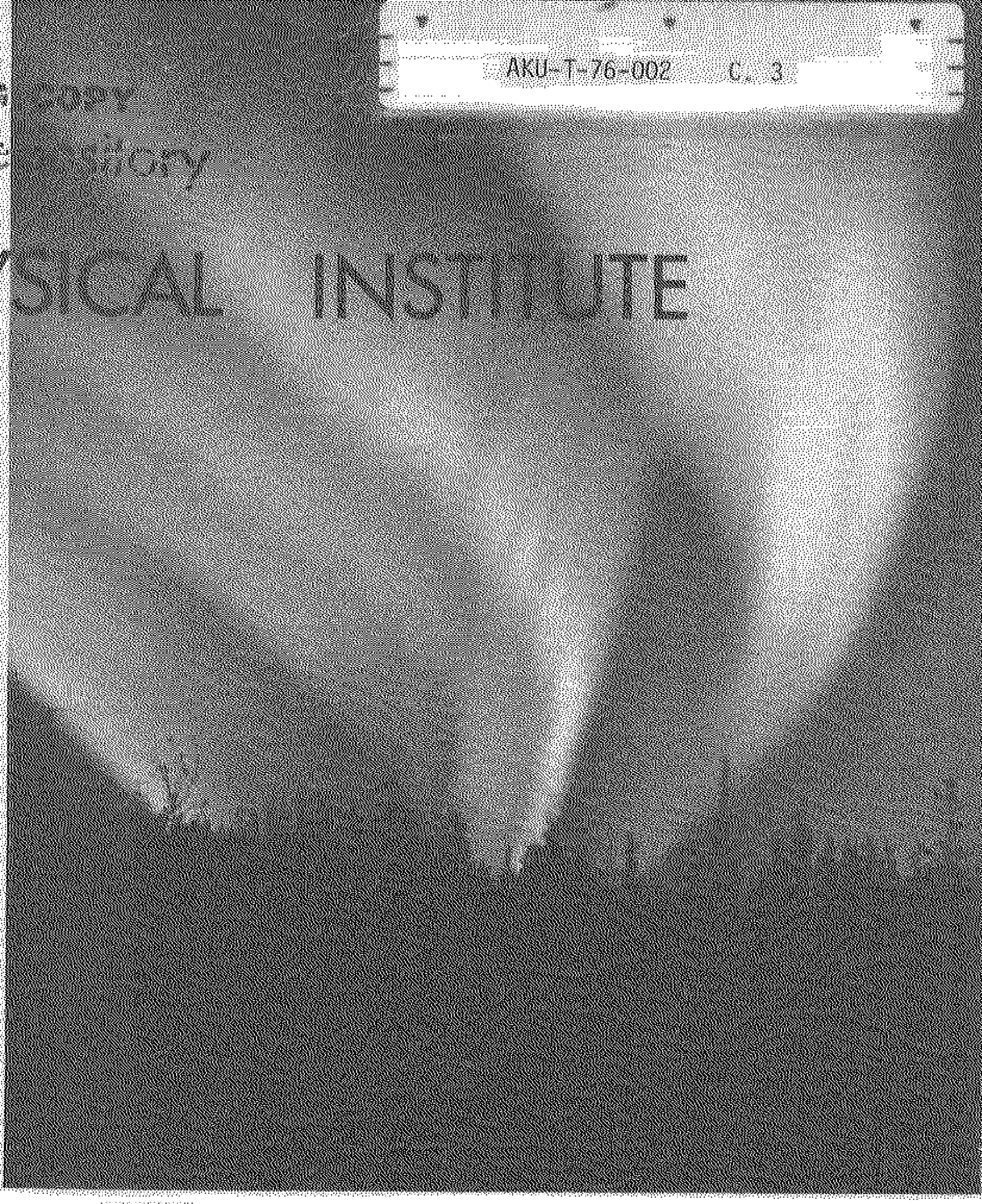

UNIVERSITY
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UAG R-246

SOME REMARKS ON THE UNUSUAL BEAUFORT SEA ICE CONDITIONS IN SUMMER 1975

by

Gerd Wendler and K.O.L.F. Jayaweera

SCIENTIFIC REPORT

May 1976

Sea Grant Report No. 76-7

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ABSTRACT

In the summer of 1975 the sea ice conditions between Point Barrow and Prudhoe Bay were the severest since 1898 when the ice did not move away from shore at all. In 1975 the movement started later than in any year since that time and was incomplete. From the meteorological point of view this event is very interesting and also had great economic ramifications because the need to resupply the Prudhoe Bay oil fields by barges could not be carried out as planned. These unusual ice conditions were caused by:

a) a thicker than normal ice cover for the winter of 1974-75 owing to a cold and snow-deficient winter,
b) a cooler than normal summer 1975 which not only slowed down the rate of ice decay but also shortened the period in which melting occurred, and
c) the unusual wind conditions in summer 1975 which were caused by a persistent low pressure system over the high Canadian Arctic for July, August, and September, adding a northwesterly wind component to the average wind which kept the ice near to shore.

This last reason is believed to be the most important.

ACKNOWLEDGEMENT

This work is a result of research sponsored by the Alaska Sea Grant Program, supported by NOAA Office of Sea Grant, Department of Commerce, under Grant #04-6-158-44039 and by the University of Alaska with funds appropriated by the State of Alaska. Further appreciation goes to Mrs. T. McClung for the drafting and Mrs. R. Hawkins for typing the manuscript.

INTRODUCTION

The sea ice conditions in the Arctic Ocean have interested mankind for several hundred years, especially in the early days in connection with the attempts to find a northeast and northwest passage. Even today, with modern technology and powerful ice breakers, sea ice conditions are still of great practical importance due to the restrictions they impose on shipping (e.g. Potocsky, 1975). Originally sea ice observations were made from the coast or by ship. Later, aircraft observations were used to obtain better coverage (e.g. Jerdon and Freeman, 1969). In recent years satellite observations (Wark and Popham, 1962; Potocsky, 1968; Barnes, et al., 1969; McClain and Baker, 1969; McClain 1970 and 1974; Barnes and Bowley, 1973; DeRycke, 1973; Wendler, 1973; Ackley and Hibler, 1974; Streten, 1974; and Campbell, et al., 1975) and radar observations (Tabata, et al., 1970; Aota, et al., 1970) have become more and more important. Besides their practical importance for shipping traffic, sea ice conditions are also of interest as a climatic indicator and barrier in the exchange of heat and momentum between the atmosphere and the ocean. For example, in winter open water will provide one or two orders of magnitude more energy to the atmosphere than an ice-covered ocean (Badgley, 1966). Therefore, the total heat balance of the Arctic is strongly influenced by the amount of open water, as pointed out by Fletcher (1966) and by the National Academy of Sciences (Committee on Polar Research, 1970).

ICE CONDITIONS FROM SATELLITE IMAGERY

High quality satellite imagery of the Beaufort Sea has been collected at the Geophysical Institute since 1973. The quality of the 1973 imagery, which consisted mostly of DMSP (Defense Meteorological Satellite Program) data (formally DAPPP, was not as high a quality as for 1974 and 1975 when we obtained VHRR data from the NOAA-2, 3 and 4 satellites at Gilmore Creek Command and Data Acquisition Station near Fairbanks which has direct readout capabilities.

On 15 July 1974, the ice had not opened at all between Barrow and Barter Island (Fig. 1). However, about three weeks later on 4 August 1974 one could see a small strip of open water along the northern coast of Alaska (Fig. 2). This was also the first day on which barges coming from the west and supplying the Proudhoe Bay oil field reached Prudhoe Bay, which lies about half-way between Barrow and Barter Island. The movement of the ice was caused by winds with a strong southerly component for the ten days prior to 4 August 1974 (see Fig. 3). By the end of August (Fig. 4) the ice had moved further out, and the whole north Alaskan shore was ice free. By 5 September 1974, the ice moved even further away from shore, at least in the western part of the Beaufort Sea (Fig. 5).

In 1975 a big area with open water occurred in mid-May off the shore of northwest Alaska (Fig. 6). This was unusually early in the year and was caused by strong and consistent easterly winds due to an anticyclone

Figure 1 NOAA VHRR satellite photo of 15 July 1974. Solid ice along the shore between Barrow and Barter Island.

Figure 2 NOAA VHRR satellite photo of 4 August 1974. A small strip of open water can be seen along the northern coast of Alaska.

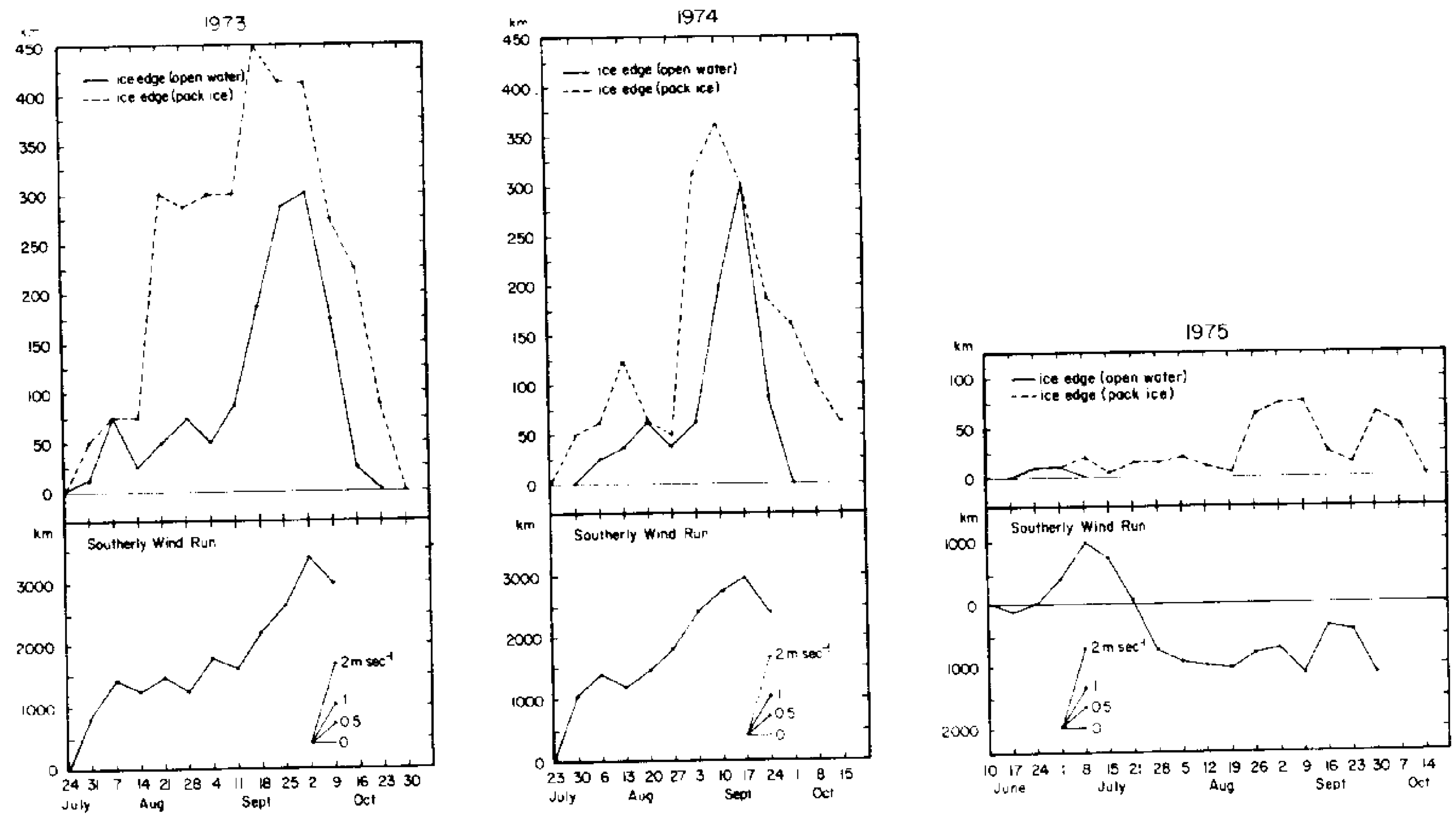


Figure 3 The distance of the ice edge north of Barrow and the accumulated wind run (southerly component is positive, a northerly one is negative) of the Barrow weather stations for the summer of 1973, 1974 and 1975.

Figure 4 NOAA VHRR satellite photo of 26 August 1974. Note that the whole Alaskan shore is ice free.

Figure 5 NOAA VHRR satellite photo of 5 September 1974. Ice retreated, at least for the western part of the Beaufort Sea, to a maximum. See also NW of Barrow a grounded floeberg (Katie's floeberg).

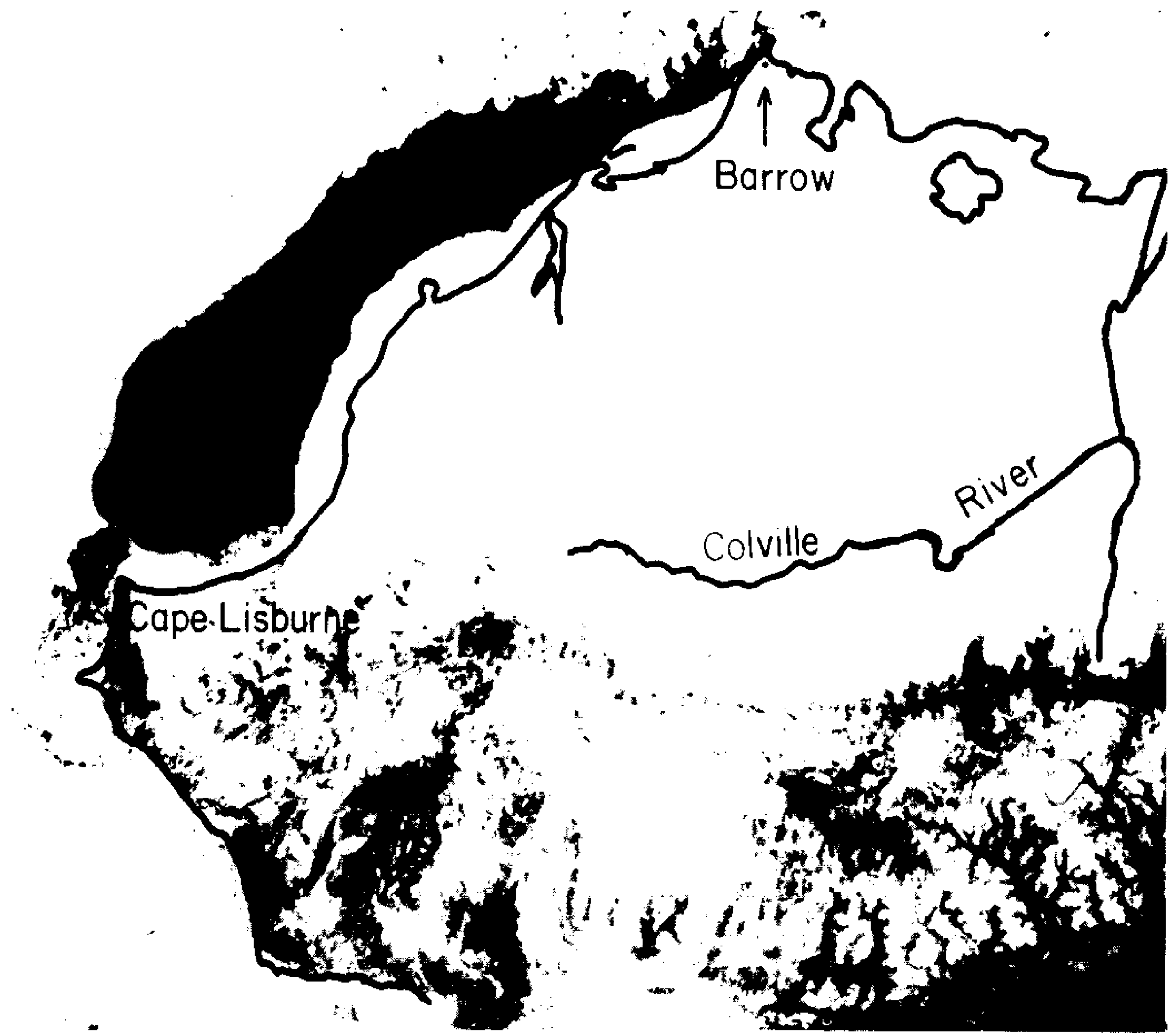


Figure 6 NOAA VHRR satellite photo of 14 May 1975. Note the big lead northwest of Barrow.

north of Barrow. Figure 7 gives the surface pressure map for the same day on which the satellite photo was taken and one can see that on this day east-southeasterly winds were blowing over the area where the lead occurred. From the satellite photo one can see that the ice did not open at the shore but further away from it, so that it was of no help in allowing ships to supply villages along the shore of the Arctic Ocean. Further, this lead soon closed again. Later in the summer, on 23 August 1975 -- the latest date the ice has ever moved out since 1898, when it did not move away from shore at all -- the ice was still solid between Barrow and Barter Island (Fig. 8). A month later (Fig. 9) the ice had moved away from the northern shore of Alaska, but now the ice conditions between Icy Cape, which is located about 230 km southwest of Barrow, and Barrow became severe. It was only after this date that barges coming from the west reached Prudhoe Bay, and that was only possible due to assistance from the Coast Guard ice breakers. Even with this help, only about half of them reached Prudhoe Bay while the others returned and a few forced to lay on the shore of northern or northwest Alaska, were damaged. Most of those which reached Prudhoe Bay could not return and due to fresh ice which had already formed, they could not come near to shore. Hence, the unloading was still not completed by January 1976.

ICE THICKNESS

The temperature at the beginning of the winter of 1974-75 for Barrow and Barter Island (Fig. 10) was substantially below the normal. For the period October 1974 through January 1975 both stations were more than $5^{\circ}C$ below the long-term average compiled by Searby (1968) and National Oceanic

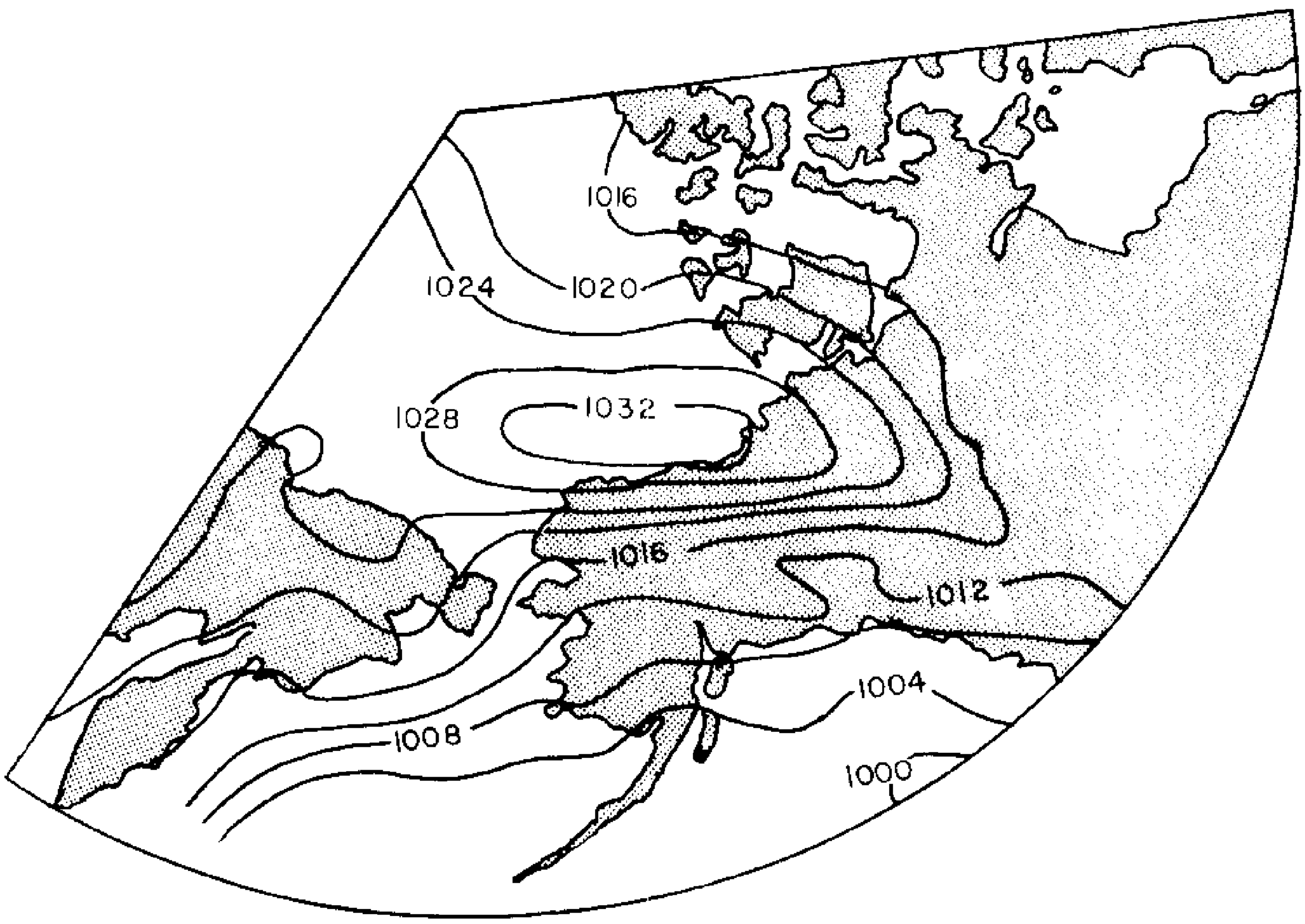


Figure 7 Surface pressure map of 14 May 1975. The strong anticyclone north of Barrow results in ESE winds in the area where the lead was formed.

Figure 8 NOAA VHRR satellite photo of 23 August 1975. Note that the ice is still solid between Barrow and Barter Island.

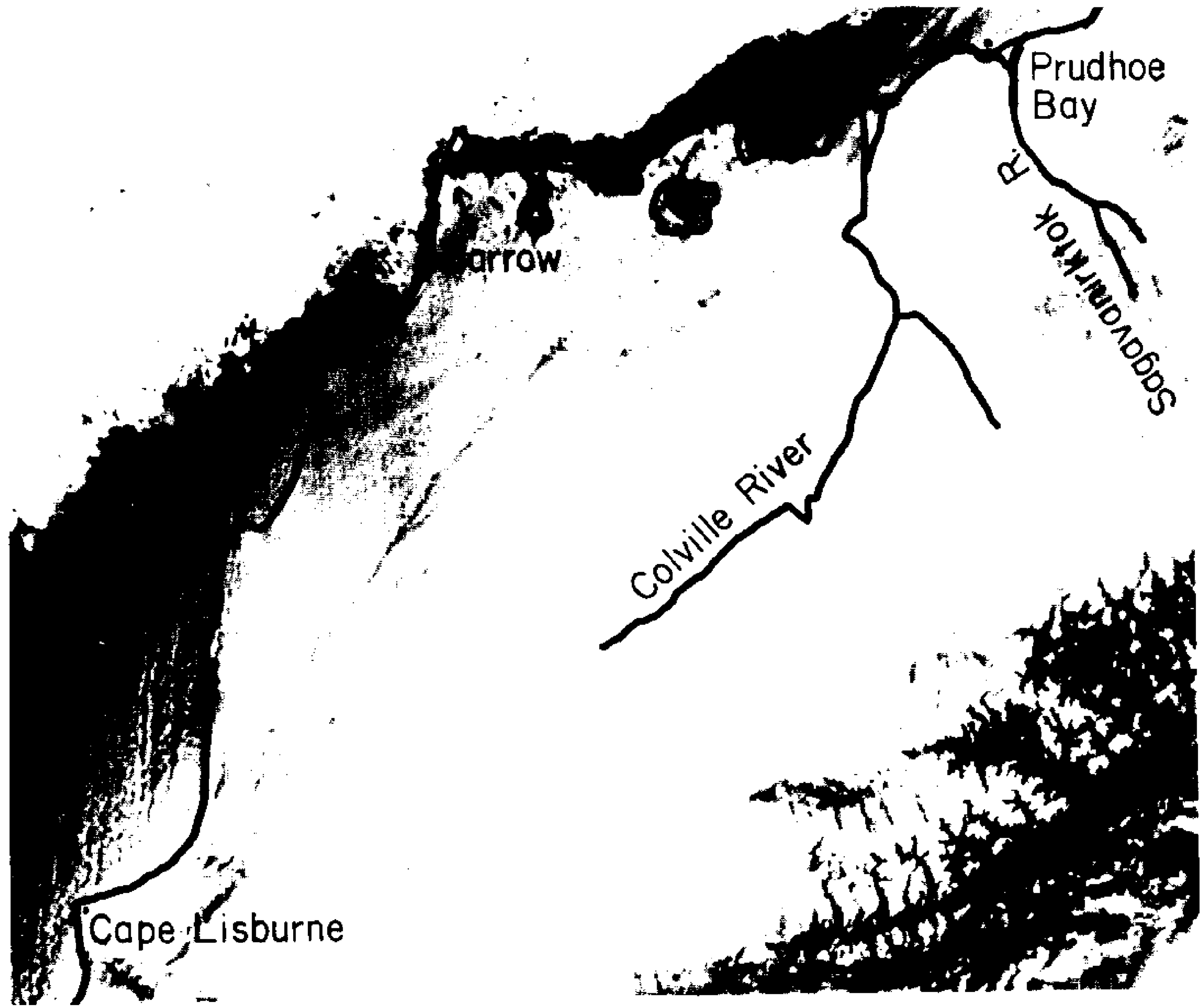


Figure 9 NOAA VHRR satellite imagery of 23 September 1975. The near coastal area between Barrow and Barter Island is ice free (in the eastern part somewhat concealed by cloudiness). However, between Icy Cape and Barrow, the ice is near to shore.

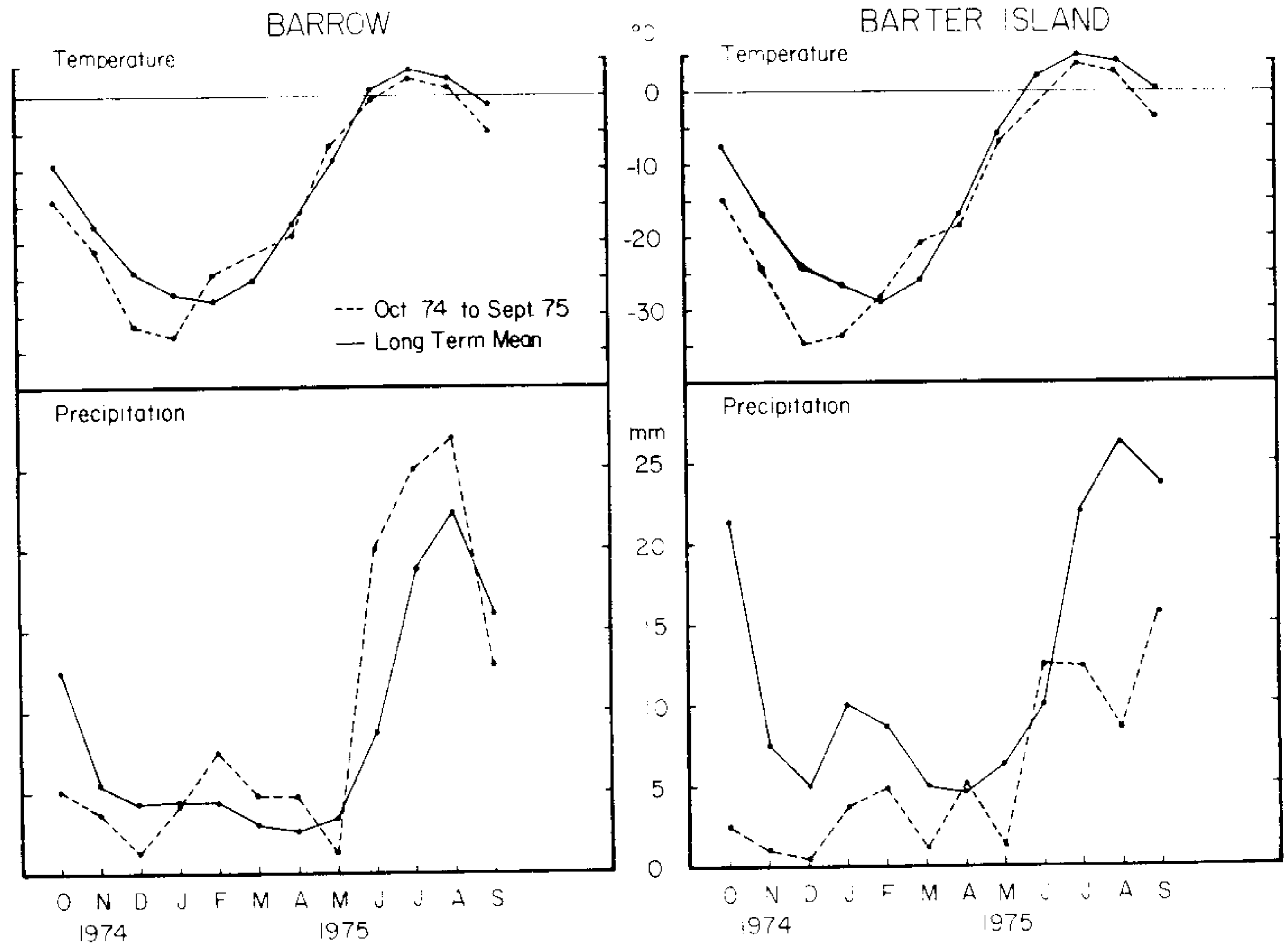


Figure 10 Temperature and precipitation for Barrow and Barter Island for the long term average and the year 1974/75.

and Atmospheric Administration (1974, 1975). These lower temperatures at the beginning of the freeze-up tended to increase the ice thickness. This effect was intensified furthermore by the fact that the precipitation (snow fall) was far below the normal at the beginning of the winter 1974-75. The expected ice thickness can be predicted from various empirical formulas. Of these formulas, those of Kniskern and Potocsky (1965) and Burns (1974) are the simplest and most readily used. The former relates the ice thickness I to the number of frost degree days (FDD) by the expression:

$$1.43\ I^2 + 28.6\ I - \Sigma\ FDD = 0$$

This expression, however, does not take into account the amount of snow cover on the ice. Based on the works of Zubov (1938), Lebedov (1940) and Leahey (1967), Burns (1974) included the effect of snow cover and derived the following expression for the change in ice thickness:

$$\Delta I = \frac{0.5\ \Sigma\ FDD}{Im + 5Sm}$$

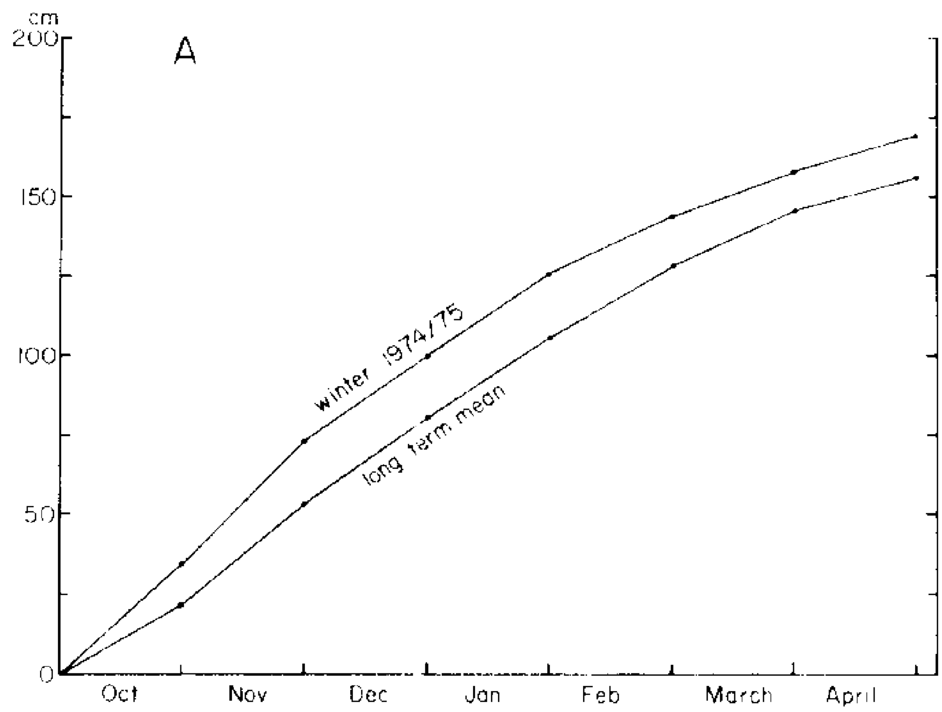
where ΔI = change in ice thickness (growth)

ΔFDD = change in number of FDD (accumulate)

Im = average ice thickness

Sm = average snow cover

Based on these two equations, the ice thicknesses were calculated for the winter of 1974-75 and for the long-term mean. In calculating the FDD, the freezing point of sea water, $-1.8^{\circ}C$ or $29^{\circ}F$, was used instead of $0^{\circ}C$. The results of these calculations are shown in Fig. 11. It is readily observable that the ice thicknesses during 1974-75 are greater than the long-term mean and when the reduced snow cover over the ice is taken into account this difference is more pronounced - a 25% or 37 cm increase (Fig. 11B) compared to 9% or 13 cm (Fig. 11A) by the end of April 1975.



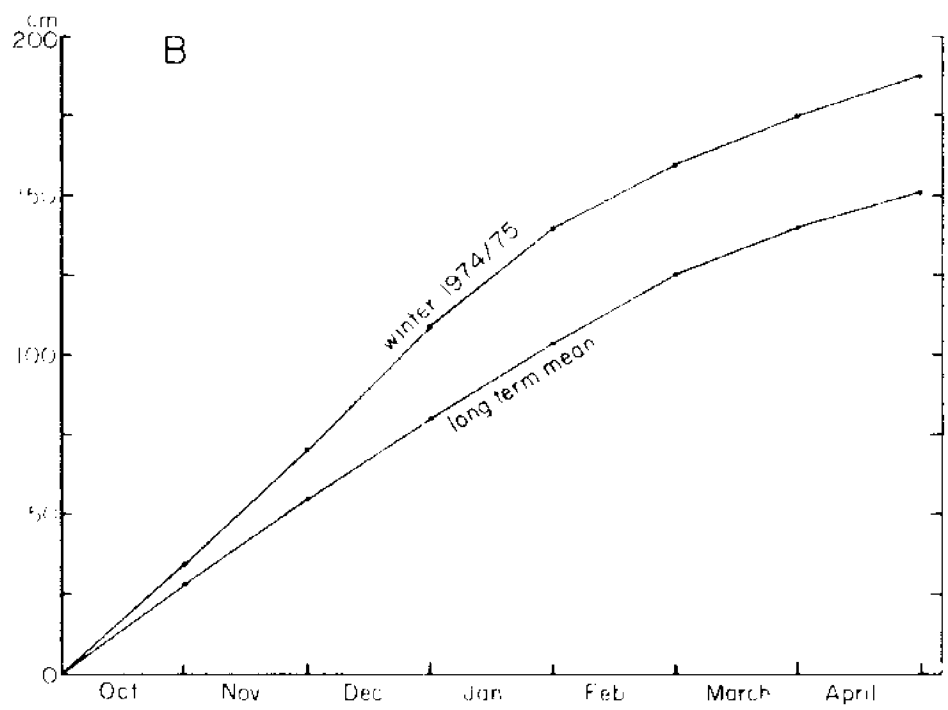


Figure 11 Calculated ice thickness for Barrow according to A) temperature conditions, and B) temperature and snow conditions, for the winter 1974/75 and the long term mean.

Although the expected ice thicknesses during the 1974-75 winter were larger than the mean value, this increase is not sufficient to solely explain the fact that ice did not move from Barrow in 1975. If ice dynamics were neglected, it would take only about a week to melt the extra amount of ice in the summer.

Naturally, a cold summer would also delay the melting of ice. Even though most of the ice is melted by solar radiation and not by sensible heat, temperature is a good indicator as temperature and radiation are normally well correlated. If we look at the temperatures of Barrow and Barter Island for the summer of 1975 (Fig. 10), we see that the temperatures were below normal. The deviation from normal is relatively small; however, the time span with a temperature above the freezing point was shortened by about 25%. Hence, the decay of ice would not only be expected to be slower, but also the time span for decay was shorter than normal, which contributed to the unusually severe ice conditions of the summer of 1975.

SEA ICE MOVEMENT

There are several forces that determine the ice movement: surface wind, surface current, Coriolis force, ocean tilt, and stress propagation in the ice. Normally, the surface wind and the ocean current are the two dominant forces. As the ocean currents cannot contribute much toward onshore motion of the pack near the shore, the explanation in the change of the ice conditions is given (in this paper only) as a function of the surface winds.

The surface winds can be derived from pressure data of coastal weather stations or from synoptic weather maps. For example, Streten (1975) worked with the pressure differences between station pairs to derive surface winds while Wendler (1973) used the synoptic surface weather maps.

Coastal Weather Stations

We are interested in the ice conditions off the North Slope, especially Barrow; hence, we used this station to calculate the southerly or northerly wind components during the summer. We concentrated on the last three years because good observations of the sea ice conditions were available for this period. Since Barrow lies near the Arctic Ocean on the flat tundra, orographic effects should not be very important. Barrow also lies far enough away from the Brooks Range so that it is not influenced by the mountains. In contrast, an influence on the wind direction of the mountain range was shown for Barter Island by Conover (1960). Easterly and westerly wind components have some influence on the ice conditions near to shore on the north coast of Alaska (e.g., Burns, 1974), but the southerly or northerly wind components are the most important. In Figure 3, the distance of the ice edge off Barrow and the total accumulated southerly wind run are given for the summers of 1973, 1974 and 1975. For the ice edge, we differentiated between the edge of the open water and the edge of the compact ice, the latter of course being further away from shore. The ice conditions were obtained weekly from the ice maps of the U. S. Navy (1973-1975) and from the NOAA satellite imagery. Also for weekly periods, the southerly wind components (a northerly wind component would be negative) were calculated from three hourly wind observations at the meteorological stations at Barrow (NOAA 1973-75). One can see that 1973 and 1974 are fairly similar. In both years the ice started to move away from shore at the end of July and the distance from shore increased until sometime at the end of September when the greatest distance, about 300 km, was reached. After this time the temperature had dropped, and the ice moved in or new ice was formed. A movement toward shore is, of course, connected with a northerly wind component. Generally speaking, the distance of the ice edge is about one-tenth of the southerly wind run in summer. In the summer of 1975 the situation was very different (Fig. 3). After the 10th of July, unlike the previous year, northerly and not southerly wind prevailed. Open water is observed only around the 1st of July, but at that time shore-fast ice existed so that the shore line was not, in real sense, ice free.

Winds Derived From Synoptic Weather Maps

Looking at the mean monthly weather maps for the three summers (June to September), one can see that with the exception of June no winds with a southerly component can be derived for 1975, while for the two previous summers southerly wind components were observed. In Table I the winds derived from the height of the 700 mb level are summarized. However, this comparison might not be valid as 1973 and 1974 might not have been typical. Hence, for the four summer months (June to September) of 1975, the deviation from the mean 700 mb height (long term) is given in Figure 12.* The winds which can be derived from these maps represent

*Our tanks go to the personnel of the Extended Forecast Section of NOAA Washington, D. C., who supplied us with the computer printouts of this data.

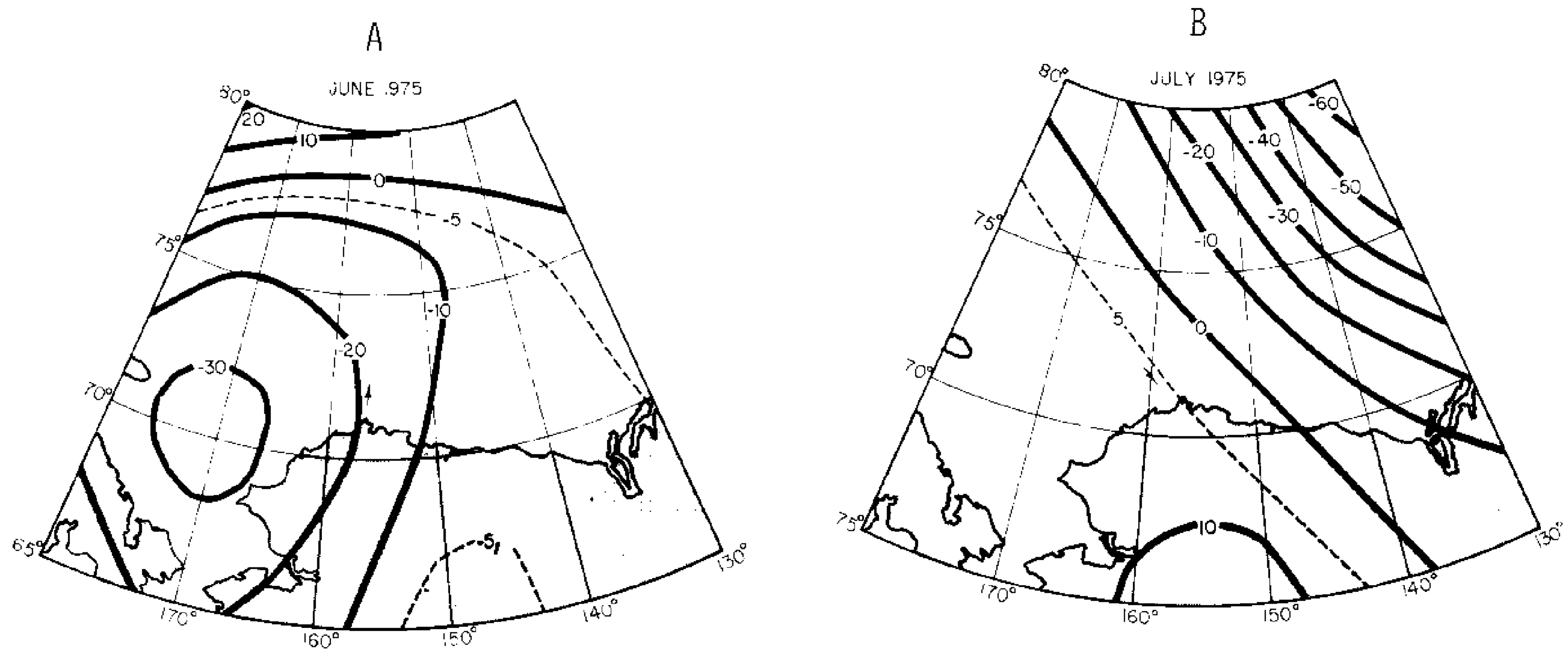


Figure 12 Deviation from the mean height of the 700 mb level for June and July, 1975.

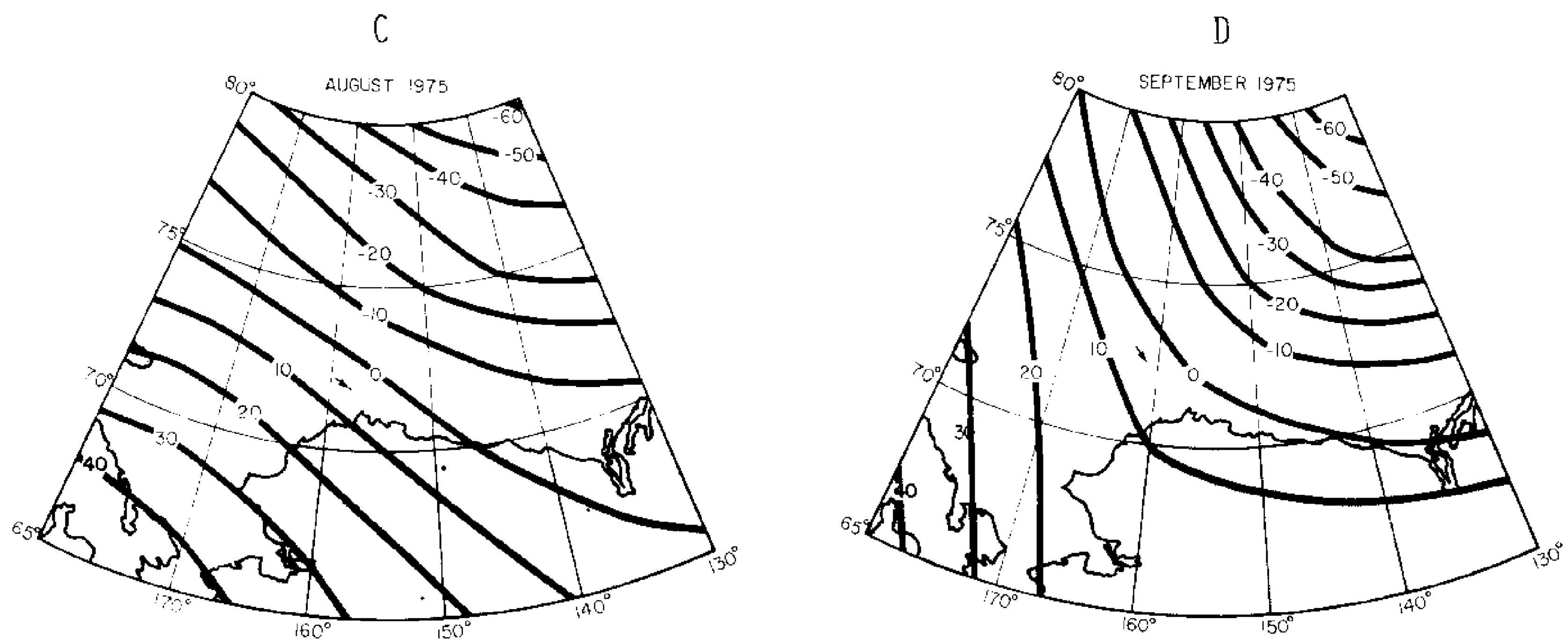


Figure 12 (cont.) Deviation from the mean height of the 700 mb for August and September , 1975.

the vectorial deviations from the mean wind for the specific month. In June (Fig. 12A) a more southerly wind than normal can be seen for Barrow which is caused by too low a pressure over the Chukchi Sea. But even if the ice would open at such an early date, it is not of much value to shipping since shorefast ice prevents cargo from reaching the shore. A different situation occurred for July, August, and September 1975 (Fig. 12B, C and D). Too low a pressure is observed over the high Canadian Arctic (Queen Elizabeth Islands) which resulted in an additional northwesterly wind component for all three months. This very steady deviation from the mean for the period when normally the ice opens at Barrow can explain the unusual ice conditions of the summer of 1975.

That the summer of 1975 was indeed very unusual can also be seen from the drift buoy data of the AIDJEX program (Fig. 13).* The movement of the buoys in the Arctic Ocean is partly against its expected direction. The big gyral did not move clockwise as expected (U. S. Navy, 1975 and Fig. 14) but counter-clockwise.

CONCLUSION

The very unusual ice conditions of the summer of 1975 off the northern shore of Alaska are believed to have been caused by a combination of reasons. The most important is the unusual wind conditions in the summer with northerly components which kept the ice near to shore. Secondary reasons are the cold and snow-deficient early winter of 1974-75, which resulted

* Our thanks go to Dr. Pritchard for supplying this data.

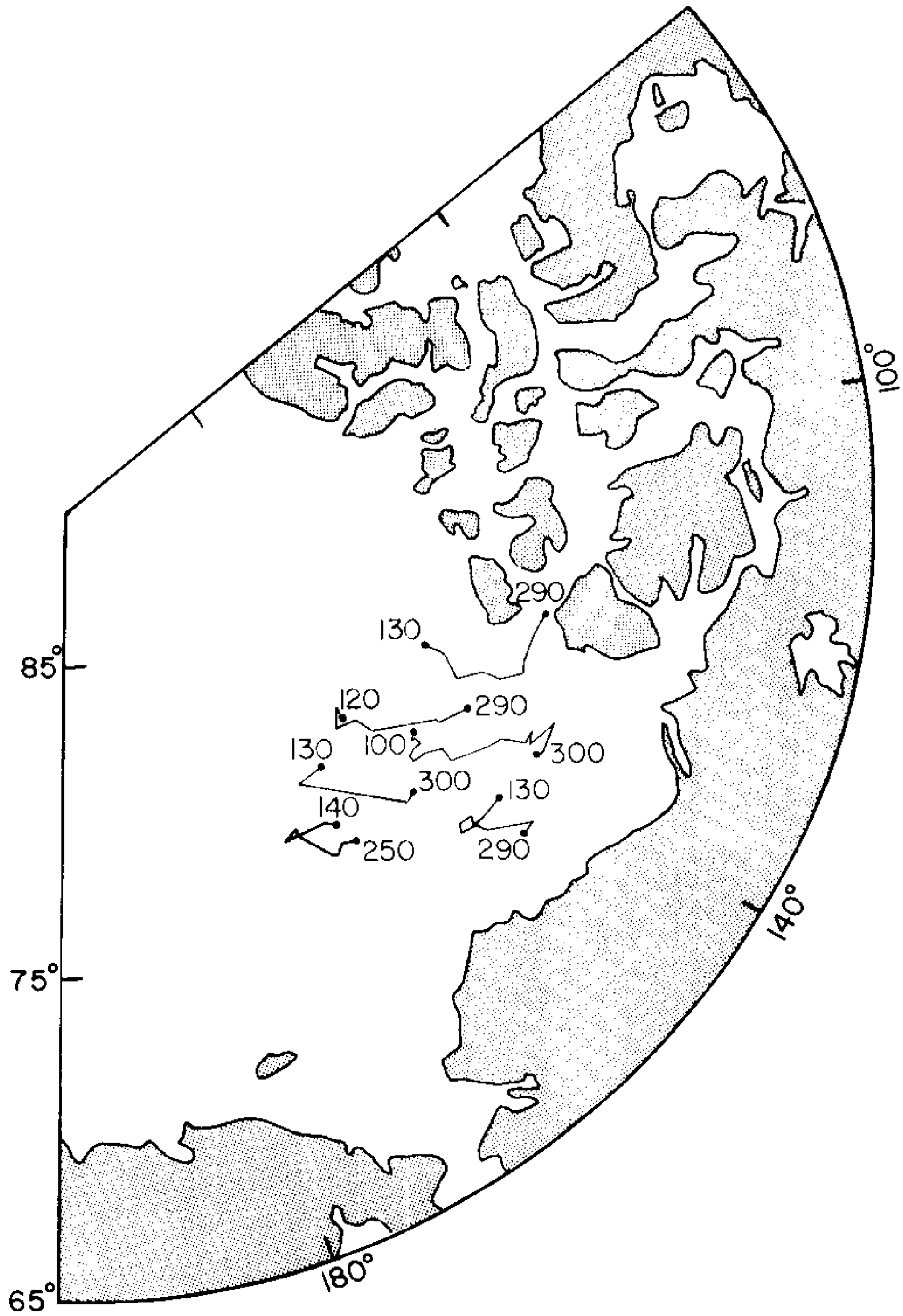


Figure 13 Drift buoy data of the AIDJEX program of Summer 1975 (number indicates Julian Days, 1975).

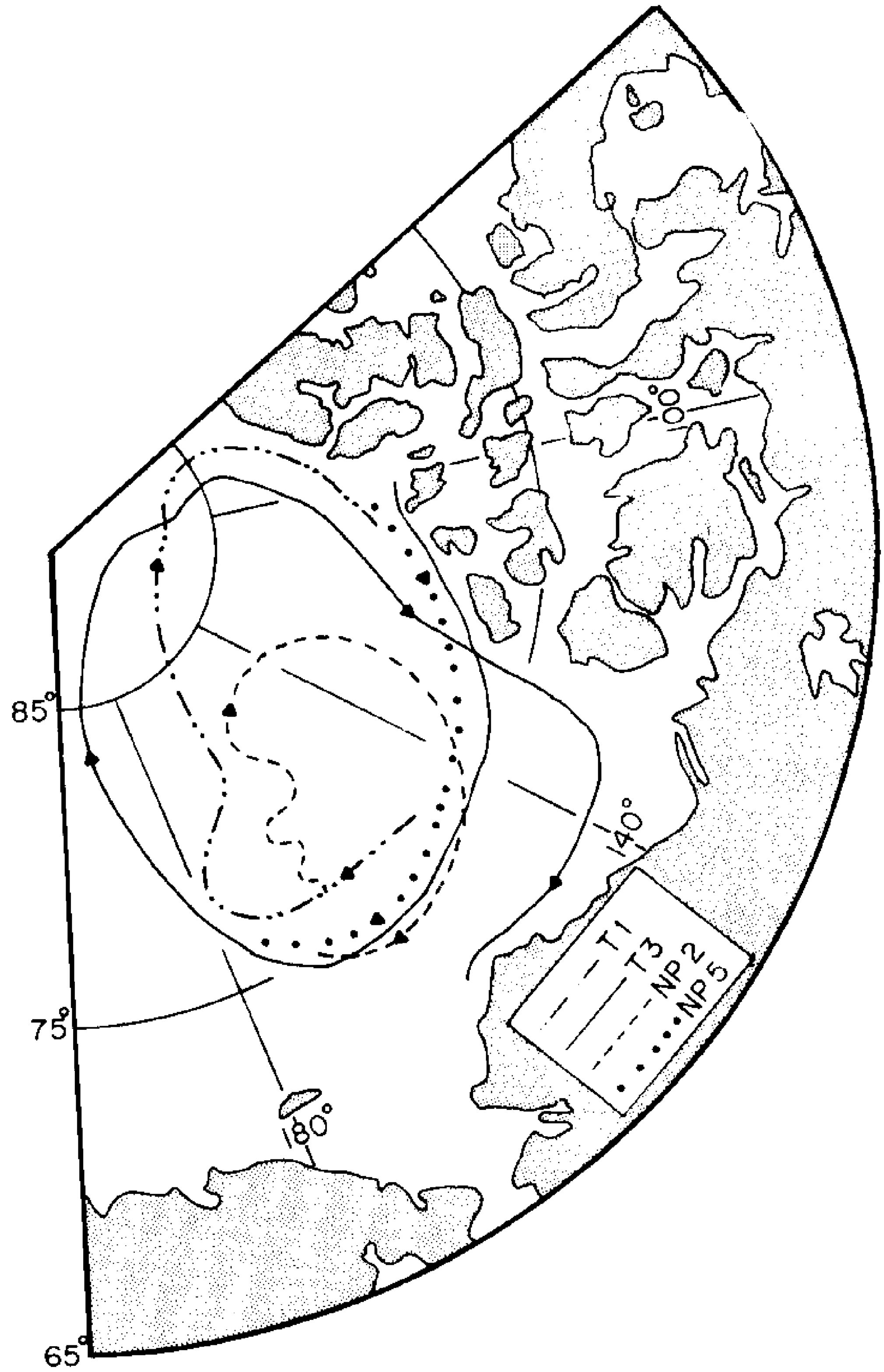


Figure 14 Drift date of the American ice islands.

in a thicker ice cover, as well as the cold summer of 1975 with a shorter ablation period and hence less decay of the ice.

Further, it has been demonstrated again that the NOAA VHRR satellite imagery is an excellent tool for studying sea ice conditions. With twice-daily satellite imagery available in near real time, an improvement in ice forecasting can be expected.

TABLE I

MEAN GRADIENT WINDS

AT BARROW, ALASKA

FOR THE 700 mb LEVEL

(from average monthly weather data - NOAA 1973-1975)

	1973	1974	1975
June	SW (weak)	W (medium)	WSW (strong)
July	WSW (strong)	W (medium)	W (strong)
Aug.	WSW (medium)	SW (medium)	W (strong)
Sept.	WSW (strong)	SW (weak)	WSW (medium)

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