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Record-hard Winters at West Greenland

by

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Introduction

This paper is a translation of the authors` paper "Isvintre ved Vestgrønland" as published in Danish and Greenlandic in "Forskning/ tusaut" Vol. 2/84 issued by the Commission for Scientific Research in Greenland, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark.

The original manuscript was send in for publication in April 1984, and very little up-dating has been made in the English version presented here. It should be noted, however, that the winter 1984/85 at West Greenland has not been another extremely cold winter.

During the winter 1982/83 the ice at West Greenland had such a distribution and thickness that this winter was characterized there as "the worst hard winter in this century". The winter 1983/84 was as cold as and showed at least the same amount of ice as that in 1982/ 83. This paper tries to elucidate the climatic events, the formation and distribution of ice off West Greenland, the oceanographic changes during these winters and the possible biological effects on fish and shrimp at West Greenland.

Climate (Stig Rosenørn)

This being written, by the beginning of April 1984, it has been extremely cold in West Greenland for more than two years, - particularly during the winters. The extraordinarily cold weather started in February 1982 and has without interruption been continuing ever since.

Compared to monthly mean temperatures at Godthåb (Nuuk) for the the standard period 1931-60, all monthly mean temperatures for the last 28 months have been below normal (Fig. 1). For January 1983 (-18.7°), January 1984 (-19.1°) and February 1984 (-19.8°) the individual temperatures are extremely pronounced new cold records since regular temperature recordings began in 1974. Previous lowest temperatures were in January 1882 (-14.9°C) and in February 1898 (-17.2°C).

Particularly the last two winters (Dec.-Mar.) have been unusually cold (see Fig.2). Each of them is exceeded, as far as the cold is concerned, only once during the past 110 years, i.e. during the winter 1883/84; but considered consecutively there is no known precedence. As regards midwinter (Jan.-Feb.) only, during which the normal is -7.5^{o}, 1984 with a mean temperature of -19.5^{o} is definitely the coldest on record; 4^{o} lower than in 1883 (-15.5^{o}) and 3.8^{o} lower than in 1983 (-15.7^{o}).

Mean summer temperatures at Godthåb for the past two years (see Fig.2) have been very low compared to the normal - in line with the cool summers around 1970; but not quite as cool as in some individual cases before 1915.

Annual means for 1982 and 1983 (see Fig.2) were both clearly below the normal of -0.6^{o}; in 1983 it was -4.1^{o}, the third coldest on record since 1874. After the first quarter of 1984 it may be expected that the annual mean will also be low, even with approximately normal conditions during the rest of the year. In Fig.2, showing individual seasonal temperature during the past 110 years, is also included a 5-years running mean for each season. This arbitrarily chosen smoothening of Godthåb temperatures is showing fairly clearly the course of the temperature since 1874. The order of magnitudes of temperature anomalies for the entire Arctic region ($65-85^{o}$N) is also indicated in the figure. The anomalies are departures from the mean for the period 1946-60 (within the standard period 1931-60) which permits a direct fairly certain comparison between this station and the whole region. This period is, by the way, situated in the warmest part of the whole period.

The trends in temperature during the entire period is to some extent selfevident. A word of warming against using the curve for prediction by extrapolation might be appropriate here, as this curve is nothing but a very simple reflexion of an extremely complicated sequence of weather events. Not only local ones; but probably hemispherically and possibly even globally. A thorough knowledge of the actual circulation both at the surface, in the atmosphere and in the ocean is a prerequisite for drawing a reliable parallelism between different time sections. However, this gives rise to serious problems as: only about one century of surface weather observations are at hand and considerably fewer oceanographic observations and upper air observations from a meagre, albeit improving, station network during the last thirty years only. Thus the probability to find similar cases to the extreme weather experienced at West Greenland during the past two years is nearly infinitesimal. The still quite chaotic and insufficient knowledge of the processes leading to climatic fluctuations, in particular of the air/surface interaction combined with the lack of basis observations, is rendering any attempt of predicting future climatic developments on any scale beyond a few weeks highly risky and quite unreliable - in particular after such an extremely atypical period.

At present only the following conclusions appear reasonable:

1) Weather at West Greenland has been extremely cold during the past two years;

2) The phenomenon experienced was on a comparatively local scale, and of greater intensity than anywhere else in the Northern Hemisphere; and

3) it has probably been related to an abnormally strong deepening of the Canadian upper air cold pool which at the same time was displaced towards the southeast, to the area between Baffin Land and West Greenland.

Various theories concerning the anomalies have been proposed, such as a connection with volcanic eruptions, certain coincidences between various natural cycles, or with the equally strong El Nino phenomenon in the Pacific.

Considering the present extension of the so-called West Ice, the only thing which appear reasonably certain seems to be that extraordinarily mild airmasses and/or warm waters in the West Greenland ocean current are required, in order to attain summer temperatures approaching normal levels.

If the Godthåb temperature deviations for indivisual seasons are compared to corresponding average anomalies for the entire Arctic region (Fig.2) there is generally a good agreement; but in some cases they are conflicting. This might be taken as an indication that the actual cold at West Greenland is a random isolated phenomenon. The actual cold does not conform to the mean of the entire Arctic region.

An odd observation is that around 1920 the temperature anomalies at Godthåb were in opposition to those of the rest of the Arctic, until the general warming of the Northern Hemisphere took place during the following years.

The West Ice (Jens Fabricius)

The extreme extension of the ice is not surprising considering the low West Greenland temperatures mentioned. This applies to the fast ice in fjords and on outer coasts as well as for the drift ice in Baffin Bay and the Davis Strait. This drift ice is in Greenland normally termed the West Ice. Its average extension for each month is shown in the upper row of maps in Fig. 7. The indicated average limits are approximate only. The general picture is correct; but comprehensive study of all available ice information is needed. The average extension of the fast ice is not shown on these maps. The extension of the West Ice is usually at a minimum in August/September. During the following months the West Ice appears at the coasts of Greenland as drift ice formed in areas in the north and the west. As far south as off Egedesminde the West Ice often joins the fast ice formed on and outward from the coast.

In the waters south of Egedesminde the formation of new ice takes place only during exceptionally cold periods such as the last 2-3 winters. The maximum extension of the drift ice is normally reached by March. Then begins the melting and the drift away from the Greenland West Coast. During the entire cyclus there is a continuous flow of West Ice along the Canadian side of Baffin Bay and the Davis Strait caused by the south going Labrador Current (vide Fig.8).

The corresponding observed ice conditions for the period August 1982 - March 1984 are shown in the other two rows of Fig. 7.

The low 1982 summer temperatures and the considerable advection of old ice (Storis) to West Greenland during that year will explain that as late as in August there were still remains of West Ice mixed with old ice in parts of Baffin Bay and the Davis Strait. Consequently the low water temperatures, the remaining ice and the low winter temperatures strongly contributed to "The worst ice winter of the century" in 1982/1983.

The 1983 summer temperatures again were low and advection of old ice once more above normal, so by August 1983 even more ice remained in Baffin Bay and Davis Strait as compared to the year before. Due to low temperatures during the winter 1983/84 the extension of the West Ice equalled the previous record of 1982/83. Conditions were so unusual that considerable formation of new ice took place all along the West Coast and right into Julianehåb Bay.

Ice charts as shown in Fig.7 are based on reports from coast stations, ships, aircraft as well as on satellite photographs. A wealth of information; but not all easily utilized. Some ice limits shown are approximated and thus marked with dotted lines.

The Danish Meteorological Institute possesses the world's longest series of published ice charts. The older charts - right up to the second world war - are based on observations from coast stations and the few vessels journeying into arctic waters during summer.

Although the older ice information is relatively sparse as compared to that available from the last 40 years of observations, we believe it a reasonably safe conclusion that the extension of the West Ice during the winters of 1982/83 and 1983/84 so far has not been exelled in this century.

The mass of ice is in the main dependant on the temperature conditions in the formative areas and the surface sea currents such as the West Greenland Current which even in these years with difficult ice conditions has quickly reopened West Greenland for sea transport during the summer months.

Sea Temperature (Erik Buch)

The northward flowing water masses along the Greenland west coast originate partly from the East Greenland polar current and partly from the Irminger current, Fig. 8. The two currents meet in the area between Greenland and Iceland flowing southward under intense mixing, so when rounding Kap Farvel some of the original characteristics of the two water masses are lost, and the hydrographic conditions along the west coast of Greenland therefore greatly depend on the relative strenght of each of the two currents, the effectiveness of the mixing between the two as well as on the meteorological conditions over the West Greenland area.

The intensity of the two currents varies within the year as well as from year to year. The seasonal variations are relatively well known. The East Greenland component is intense during spring and summer with the greatest intensity in June - July, while it is weak in the autumn and winter time. The Irminger current has a low intensity during the first half of the year, then the intensity increases to a maximum in November - December.

The variations of the two currents´ intensity from year to year are much more complex to describe and explain, because they are brought about by dynamical processes in the whole North Atlantic area which again highly depends on the conditions in the atmospere.

In Fig. 9 the mean temperature of the water column over the Fylla Bank (0 - 40m) in the middle of June is shown for the period 1950-1983. The actual observations as well as a 3-year running mean are shown. Between 1950-65 the temperature is relatively high, around 2°C. The next 5 years are characterized by a strong cooling where the temperature drops below 0.5°C. Between 1970 and 1974 the temperature increases again, followed by a period with relatively stable conditions, but with temperatures at a lower level than in the fifties. After 1980 a strong cooling period starts again with temperatures comparable to those observed around 1970.

The cold period in the late sixties can be explained by an increase in the atmospheric pressure over Greenland and decrease over the Norwegian and the Barents Sea, Dickson et al. (1974). The resulting pressure gradient brought about a high frequency of northerly winds over the Greenland Sea, which pressed great volumes of cold, ice-filled water from the Arctic Sea southward along the East Greenland coast and further on to West Greenland. The High intensity of the East Greenland current resulted in low sea temperatures and great amounts of sea ice in the East and West Greenland area as well as at the northern and eastern part of Iceland.

The low temperatures found in the West Greenland area at present can not solely be explained by great inflow of cold East Greenland polar water although the intensity has been relatively high during the last 2-3 years, which is reflected in the presence of "great ice" in quantities above average, Fig. 7. The main reason for the low sea temperatures may on the other hand be explained by the above mentioned inflow of extremely cold air masses from Canada, which has caused a cooling of the water masses during the autumn and winter period which has totally suppressed the admission of heat from the Irminger water. At the same time the relatively cold summers have not been able to rewarm the water masses, and this has radically changed the course of the temperatures of the upper layer in the West Greenland area.

In Fig.10 is shown how the temperature varies in the upper 150 m near the Fylla Bank in the period from October 1 to April 1 during a "normal" winter. A uniform decrease in temperature takes place from October to the middle of February, and negative temperatures occur around January 1. The minimum temperature is a little less than -0.5°C.

During the winter 1983-84 the temperature drops below 1°C as soon as in October. Negative temperatures are observed at the middle of November. At the end of January the temperature is low enough (-1.8°C) for ice formation to take place. The ice cover prevents further cooling of the underlying water masses so that heat can be added from the inflowing Irminger water. This is the reason why in February, despite the very low temperatures in the atmosphere, only negative temperatures are observed only in the upper 40 metres with a miminum temperature of -0.9°C, which after all is well below normal.

The quite different temperature conditions that exist in a "normal" winter and the present cold winters can further be illustrated by looking at vertical sections across the Fylla Bank from January 1977 and January 1983, Fig. 11a, b. In January 1977 only the upper 10-25 metres of the two innermost stations showed temperatures below 0°C, while St. 3 and St. 4 had relatively high temperatures due to the inflow of Irminger water. In January 1983, on the contrary, the westernmost stations showed the coldest surface temperatures, below -1.5°C, in a 20-50 metre thick layer, which is due to a local cooling caused by the inflowing cold air masses from Canada.

Possible Effects on Marine Organisms and on the Fisheries

(Svend Aage Horsted)

The preceeding parts of this paper clearly illustrate that in Greenland the winters 1982/83 and 1983/84 were extremely cold. This has caused great public concern with regard to the possible effects on those living ressources on which Greenland's fishery is based. This section considers that question but has by nature to be more speculative than the preceeding sections which were based on exact observations.

When discussing the effects of the hard winters on the fishery on has to distinguish between the immediate, physical effect on fisheries conditions and the short-term or long-term effects on the ressources.

Hard winters lead to physical blocking of wide areas where sailing and fishing from vessels become impossible. The distribution of ice (Fig. 7) clearly shows that north of Manîtsoq (Sukkertoppen) fishing by vessels was virtually impossible in the period December 1982 to April 1983 and again from December 1983 through March 1984. The most important offshore shrimp grounds have generally been inaccessible in the periods just given.

Also the most important inshore fishery, viz. that for shrimp in the Disko Bay was hindered for many months. Table 1 illustrates the effects of such a stop for the shrimp fishery.

Year month	10	11	12	1	2	3	4	5
1979/80............	221	424	240	409	344	539	480	926
1980/81............	435	0	0	592	152	486	842	1471
1981/82............	510	569	281	143	5	0	96	971
1982/83............	987	568	22	0	0	1	24	904
1983/84............	655	499	36	5	107	676	1387	1672

Table 1. Annual catches (tonnes) of shrimp by state-owned Greenland trawlers in the area from Sukkertoppen Deep (Div. 1C) and northwards for the months October to May, 1979-84.

Although the figures are influenced by trawlers' performance, i.e. whether they were directed on cod or on shrimp fishing or went to fishing grounds outside those covered by the table, the table clearly illustrates that in 1982/83 there was a nearly 5 months stop for shrimp fishing in the area considered. The less obvious influence of the 1983/84 winter is due to the fact that in the beginning of 1984, in contrast to 1983, shrimp grounds in Div. 1C showed good abundance of shrimp, while grounds in Div. 1B were inaccessible due to ice as in 1983.

The Salmon Fishery

Another direct effect may possibly have been seen in the fishery for Atlantic salmon i 1983 and again in 1984. The catch for 1983 was 310 tonnes as compared to a quota of 1190 tonnes. The TAC was lowered to 870 tonnes for 1984, but catches were only about 300 tonnes. The ICES Working Group on North Atlantic Salmon (Anon., 1985) has pointed to serveral possible causal factors for the sudden decrease. The three major factors were identified as

1) Adverse environmental factors
2) Lower than normal sea survival rate of relevant smolt classes and low stock abundance
3) Reduced fishing effort at Greenland

Exactly how the environmental factors have operated is not fully understood, but it is, for instance, possible that coastal, relatively cold water may have kept salmon away from some coastal waters, or cold surface water may have caused that salmon was found below the few-meter range of the drift nets. Local phenomenons of that kind were observed in 1972, when the International Salmon Tagging Experiment was carried out at Greenland.

Mortality as a Direct Consequence of Low Water Temperatures.

At some of the previous occasions of extreme cooling of the sea, observations of mass mortality of fish and shrimp have been made (Horsted and Smidt, 1965). Thus all shrimp and a lot of redfish died in the Amerdloq fiord at Sisimiut/Holsteinsborg after the very cold winter 1948/49 (see Fig. 2) when bottom temperatures in the fiord reached - 1.6 ^{o}C. There are also records of mortality, especially of redfish, after the winter 1937/38 and in the cold period by the end of 19th century.

The author is not aware of any observations of direct mortality of fish and shrimp due to cold water during the recent cold years. The hydrographical observations do also show, that the extreme cooling of the water masses over the West Greenland fishing banks has been limited to the upper layers while at depths beyound about 100 m temperatures were rather normal, in some periods even above normal (see Fig. 11 a-b). The coverage of vast areas by winter ice seems to have limited the cooling of the water, at least in a narrow zone along West Greenland. The observations do, however, indicate a considerable extent of the cold Labrador Current which may have pressed the warm water from the Irminger Current closely towards the West Greenland banks.

Long-term Influence on the Cod Stock

The public concern and the many questions on the possible influence of the cold winters have mainly been with regard to the possible long-term effects, especially on the cod stock. In regard to this it should be pointed out, that it is not so much the water temperatures during winter as the conditions during spring and early summer that are critical. The problem during winter seems limited to the question of cod being able to find water masses with reasonable good temperatures and with sufficient food. Both conditions are normally found on the western slopes of the West Greenland fishing banks, where shrimp is one of the food items. It is usually also on the western slopes of the banks that shoals of pre-spawners and spawning fish are found some months later. From the hydrographical observations we cannot say that reasonable conditions for cod were not found on the western slopes of the banks after the recent severe winters, although the zone with such conditions may have been rather narrow.

After spawning, cod eggs and later on larvae drift with the current, especially in the upper water layers. The temperature in these water layers at that time seems a critical factor, and a good survival of eggs and larvae seems to require a temperature of 1.8°C or more. It may well be an indirect rather than a direct temperature influence, e.g. a question of synchronization of primary production, occurrence of copepod nauplii and copepodites and start of activ feeding of cod larvae. Our experience is that the chance of seeing a good cod year class is much higher for years when the water over the banks at that time (June) is at or above the said temperature, whereas in years with lower water temperatures good year-classes have been seen only seldomly (Hermann, Hansen and Horsted, 1965). When the general water temperature level decreased in the late 1960ies (Fig. 9) a series of poor cod year-classes occurred and the total stock thereby gradually decreased leading to the significant drop in catches. The 1973 year-class, evidently entering West Greenland waters as young fish of East Greenland origin, meant a temporary improvement in a very critical situation.

The Fishery in 1983 and 1984

The cod fishery in 1983 and 1984 was based nearly intirely on the year-class 1977 and 1979 (in both years water temperatures were higher than in 1978, see Fig. 9). These two year-classes are, however, not at all as good as were those called good before 1970. They ought, however, to have supported much better catches than the trawlers have reported during 1984. The very bad fishery in 1984 cannot be fully explained by low water temperatures unless most of the cod should have followed the inflow of deep, relatively warm water to the north to Holsteinsborg Deep or further north.

However, this has not occurred. The biologists are not very proud of the situation since the biological prognoses were much more favourable than the actual situation has turned up to be. It is hard to believe that the winters have caused a direct decrease in abundance. The cold winters may, however, lead to relatively cold conditions in the following spring and summer. This, at any rate, was the case in 1983. Whether the same counts for 1984 remains to be seen, but there was a lot of ice to delay summer heating of the water.

Occurrence of Rare Fishes

By the inflow of warm water of Irminger Current in the beginning of 1984 some fish species, usually regarded as rare at West Greenland occurred much more frequently. Very pronounced has been an inflow of Blue Whiting. Also some generally uncommon fish species (e.g. Caristius groenlandicus, Jensen) have been reported. For fishermen and the community it is, however, more important that shrimp again seems to occur in fishable abundance in the Sukkertoppen Deep (Div. 1C) and on other grounds outside the more northern major grounds in Div. 1B.

Shrimp fishing has to a great extent substituted cod fishing in 1984. The background seems a very interesting situation for science - a bit too interesting for those who have to make their living directly or indirectly from fishing.

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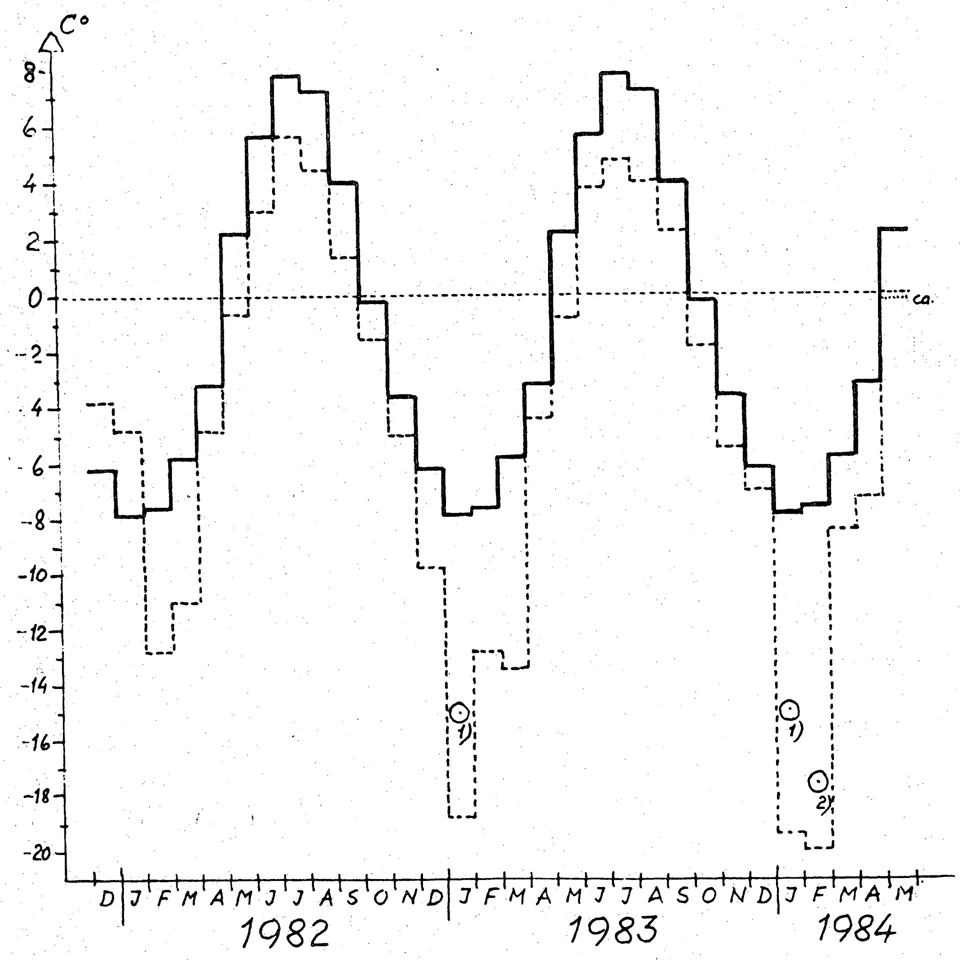


Fig. 1. Monthly mean air temperature at Nuuk/Godthåb averaged for the norm-period 1931-60 (full-line) and shown for each month for the period December 1981 to May 1984. Point numbered 1) indicates coldest January (1882) and 2) coldest February (1898) recorded before 1983/84.

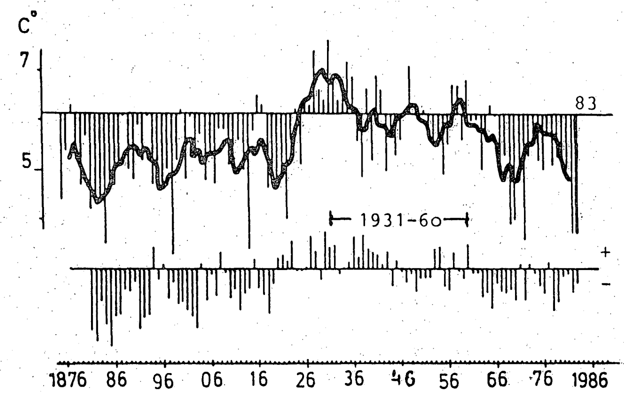


Fig. 2a.

Mean air temperature anomalies for the summer periode (June-September) at Nuuk/Godthåb (upper part) and for the total arctic region (lower part). Base period For Nuuk/Godthåb is 1931-60, for which summer temperature was 6.1°C, while for the total arctic region the base period is 1946-60, temperature 0.6°C. Curves are 5-year running means of anomalies.

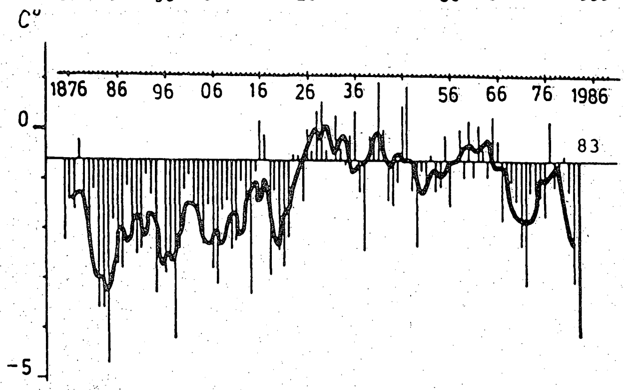


Fig. 2b.

Mean air temperature anomalies for the whole year at Nuuk/Godthåb. Base period is 1931-60 for which the average was -0.6°C. The curve shows 5-year running means of anomalies. The mean for 1983 is the lowest but two over the period since 1874.

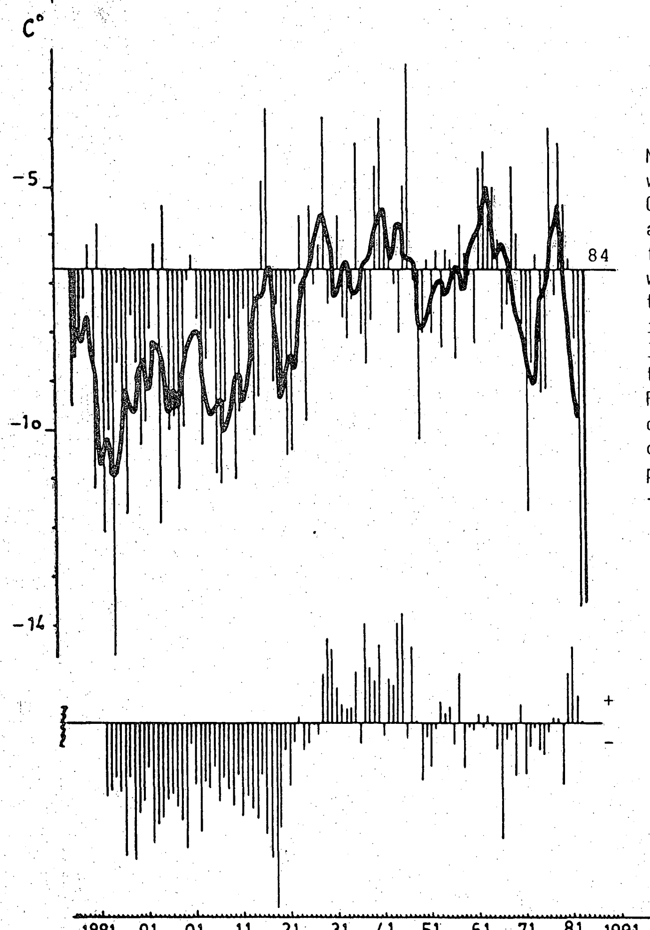


Fig. 2c.

Mean air temperature anomalies for the winter period (December-March) at Nuuk/Godthåb (upper part) and for the total arctic region (lower part). Base period for Nuuk/Godthåb is 1931-60, for which winter temperature was -6.7°C, while for the total arctic region the base period is 1946-60. Only the winter 1883/84 shows lower temperatures than each of the winters 1982/83 and 1983/84. If only January/February were regarded 1984 would show the coldest winter (mean -19.5°C) ever recorded at Nuuk/Godthåb, about 4°C colder than previous records (1883: -15.5°C; 1983: -15.7°C.)

Fig. 3 + 4. These two figures show the mean air temperature anomalies over the arctic region.

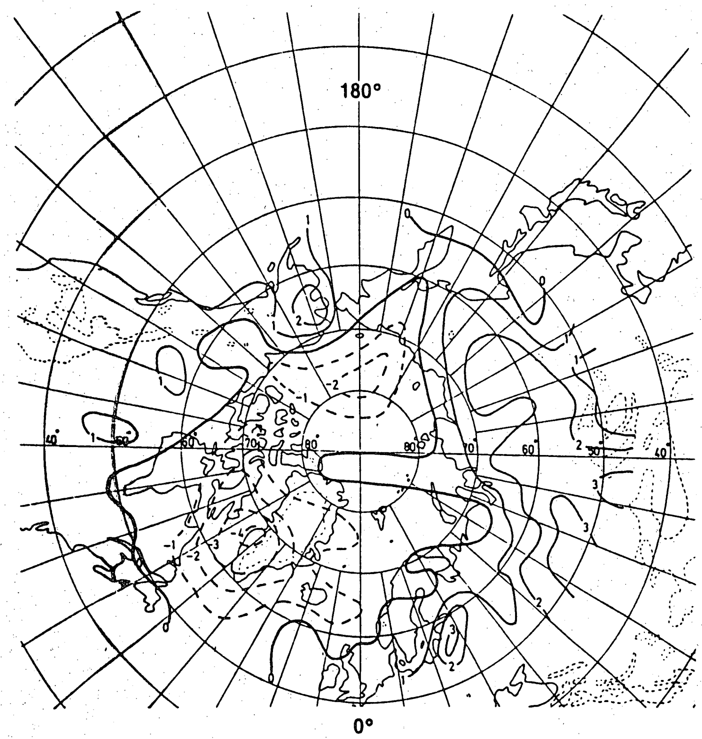


Fig. 3. For the year 1983.

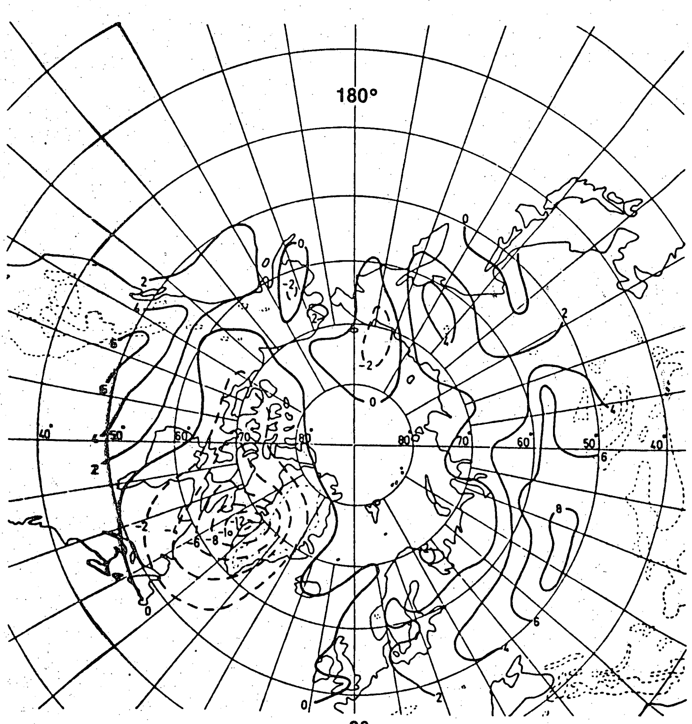


Fig. 4. For January-February, 1983.

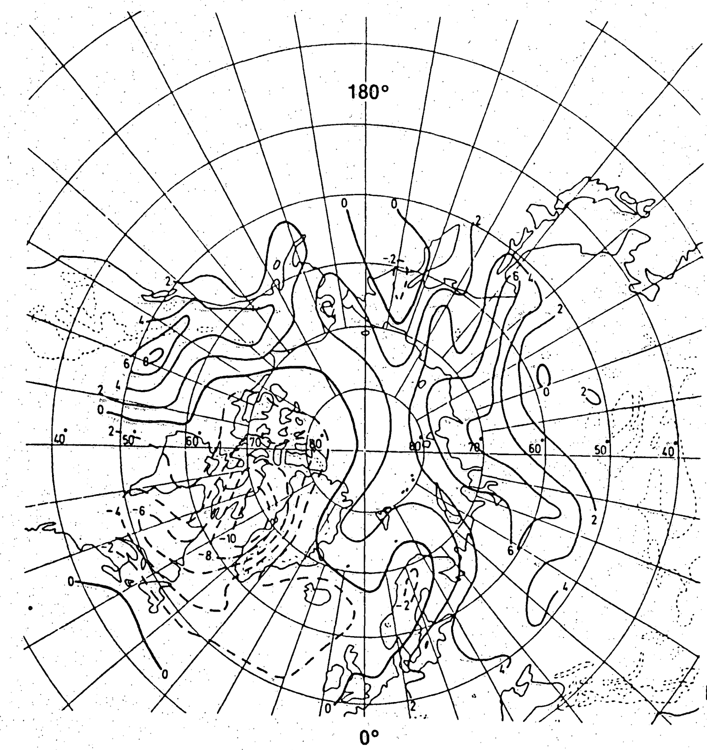


Fig. 5 + 6. These two figures show the mean air temperature anomalies over the arctic region.

Fig. 5. For January, 1984.

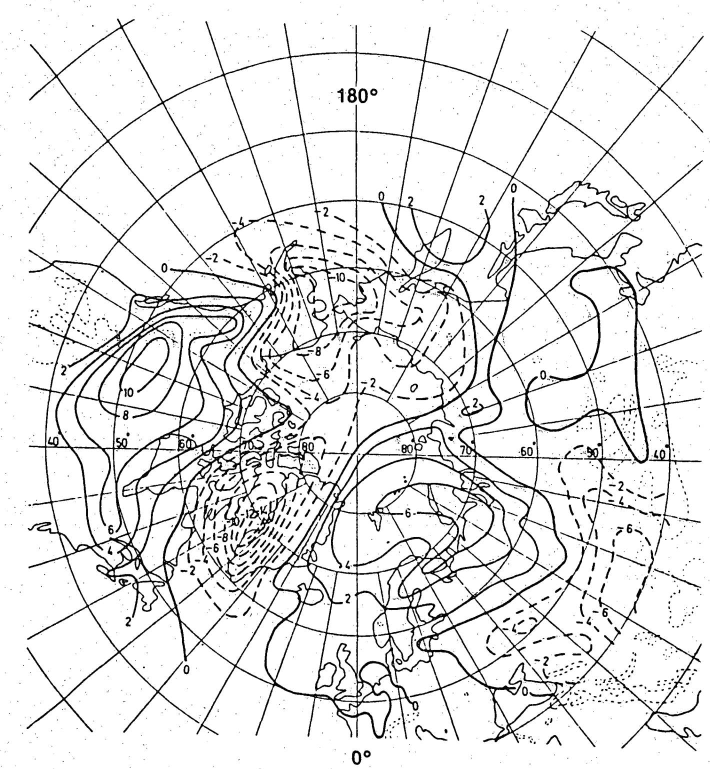


Fig. 6. For February, 1984.

For February, 1984 the mean air temperature at West Greenland was up to 14°C colder than normal while at the same time the mean over the western part of Canada was up to 10°C warmer than normal.

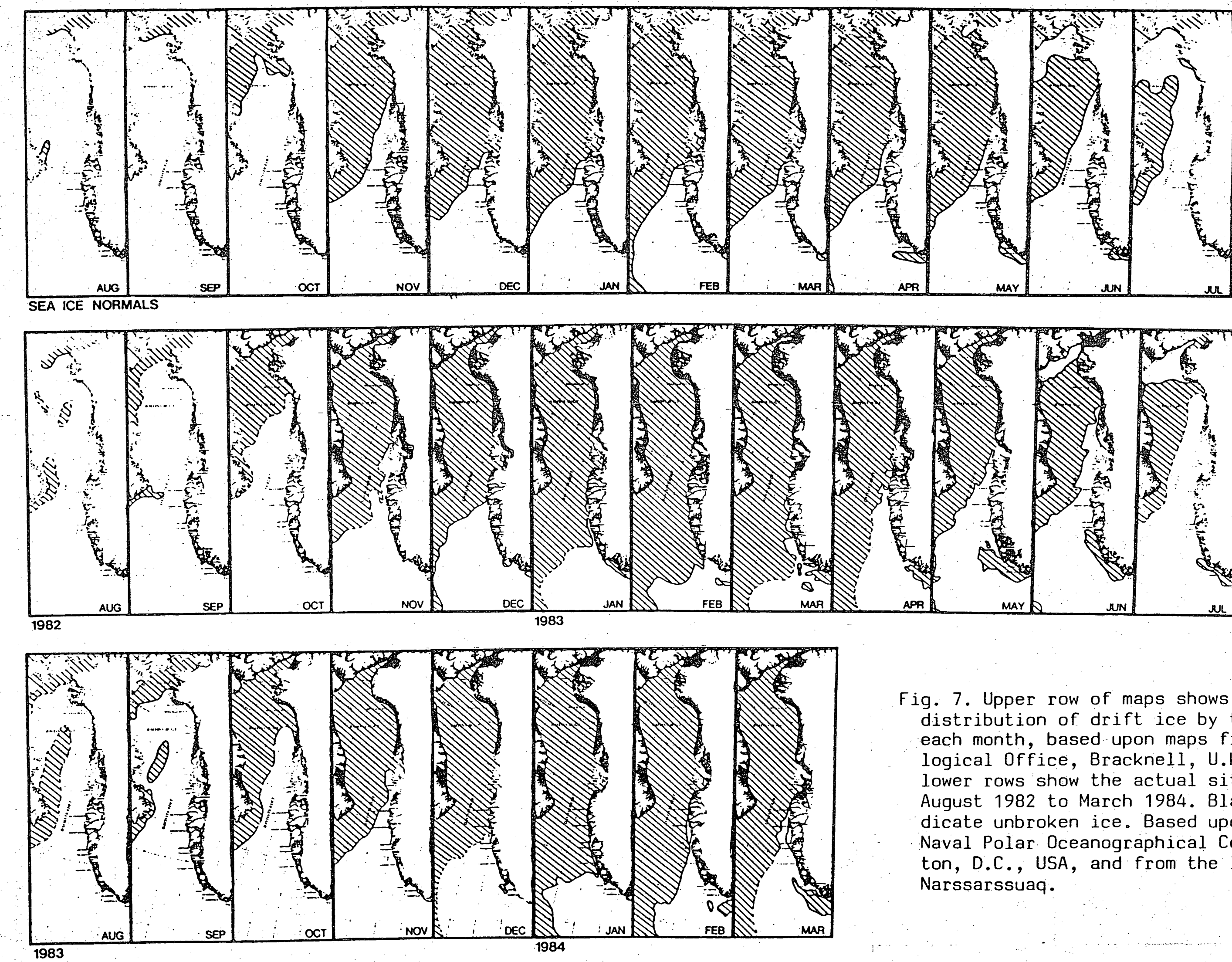


Fig. 7. Upper row of maps shows the average distribution of drift ice by the end of each month, based upon maps from Meteorological Office, Bracknell, U.K. The two lower rows show the actual situation from August 1982 to March 1984. Black areas indicate unbroken ice. Based upon maps from Naval Polar Oceanographical Center, Washington, D.C., USA, and from the Ice Central at Narssarssuaq.

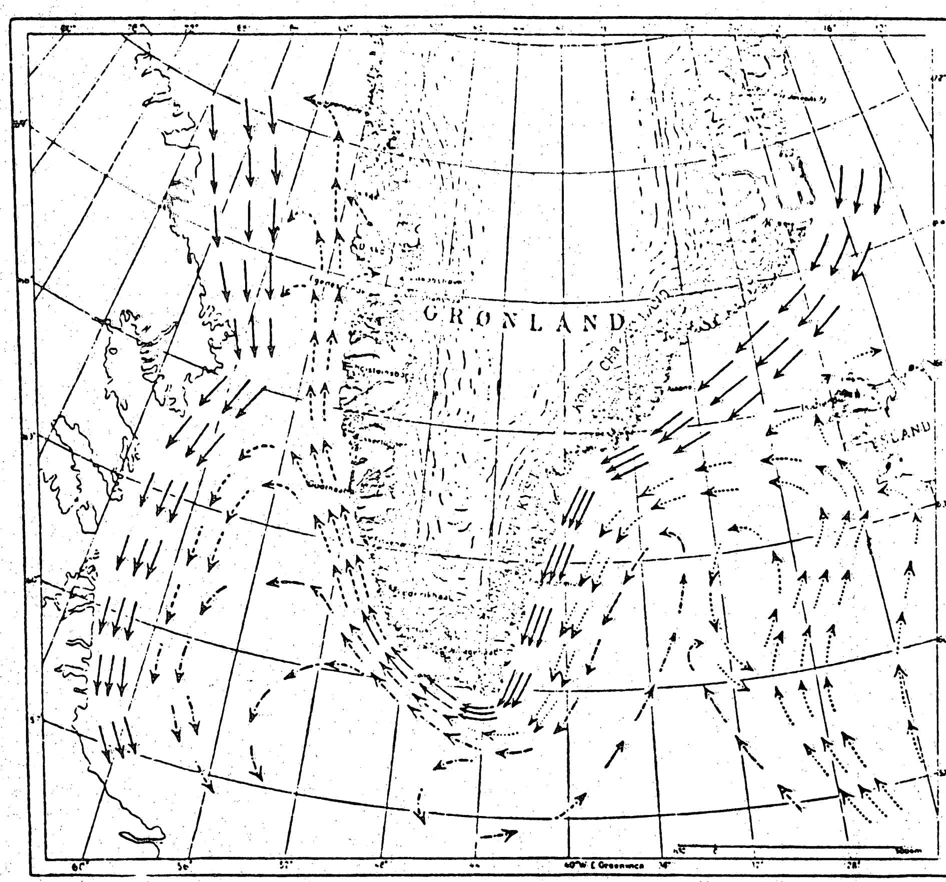
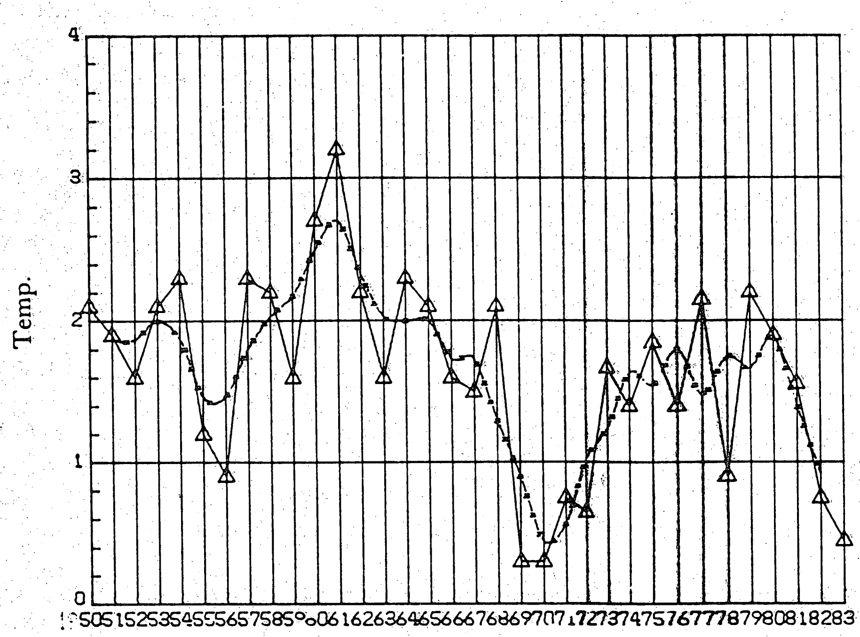


Fig. 8. The current systems round Greenland.

⟶ The East Greenland and Baffin Islands-Laborador Polar Currents.

···▸ The Irminger Current.

--▸ The West Greenland Current.



—·— 3-years running mean

△—△ annual observations

Fig. 9. Mean temperature 0-40m over the shallow part of Fyl-la Bank by mid-June, 1950-83. (Station 2, see Fig. 11).

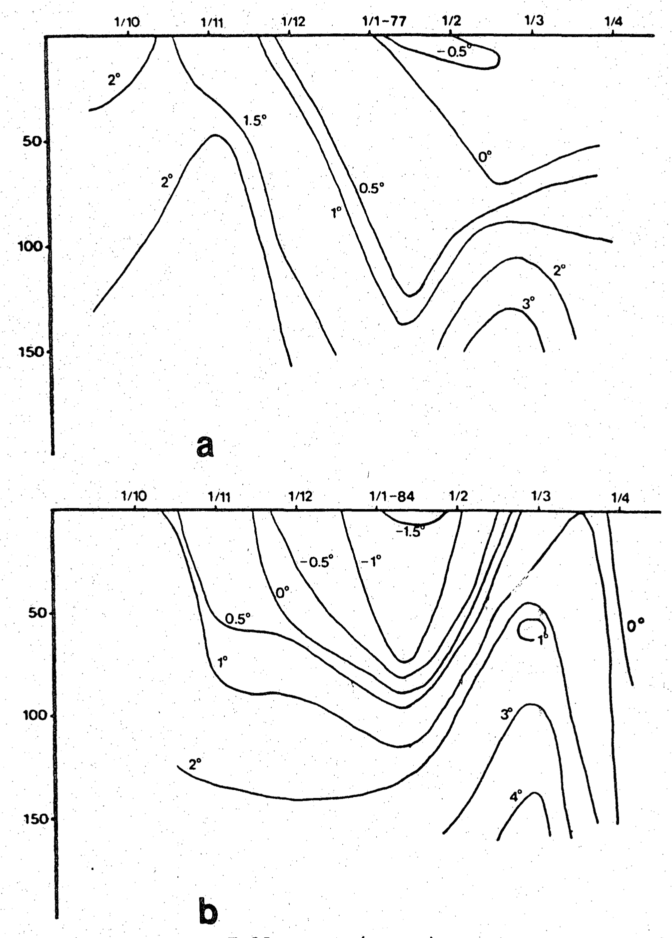


Fig. 10. Water temperatures over Fylla Bank (St. 1) by Janaury 1977 (a) and by January 1984 (b).

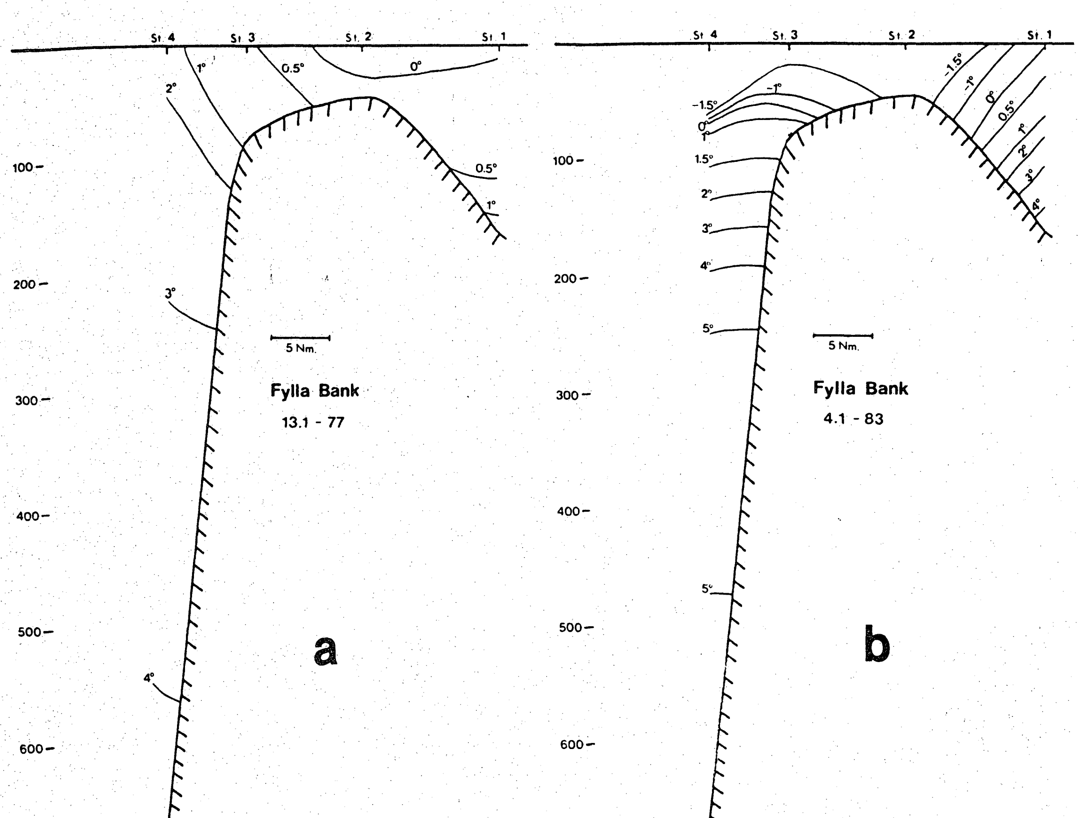


Fig. 11. Water temperature over Fylla Bank by January 1977 (a) and by January 1983 (b).