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Seasonal Variability of the Shelf Waters off Southwest Greenland

by

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ABSTRACT

The seasonal variability of the shelf waters off southern West Greenland are explored through an analysis of historical data collected between 1920 and 1988. The shelf region is divided into 14 separate areas from Cape Farewell to Upernavik. In each area, monthly means of temperature, salinity and density were calculated at standard depths. The near surface temperatures show seasonal atmospheric heating and cooling with a maximum typically in August. Waters below 50 m peak during September-November. The time of the monthly mean near-surface salinity minimum occurs progressively later from south to north, in August off Cape Farewell to October in the Davis Strait region. We suggest that the salinity minimum reflects ice melt off East Greenland which is advected northward along West Greenland by the residual current. A northward velocity of approximately 0.16 ms^{-1} estimated from the timing of the salinity minima along the coast closely matches that of the residual speed of the West Greenland Current.

INTRODUCTION

This paper examines the seasonal variability of the shelf waters off southern West Greenland. Our interest in the physical oceanography of the region has primarily arisen through attempts to understand its influence upon fish stocks (Jensen and Hansen 1931; Hansen 1949; Hovgård and Buch 1990; Dickson and Brander 1993; Buch et al. 1994) and possible links with the hydrographic conditions on the Labrador and Newfoundland shelves (Myers et al. 1988; Dickson et al. 1988; Stein 1993; Drinkwater 1994). As part of a study of the interannual variability in the Labrador Sea, we calculated the long-term monthly means of the hydrographic characteristics for several areas including the shelf region off West Greenland.

The continental shelf off West Greenland is relatively narrow with complex topography consisting of a series of offshore banks separated by channels and gullies. The residual circulation is dominated by the northward flowing West Greenland Current. The majority of its transport is located over the continental slope and consists of water originating from the North Atlantic Current (Buch 1993, 1994). These water are relatively warm (3.5-5.5°C) and saline ($34.5<S<34.88$ for Subatlantic Water and $S>34.88$ for Irminger water). In contrast, the shelf waters primarily originate from the East Greenland Current which carries cold polar waters of low salinity. Off West Greenland the shelf temperatures range from -1 to 4°C and salinities from 31.5 to 34.5. The upper layer waters over the shelf break are usually of shelf origin.

Buch (1984, 1994) has discussed the seasonal variability of the waters off West Greenland. Based primarily upon changes at a station near the shelf break on Fyllas Bank, he described the seasonal heating and cooling of the waters and the importance of annual variability in the strength of the East Greenland, Irminger and North Atlantic Currents.

In this paper we present a preliminary analysis of the seasonal variability in the shelf waters off southern West Greenland from Cape Farewell to Upernavik. The next section describes the data and methods used. This is followed by the results of the seasonal analysis in the temperature, salinity and density of the shelf waters and a discussion of their possible forcing mechanisms. A summary of the conclusions and future work is presented in the final section.

DATA AND METHODS

Historical temperature and salinity data have been assembled into a climatological database at the Bedford Institute of Oceanography (BIO). Initially, the database covered only the Scotian Shelf and the Gulf of Maine (Drinkwater 1992) but it has been enlarged to encompass Baffin Bay, the Labrador Sea (including off West Greenland), the Grand Banks, the Gulf of St. Lawrence, the Middle Atlantic Bight and adjacent offshore areas. The data are derived from the Marine Environmental Data Service (MEDS) archive in Ottawa, Canada but have undergone additional editing and quality control.

For the present study, we divided the shelf region from Cape Farewell to Upernavik, West Greenland, into 14 areas that roughly correspond to topographic features (Fig. 1). All available data within these areas having profile depths of 200 m or less were extracted from the BIO database. Monthly mean temperatures, salinities and densities were estimated at standard depths (0, 10, 20, 30, 50, 75, 100, 125, 150, 175 and 200 m) for each area. To avoid possible bias from heavy sampling within a particular year, we first averaged all profiles in an area by month for each year. All these means were then combined to calculate the long-term monthly means. No adjustments were made for differences in either the location within the area or for the day of the month. For the more northern areas, which are ice covered in winter, no data were available in the winter months. In some months for some areas the means are based upon a single measurement or a single year and as such may not represent a true "mean". Occasionally, because there are different number of observations at each depth, the averaging process may produce apparent density inversions but these are not considered real. The database covers the period from the 1920s to 1988.

RESULTS

The monthly mean temperatures, salinities and densities (sigma-t) from 6 out of the 14 areas are shown in Figs. 2-7. These areas tended to have the most data, cover the geographical extent of the study region, and are representative. Temperatures in the upper 50 m are typically <0°C from January through into the spring. These below zero temperatures extend into May north of Fyllas Bank and at Cape Farewell but disappear by May elsewhere. Rapid heating of the upper layer waters occurs during the late spring and continues into the summer as temperatures rise to 4-5°C in the surface by August. Surface temperatures are lower in the extreme south, only reaching upwards of 3°C at Cape Farewell and in the Frederikshaab area. Also, at Cape Farewell the temperature increase is more gradual, staying colder longer and peak temperatures occur later, i.e. in September. The temperature of the waters at depths of 100-200 m typically decrease through the winter to a minimum in late winter or spring. They increase through until the summer with a rapid rise in autumn. Minimum temperatures in these deep waters does not usually drop below 0°C and will attain a maximum of 3-4°C. In contrast to the Labrador Shelf and off Newfoundland on the other side of the Labrador Sea, there is no distinct cold intermediate layer on the shelf. Instead, off West Greenland temperatures generally decrease with depth during the summer and increase in the autumn and winter (Fig. 8).

Salinities in the top 50 m are maximum in April, then decrease through the late spring and summer. The salinity minimum occurs in August off Cape Farewell and progressively later further to the north (Fig. 9). Also the beginning of the salinity decrease occurs early at Cape Farewell and progressively later northward. No distinct minimum is observed on Store Hellefiske Bank though salinities decline from spring through to December and off Disko Island salinities show no trend between June to November. There is little change in the salinity minimum (31-31.5) between Cape Farewell and Fyllas Bank but it increases to the north, rising to over 32 by Sukkertop Bank and 33 off Disko Island. The timing of the salinity minimum at 100 m appears to occur slightly later in the year than at shallower depths. Below 100 m the seasonal cycle is less evident but at Fyllas Bank the salinity minimum occurs in June at 200 m and in July at 150 m.

At the relatively low temperatures (-1 to 5°C) observed off West Greenland, the change in density with temperature is small. Thus, the density is determined mainly by salinity changes and minimum densities in the near surface layers correspond to the time of minimum salinity. The minimum density gradient through the water column occurs in the spring. This is most clearly shown at Fyllas Bank where it occurs in May.

DISCUSSION

The rise in temperature through the summer in the upper layers is due to atmospheric heating. This is suggested by the similarity in timing of the ocean temperature maximum in August. The later maximum and lower temperatures at Cape Farewell are believed to be related to the cooling influence of the cold East Greenland Current waters. The decrease in the temperature and salinity of the deep waters on the shelf in the spring results in the vertical density gradient being greatly reduced. This means it takes less energy to mix the water column, for example by the winds. In the autumn, the surface water temperatures decrease through heat losses to the atmosphere but at depth the waters gain heat at a rate higher than could be accounted for by vertical mixing. Also, there is a tendency for the peak temperatures to occur slightly later in the year, further north. Similar warming of the deep water off the shelf in the autumn was observed by Buch (1984). Thus the warming of the deep waters on the shelf is believed to be forced by inflow of water from offshore. Data from off East Greenland (Fig. 10) shows that the warm deep waters penetrate that shelf by September. The residual circulation would advect them around Cape Farewell and then northward along West Greenland. Some of the warm deep water observed off West Greenland may also have penetrated from adjacent offshore waters, although the relative importance of this process compared to the northward advection is unclear.

The later appearance of the salinity minimum northward along the West Greenland coast can only be explained by advection of the West Greenland Current as there is no large local sources of runoff that account for this pattern. The salinity minimum appears to be advected from East Greenland where to the east of Cape Farewell salinities show a near surface minimum in July (Fig. 10). This salinity minimum is believed to be due to ice melt. Between Cape Farewell and Sukkertop Bank there is a difference of 2 months between the salinity minima. The distance between the two areas is approximately 825 km which implies an advection speed of 0.16 ms^{-1}. This matches closely the estimated mean speed of the West Greenland Current over the shelf during the NORTHWESTLANT studies (ICNAF 1968). These low salinity waters appear to be advected further north than Sukkertop Bank but the timing of the minimum is not resolved due to the lack of data in the winter. The increase in the value of the salinity minimum suggests that less of these low salinity waters make it north of Fyllas Bank which is consistent with the circulation patterns that show the West Greenland current decreases in strength and part of the flow is deflected westward near Fyllas Bank. Given the lack of any seasonal trend in salinity off Disko Island from June to November, it appears that they do not penetrate that far north.

SUMMARY

The seasonal variability of the shelf waters off West Greenland are explored through an analysis of historical temperature, salinity and density data. The near surface temperatures show evidence of atmospheric heating with a maximum typically in August. Waters below 50 m peak later during September to November and is believed to reflect forcing by offshore waters off East Greenland and advected northward along West Greenland by the residual current. The timing of the monthly mean near-surface salinity minimum occurs progressively later in the year further to the north, in August off Cape Farewell to October in the Davis Strait region. We suggest that the salinity minimum reflects ice melt off East Greenland which is advected northward along West Greenland by the residual current. A northward velocity of approximately 0.16 ms^{-1} estimated from the timing of the salinity minima along the coast closely matches that of the residual speed of the West Greenland Current.

This study represents an initial analysis of the data. We propose to add additional data, notably those collected since 1988 and recalculate the monthly means. This is not expected to change any of the patterns or conclusions but will add to the statistical reliability of the means.

In addition we plan to estimate the heat fluxes and compare them to the observed changes in the heat content on the shelf. Finally, we are presently calculating the seasonal variability in the offshore waters near the shelf break and will report on those in future paper.

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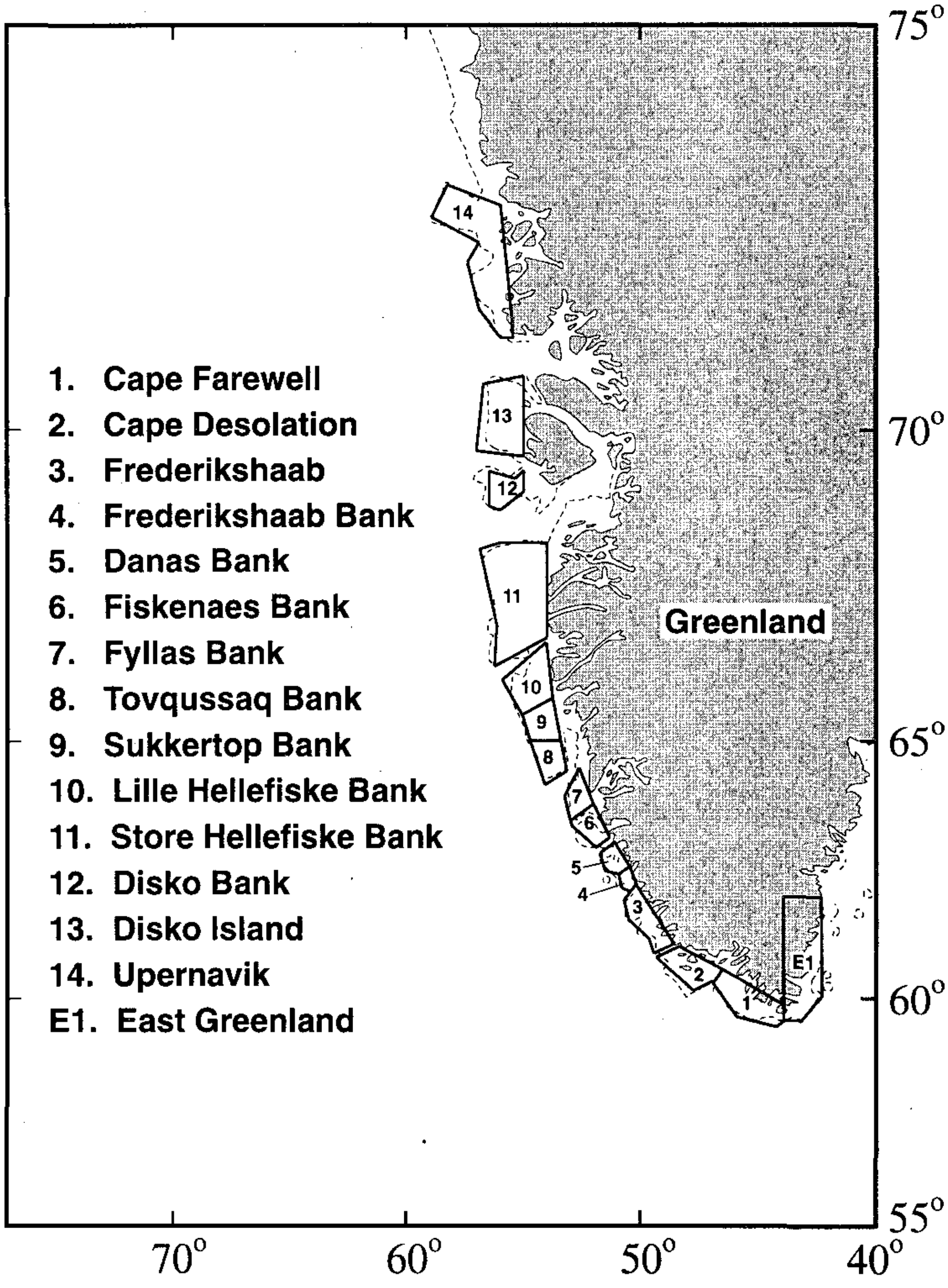

Fig. 1. Map of Greenland showing shelf areas where monthly means of temperature, salinity and sigma-t were calculated.

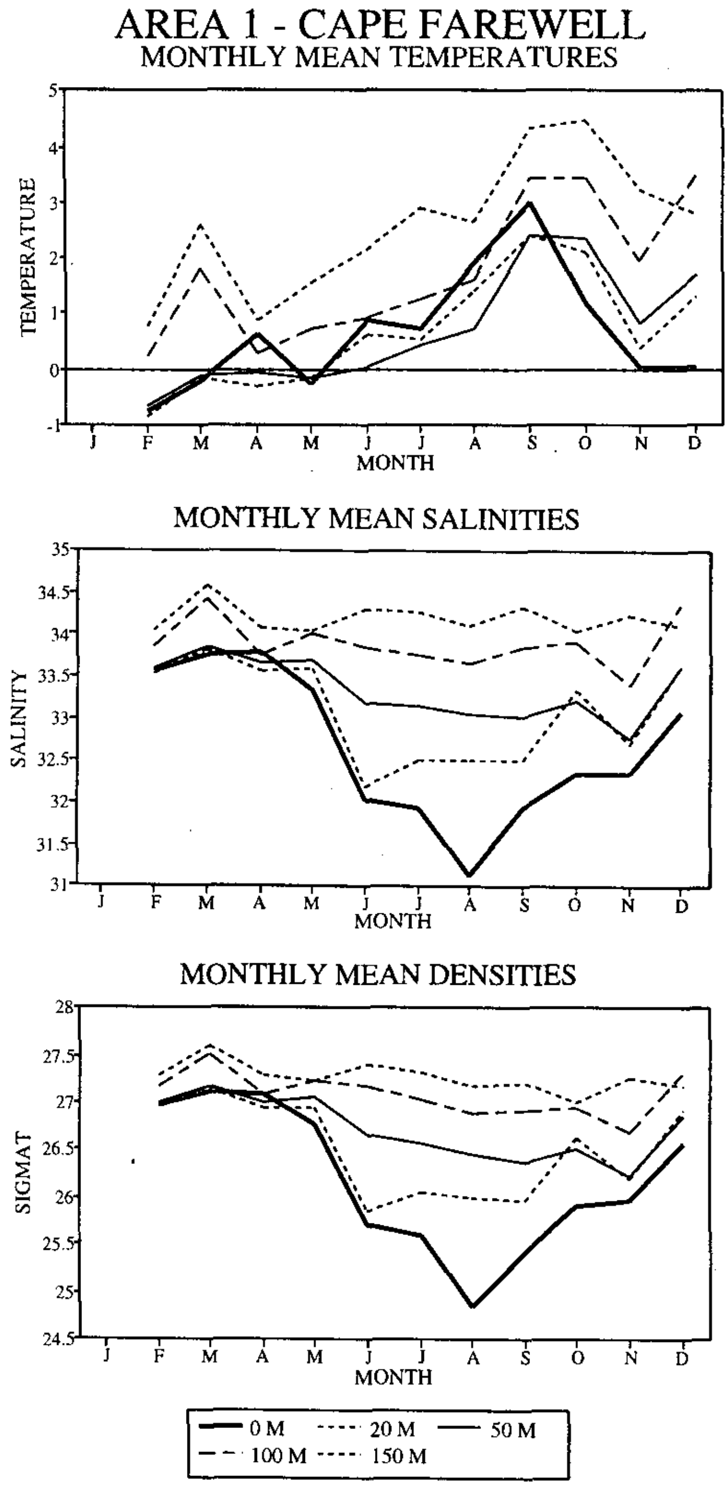

Fig. 2. The monthly means of temperature, salinity and sigma-t at various depths for Area 1 off Cape Farewell.

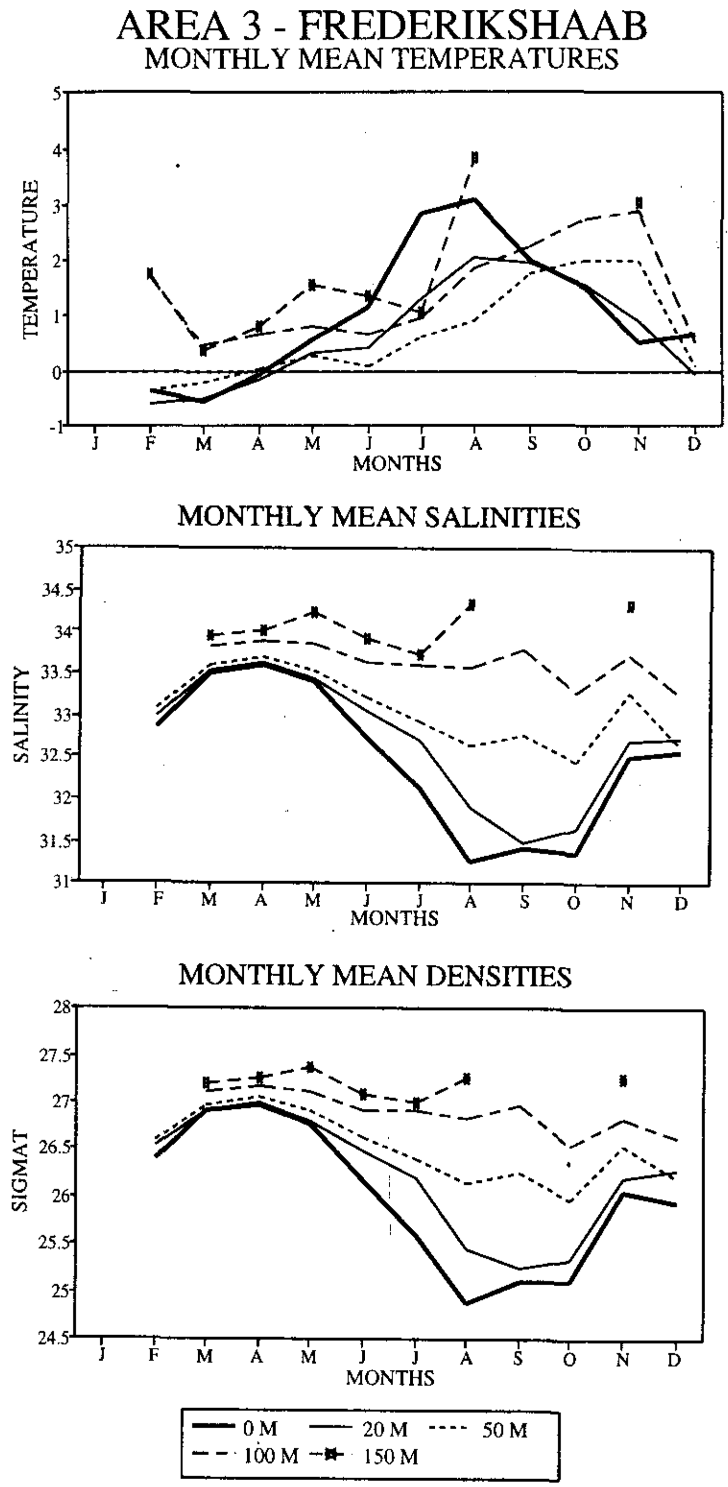

Fig. 3. The monthly means of temperature, salinity and sigma-t at various depths for Area 3 off Frederikshaab.

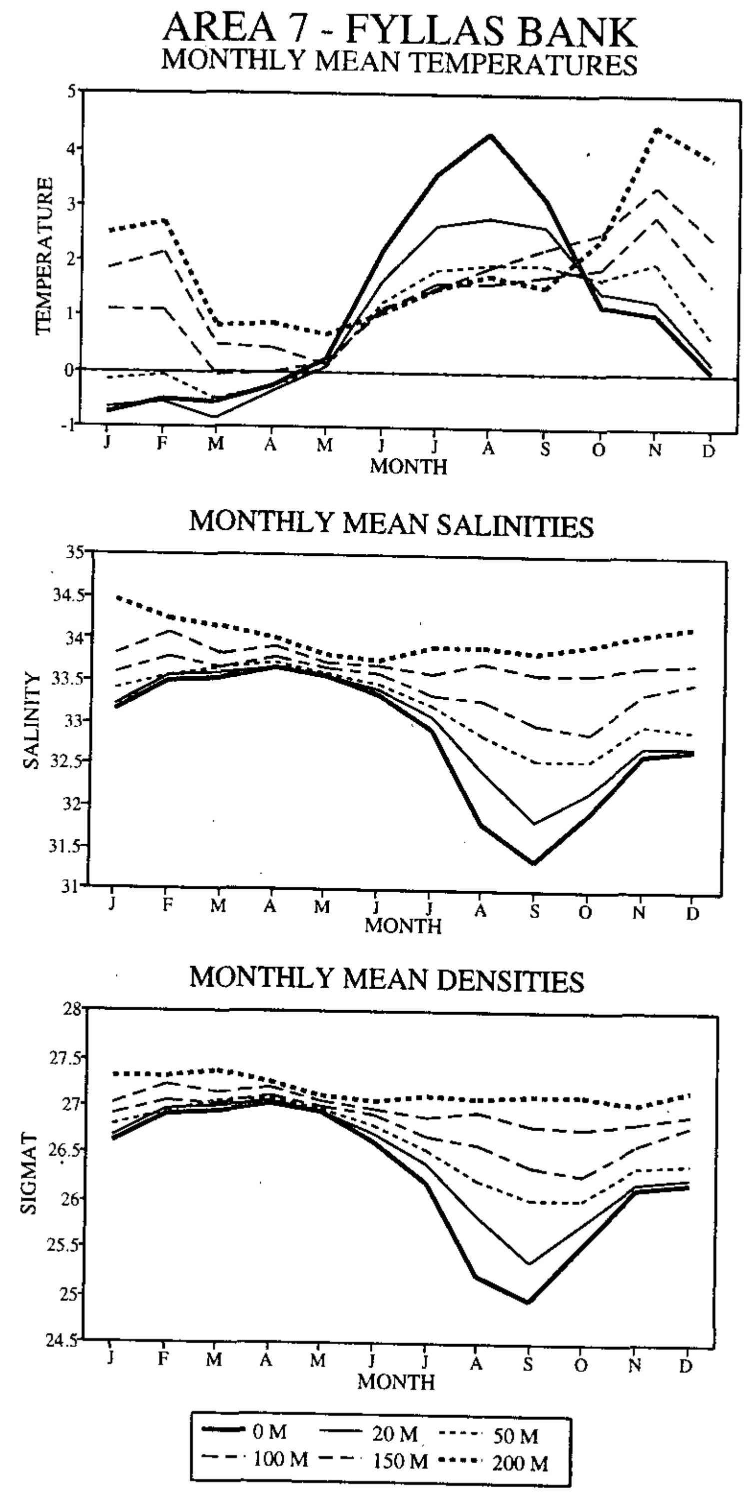

Fig. 4. The monthly means of temperature, salinity and sigma-t at various depths for Area 7 over Fyllas Bank.

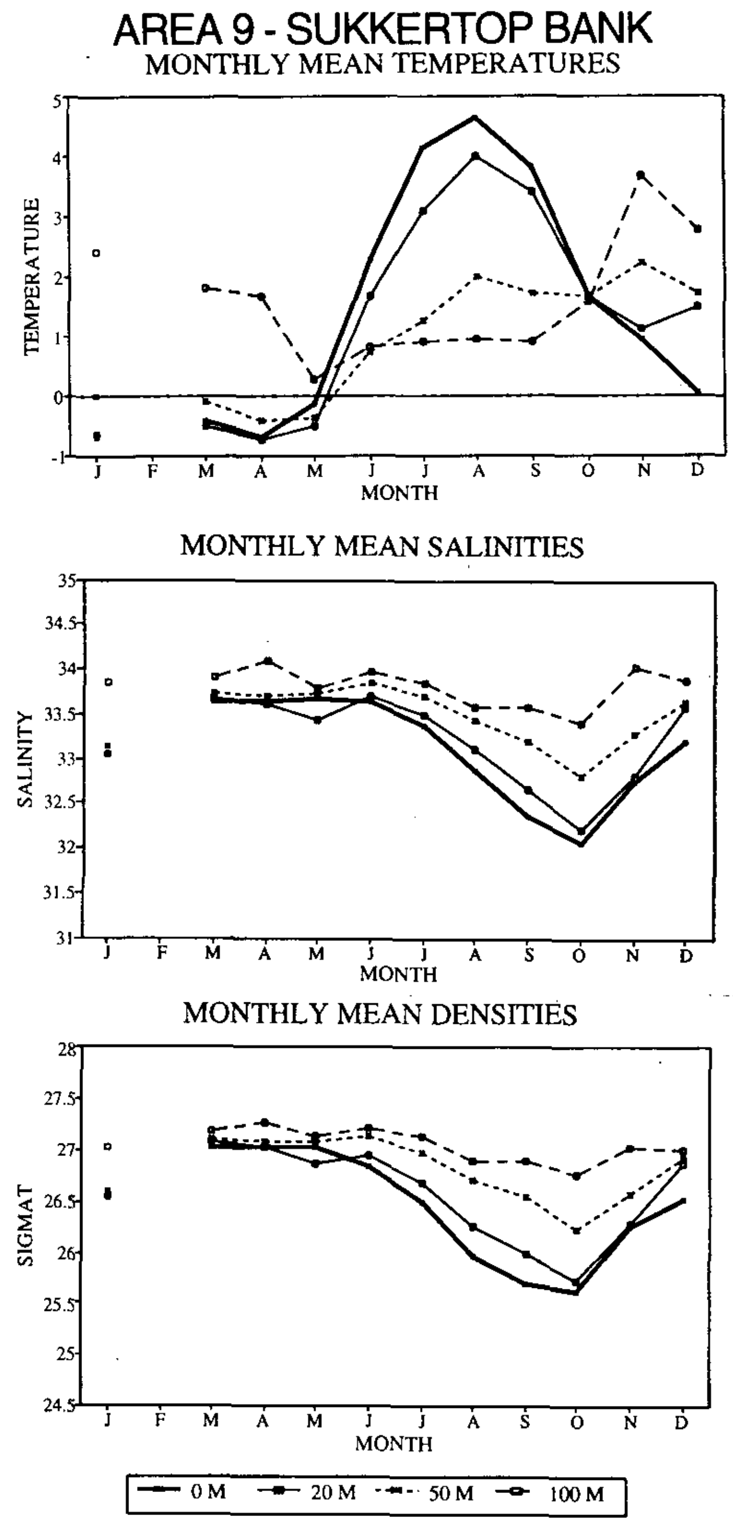

Fig. 5. The monthly means of temperature, salinity and sigma-t at various depths for Area 9 over Sukkertop Bank.

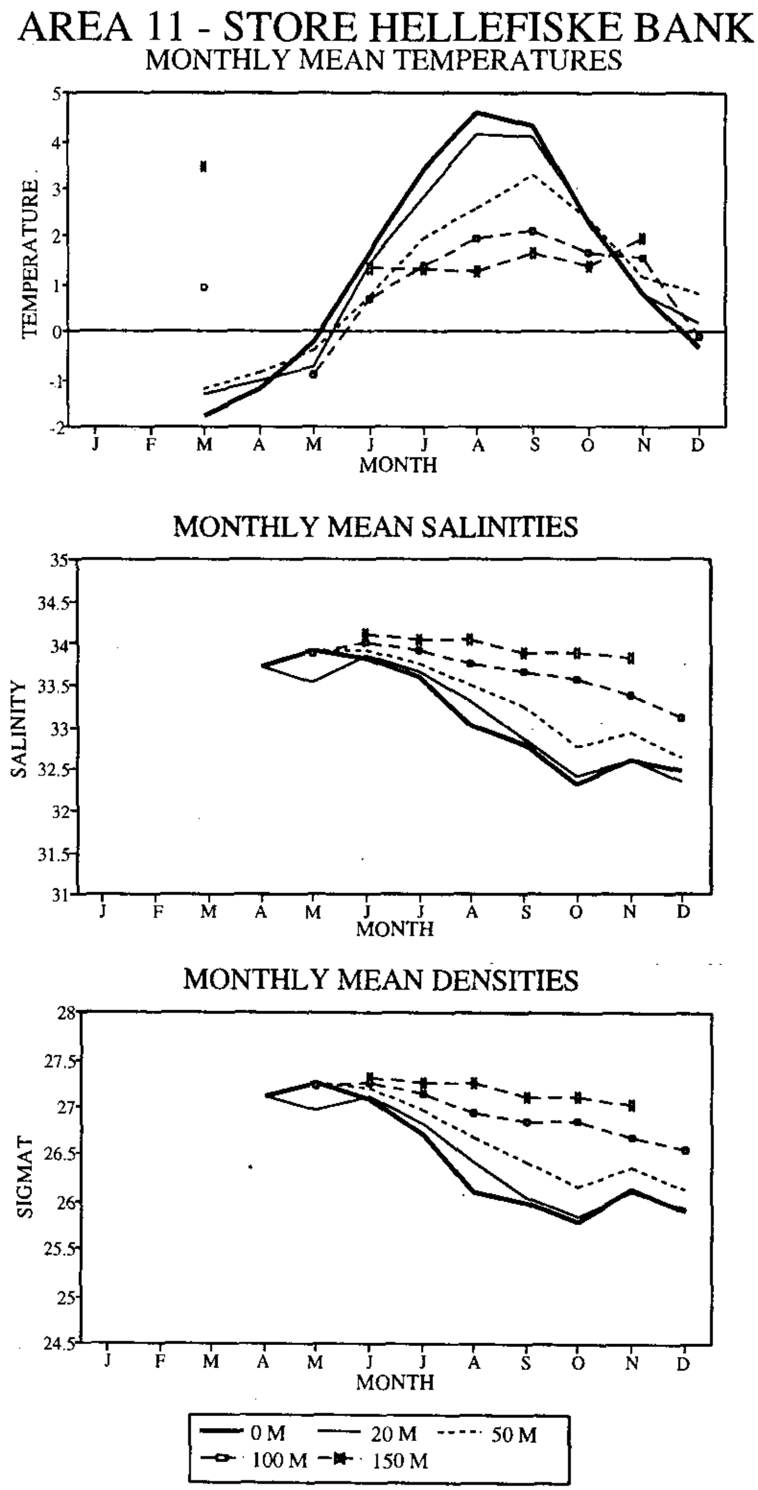

Fig. 6. The monthly means of temperature, salinity and sigma-t at various depths for Area 11 over Store Hellefiske Bank.

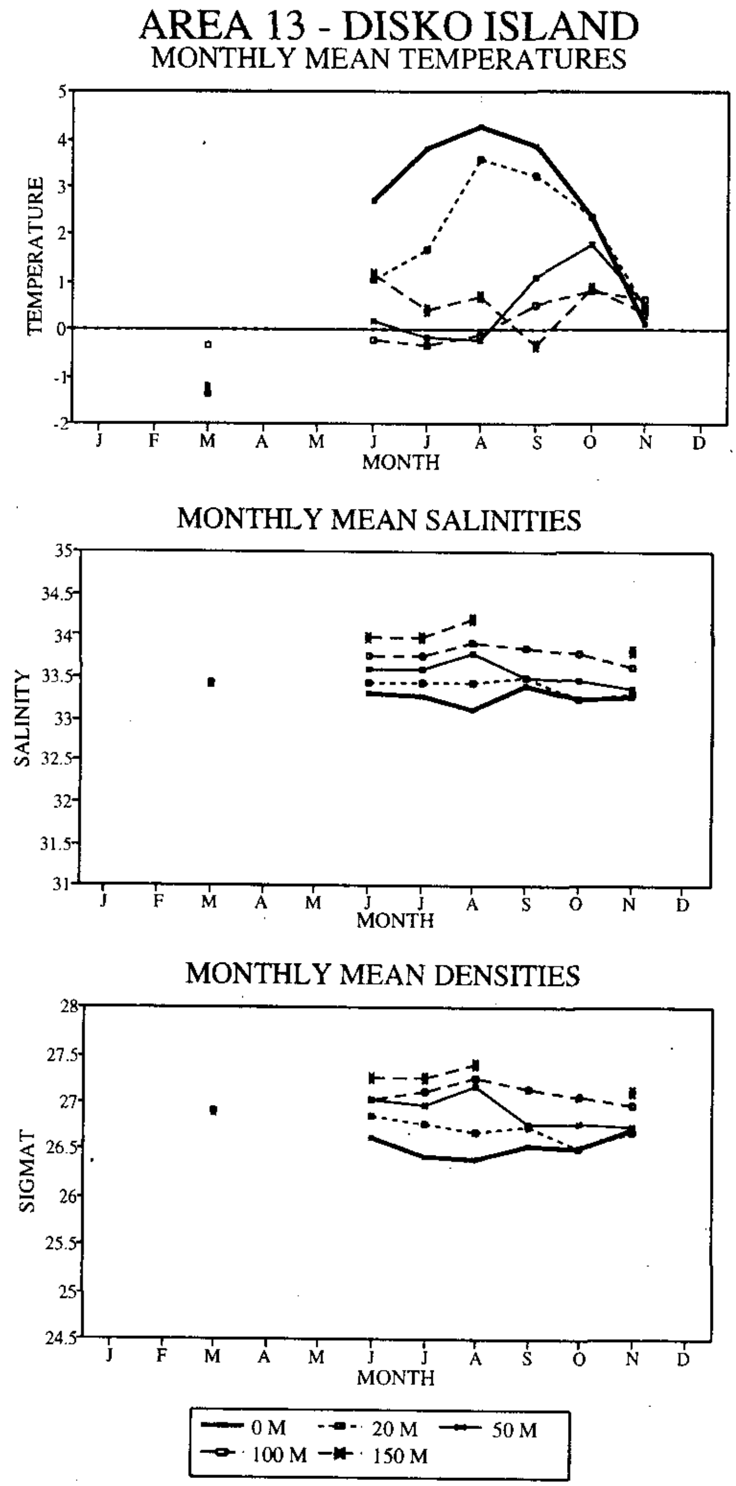

Fig. 7. The monthly means of temperature, salinity and sigma-t at various depths for Area 13 off Disco Island.

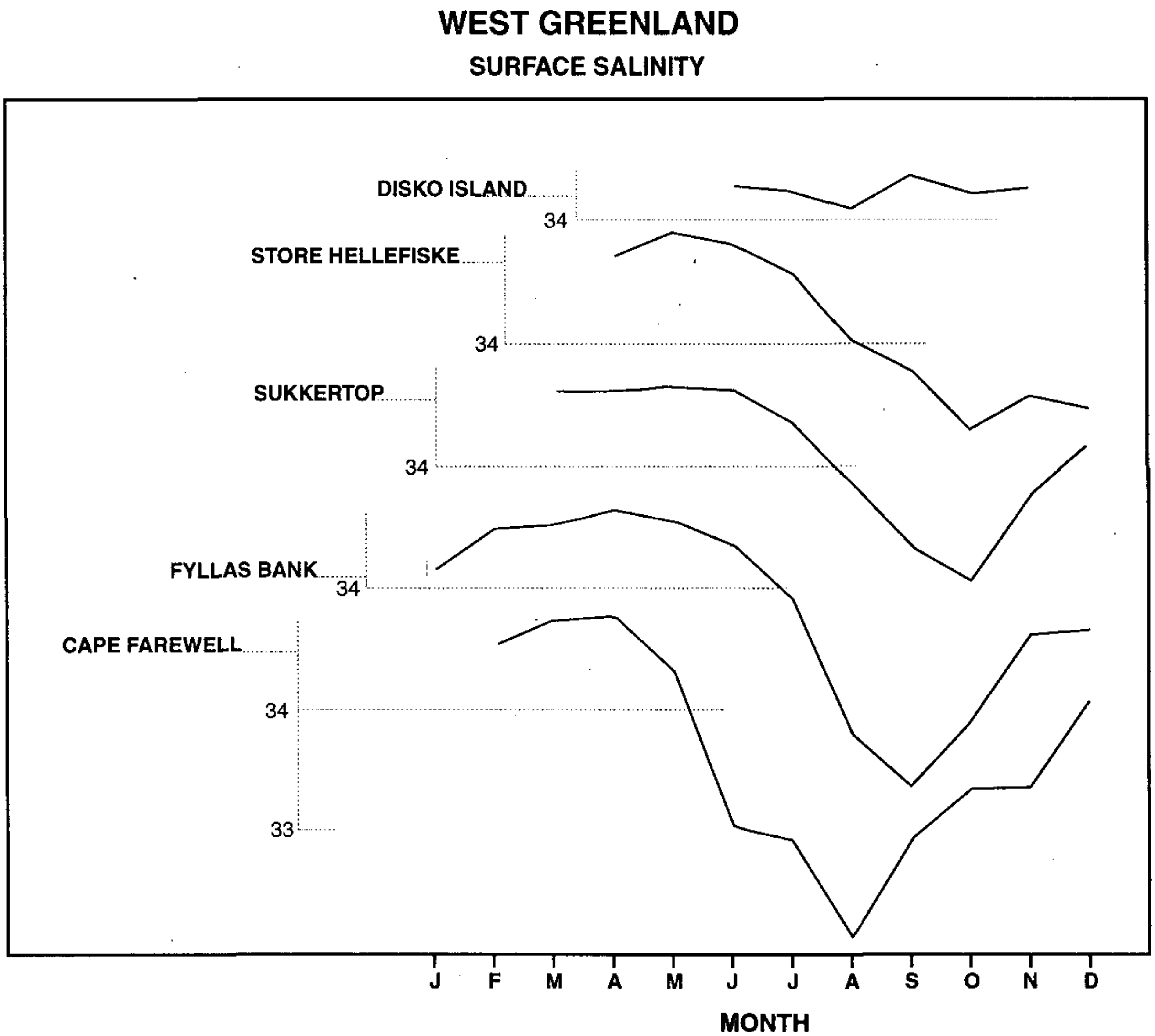

Fig. 8. Monthly mean surface salinities for five areas along West Greenland from Cape Farewell to Disko Island.

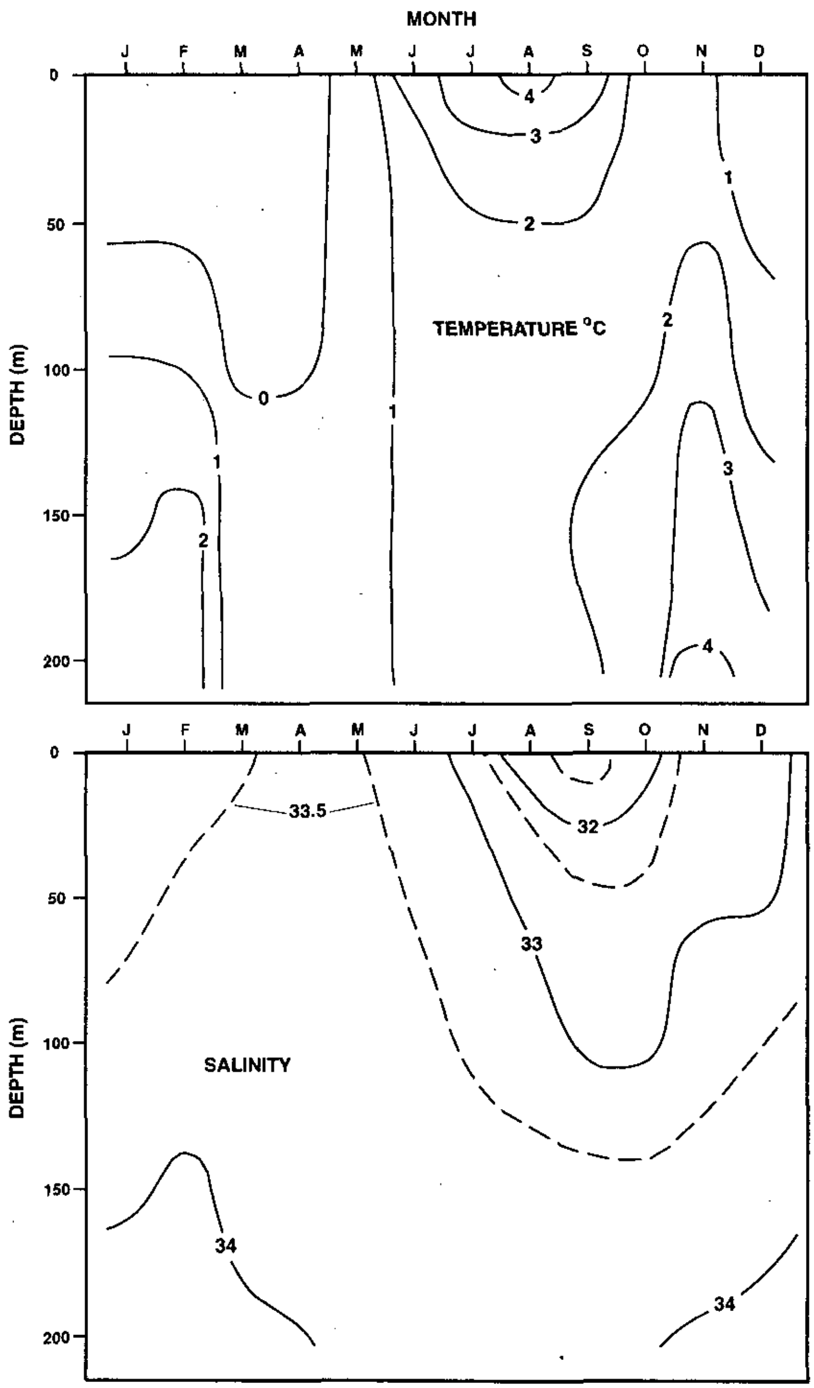

Fig. 9. Vertical distribution of temperature and salinity based upon monthly means for Fyllas Bank.

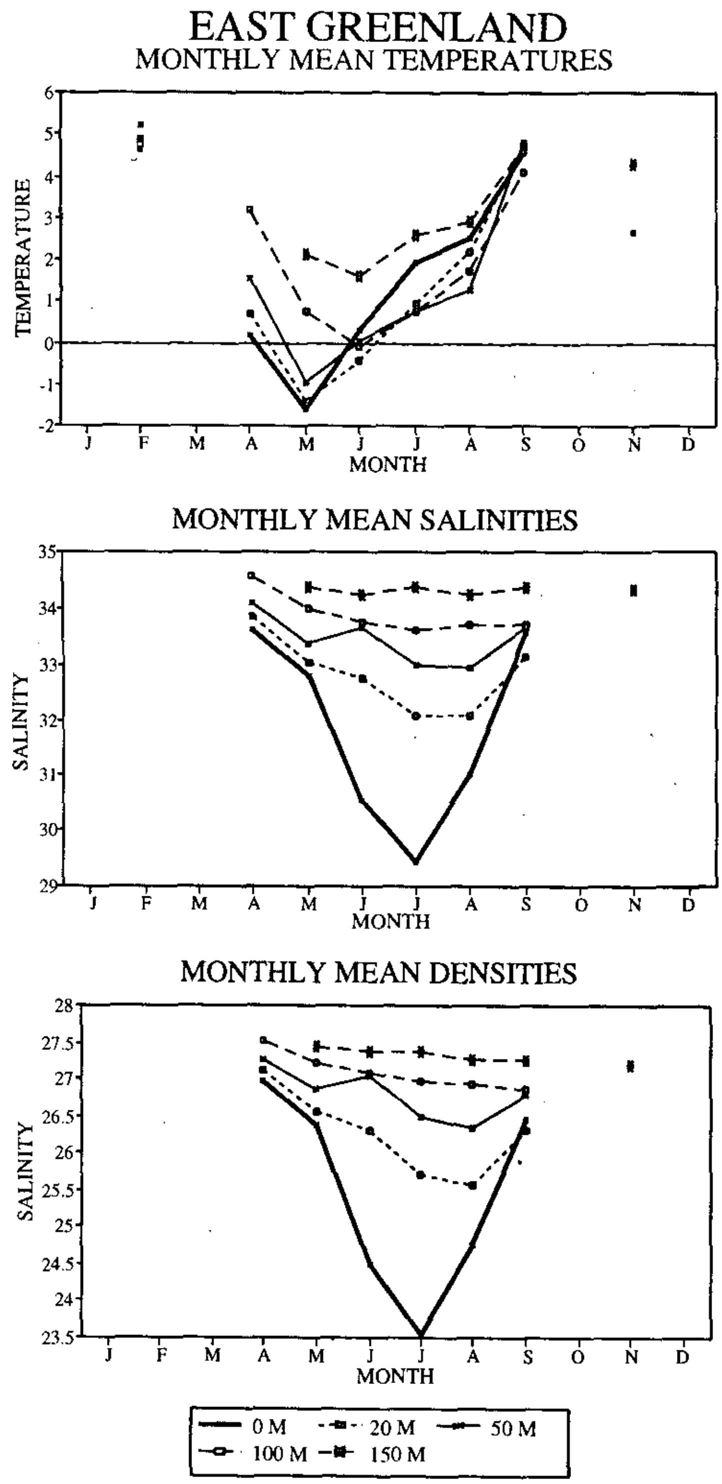

Fig. 10. The monthly means of temperature, salinity and sigma-t at various depths for Area E1 off southern East Greenland.