Northwest Atlantic Fisheries Organization

**Serial No. N5339** **NAFO SCR Doc. 07/1**

**SCIENTIFIC COUNCIL MEETING – JUNE 2007**

**Oceanographic Investigations off West Greenland 2006**

by

**Mads Hvid Ribergaard**
**Danish Meteorological Institute**
**Centre for Ocean and Ice**

**Abstract**

Results of the summer 2006 standard section cruise along the west coast of Greenland are presented together with CTD data gathered during trawl surveys. Seven Southwest Greenland fjords were measured as well and results are presented.

The NAO index was negative and the westerlies was weakened, i.e. anomaly easterlies, over the North Atlantic Ocean in 2006.

The time series of mid-June temperatures on top of Fylla Bank (st.2) was about 0.9°C above average conditions, while the salinity was the third lowest observed 0.35 below normal.

The inflow of Irminger Water to West Greenland waters seems to be normal or slightly above normal in 2006. Pure Irminger Water was observed at the sections off Cape Farewell and Cape Desolation, and Modified Irminger Water could be traced north to the Maniitsoq section. The waters of Atlantic origin were warmer than normal, but their salinities were just above normal. The mean (400–600 m) salinity west of Fylla Bank (st.4) was only slightly above normal while the temperature was 0.5°C above normal.

The inflow of Polar Water to West Greenland Waters seems to be normal in 2006. The concentration of multi-year-ice ("Storis") was about normal. West of Fylla Bank a clear cold Polar Water core was observed, which had higher temperatures than normal but about normal salinities. A low saline surface layer of Polar Water extending towards the interior of the Labrador Sea, which could be due to abnormal easterlies in the waters southwest of Greenland.

## 1. Introduction

The North Atlantic marine climate is largely controlled by the so-called North Atlantic Oscillation (NAO), which is driven by the pressure difference between the Azores High and the Iceland Low pressure cells. We use wintertime (December–March) sea level pressure (SLP) difference between Ponta Delgada, Azores, and Reykjavik, Iceland, and subtract the mean SLP difference for the period 1961–1990 to construct the NAO anomaly. The winter NAO index during winter 2005/2006 was negative[1] (Figure 1

Figure 1). The Icelandic Low was during the winter months (December–Marts) deflected slightly to the southwest with its new center south of Greenland (Figure 2). Both the Icelandic Low and the Azores High was weakened (Figure 3) resulting in a decreased pressure difference over the North Atlantic sector than normal.

[1] The NAO index using December − February was slightly positive. This means, that in March the NAO index was particular negative.

The pressure difference has the effect that the westerlies over the North Atlantic Ocean was weakened, i.e. the wind anomaly[2] was towards west including the waters southwest of Greenland (Figure 4). Over the Julianehaab Bight in the southwest, the mean wind was actually southwestward (Figure 5). Over the East Greenland shelf including the Denmark Strait area, the average wind condition was close to normal.

West Greenland lies within the area which normally experiences warm conditions when the NAO index is negative. As can be seen from Figure 6 the annual mean air temperature for 2006 in Nuuk was -0.21$^{o}$C which is about 1.5°C above average, reflecting well the negative NAO value. The mean annual air temperature for 2006 was above normal for almost the entire North Atlantic region with anomalies above 2°C West of Greenland and even above 3°C over the Davis Strait region (Figure 7).

Changes in the ocean climate in the waters off West Greenland generally follow those of the air temperatures, exceptions are years with great salinity anomalies i.e. years with extraordinary inflow of Polar Water or water of Atlantic origin. In 2006 the mean temperature[3] on top of Fylla Bank in the middle of June was 2.69$^{o}$C which is 0.91°C above the average value for the 56 year time series and the sixth highest value observed, whereas the mean salinity value, 33.06, is the third lowest value observed 0.35 lower than normal (Figure 8 and Table 1). This low salinity is comparable with the low salinities observed during the "mini-salinity anomaly" in the mid-1990s.

## 2. Measurements

The 2006 cruise was carried out according to the agreement between the Greenland Institute of Natural Resources and Danish Meteorological Institute during the period July 14–27, 2006 onboard the Danish naval ship "TULUGAQ"**.** Observations were carried out on the following stations (Figure 9):

Offshore Labrador Sea/Davis Strait:

- Cape Farewell St. 3–5
- Cape Desolation St. 1–5
- Fylla Bank St. 1–5
- Maniitsoq St. 1–5
- Sisimiut St. 1–5 and St. 0

Fjords around Sisimiut (Figure 10):

- Amerdloq St. 2, 4
- Ikertoq St. 1, 4
- Kangerdluarssuk St. 1–3
- Itivdleq St. 1–4

Fjords around Julianehaab Bight (Figure 12):

- Bredefjord St. 2–3 and St. 0 (offshore the sill)
- Skovfjord St. 2

On each station the vertical distributions of temperature and salinity was measured from surface to bottom, except on stations with depths greater than 750 m, where approximately 750 m was the maximum depth of observation.

Due to normal concentration of "Storis"[4] (Figure 13) in combination with fog and swells, only the 3 outermost stations at Cape Farewell were carried out. Unfortunately, several days of stormy weather conditions prohibited us to carry out the Paamiut section – exactly as last year! As usual "Vestice"[5] was not present on these sections.

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[2] Anomaly defined as the difference from normal conditions relative to the period 1968–1996.
[3] The temperature has been corrected as described in the text to Table 1.
[4] "Storis" is multi year ice transported from the Arctic Ocean through Fram Strait by the East Greenland Current to Cape Farewell, where it continues northward by the West Greenland Current.
[5] "Vestice" is one year ice formed in the Baffin Bay, Davis Strait, and western part of the Labrador Sea during winter.

During the period July 3–30, 2006 the Greenland Institute of Natural Resources carried out trawl surveys from Sisimiut to the Disko Bay area and further North onboard “R/V PAAMIUT”. During these surveys CTD measurements were carried out on national oceanographic standard stations (Figure 9):

Offshore Davis Strait/Baffin Bay:

- Sisimiut St. 1-5
- Aasiaat (Egedesminde) St. 1–6
- Kangerluk (Disko fjord) St. 1–4
- Nugssuag St. 1,3–5
- Upernavik St. 1–5

Disko Bay:

- Qeqertarsuaq–Aasiaat (Godhavn–Egedesminde) St. 1, 3−4
- Akunaq–Skansen St. 1–4
- Ilulissat (Skansen–Jakobshavn) St. 1–3
- Appat (Arveprinsens Ejlande) St. 1–3

During the period March 23–26, 2006 the Danish Meteorological Institute and Greenland Institute of Natural Resources carried out 4 CTD stations within Nuuk (Godthaab) Fjord onboard “R/V Adolf Jensen” and “Erisaalik”. At the same time standard stations was defined in Nuuk Fjord. Nuuk fjord st. 3 correspond to the station also known as “hovedstation Nuuk” in the old literature. These were carried out in May 15–20, 2006 together with Fylla Bank station 1–4 plus intermediate stations (Figure 11):

- Nuuk (Godthaab) Fjord St. 4–6,10 (March)
- Fylla Bank St. 1–4
- Fylla Bank St. 1.5, 2.5, 3.5 (intermediate stations)
- Nuuk (Godthaab) Fjord St. 1–13

## 3. Data handling

Measurements of the vertical distribution of temperature and salinity were carried out using a SEABIRD SBE 9-01 CTD. For the purpose of calibration of the conductivity measurements of the CTD, water samples were taken at great depth on stations with depths greater than 500 m or below sill depth on the fjords. The water samples were after the cruise analysed on a Guildline Portosal 8410 salinometer. For the Nuuk Fjord cruise in May 2006, a Seabird SBE 19plus was used which additional was equipped with sensors for oxygen, irradiance, fluorescence and turbidity.

The CTD data were analysed using SBE Data Processing version 5.37d software provided by SEABIRD (www.seabird.com). Onboard the data was uploaded using term17 in SEASOFT version 4.249 (for DOS) also provided by SEABIRD.

CTD data collected by the Greenland Institute of Natural Resources, during the cruise with R/V Paamiut and using the same instrumentation, have gone through the same calibration and quality check.

All quality-controlled data are stored at the Danish Meteorological Institute from where copies have been sent to ICES and via ICES to MEDS.

## 4. Oceanographic conditions off West Greenland in 2006

The surface temperatures and salinities observed during the 2006 cruise are shown in Figure 14. The cold and low salinity conditions observed close to the coast off Southwest Greenland reflect the inflow of Polar Water carried to the area by the East Greenland Current. Water of Atlantic origin (T>3$^o$C; S>34.5) is normally found at the surface at the three outermost stations on the Cape Farewell and Cape Desolation sections (Figure 20 and Figure 21). This year the salinity of these surface waters was lower than observed the last few years. The relative low salinities are caused by a thin layer of Polar Water that was spread out towards the interior of the Labrador Sea. This water was mainly heated by solar radiation, and partly from below by the warmer waters of Atlantic origin.

In the Baffin Bay the low surface salinities, generally below 33, mainly originating from the large outlet glaciers but also melting of sea-ice during summer. Salinities about 33.5–34 reflect the core of the West Greenland Current, which is slightly modified by Atlantic Water. The warm surface waters in and around the Disko Bay was caused by solar heating of the 20–30 m thin low-saline surface layer.

A vertical section of salinity, temperature and density over the shelf break from Cape Farewell to Sisimiut is shown in Figure 18 and over the shelf in Figure 19. The vertical distribution of temperature, salinity and density at sections along the West Greenland coastline is shown in
Figure 20 –
Figure 30 and within the Disko Bay in Figure 31 – Figure 34.

At intermediate depths Pure Irminger Water (T ~ 4.5$^o$C; S > 34.95) was traced north to the Cape Desolation section. Unfortunately, it is unknown if Pure Irminger Water was also present at the Paamiut section, as stormy weather prohibited measurements. Modified Irminger Water (T > 3.5$^o$C ; 34.88 < S < 34.95) was observed all the way north to Maniitsoq section. The northward extension of Modified Irminger Water indicates normal inflow of water of Atlantic origin to the West Greenland area. However, the temperature of the Irminger Water was in general higher than normal. As the Irminger Water is not in direct contact with the atmosphere in West Greenland waters, the heat gained must have taken place in the North Atlantic, likely within the Irminger Basin, which has warmer air temperature than normal (Figure 7).

The average salinity and temperature at 400–600 m depth west of Fylla Bank (st. 4), which is where the core of the Irminger Water normally is found, is shown in Figure 16 (red curves). The temperature of this layer was 4.67°C which is half a degree higher than normal whereas the average salinity of 34.84 was just above normal by 0.03 (Table 1). The high temperatures combined with normal salinities indicates, that the Irminger Water was warmer than normal in 2006 but the Irminger Current was not necessary stronger than normal.

In the early 2000s the air temperatures has increased considerable (Figure 6). In 2006 the air temperature in Nuuk was still very high, whereas the air temperature at Tasiilaq was lower than the past few years. However, the Tasiilaq air temperature was still above normal and comparable with the warm period from the mid-1920s to the mid-1960s and the recent warm period. The high air-temperature at Nuuk could be a result of a general positive air-temperature anomaly centred over the Davis Strait (
Figure 7).

In general, the surface salinity over the shelf seems to be close to normal and the multi-year-ice “Storis” was present off the southeast coast of Greenland and in the Julianehaab Bight in normal concentrations (Figure 13). In all sections, including the southernmost at Cape Farewell and Cape Desolation, a low saline water lid of (modified) Polar Water was observed throughout the sections extending towards the interior of the Labrador Sea even at the westernmost stations. This lid could have been formed due to abnormal easterlies over the southwest Greenland waters (Figure 4 and Figure 5) combined with normal inflow of Polar Water.

In 2006, a well defined core of Polar Water, revealed by its low temperature, was observed west of Fylla Bank at 50–100 m depth. It was more pronounced than in 2003–2005 (Ribergaard and Buch, 2004; Ribergaard and Buch, 2005; Ribergaard, 2006). A weaker Polar Water core was also observed on the Sisimiut section. From the Aasiaat section in the south to the Upernavik section in the north, a distinct Polar Water core was absent. Instead a colder layer was found with temperatures below 1°C (below -1°C at Nugssuaq and Upernavik) in the center at depth at about 75 m. This layer was most likely formed during winter by convection. Brine rejection increases the low surface (0–50 m) salinities, so it can overcome the strong surface gradients which are created during summer by melting of sea-ice and run-off of fresh water from land. Below the cold subsurface layer, a relative warm (> 2–3°C) watermass was found with a core around 400–500 m. This water is the extension of the Irminger Water component of the West Greenland Current.

Measurements west of Fylla Bank (st.4) support normal inflow of Polar Water and Atlantic Water (Figure 16). The salinity was about normal in the upper 150 m and slightly above normal below 150 m (Table 1). The surface temperature (0–50 m) was more than 1°C above average, while the temperature in the core of the Polar Water in 50–150 m was a little above normal by 0.44°C. The high mixed layer temperatures in the surface is then concluded to be a result of local atmospheric heating indicated by anomalies high temperatures over the Davis Strait area (Figure 7). At intermediate depth at 150–400 m the temperature was 0.66°C higher than normal and the temperature at 400–600 m was more than half a degree above average.

Noticeably, since the mid-1990s, the temperature above 400 m west of and on top of Fylla bank seems to be relative warm without sudden particular cold periods as has happen in the late 1960s, the early 1980s and the early 1990s (Figure 8 and Figure 16). Likewise, since the early 2000s, the mean salinity at 400–600 m depth west of Fylla Bank (st.4, Figure 16) has increased indicating increased strength of the Irminger Current as pointed out by Ribergaard (2004), which again is linked to the North Atlantic subpolar gyre circulation (Hátún *et al.*, 2005). This warming of the subpolar gyre was also observed by Stein (2005). However, in 2006 the salinity was lower than the former years, but still moderately above normal. This indicates a decline of the strength of the Irminger Current. According to Stein (2004), warming over time, and not just interannual variations, seems to be important for the abundance of juvenile cod and haddock in Greenland waters.

At the Cape Farewell station 4 (Figure 20) relative cold and low-saline water was found in the upper ~200m. This could be an anticyclonic cold-core eddy formed in the front between Polar Water and Irminger Water closer to the coast, which was transported westward towards the interior of the Labrador Sea. Such eddies has the effect of lowering the salinities in the top of the Labrador Sea as they break down.

On station 3 on the Nugssuaq section (Figure 29), higher temperatures and salinities was measured at ~50–100 m depth and lower temperatures and salinities in the interval ~150–350m compared to the neighbour stations. It is unclear why, but eddies could play a role.

**West Greenland fjords 2006**

The hydrography in fjords is to a large extent determined by the land runoff of fresh water in the surface and at the inflow near the bottom at the mouth of the fjord (see Figure 17). Often fjords have a sill at the opening to the open ocean and it is the depth of this sill that determinate which watermass is allowed to enter near the bottom. Above sill depth water can freely flow either in or out of the fjord. At the surface the current are often directed out of the fjord caused by the runoff of fresh water, which will increase the sea level in the fjord. Thereby a pressure gradient is established and surface water will flow out of the fjord. Normally this surface water will entrain water from below. To compensate for this entrainment, inflow is taking place at the bottom as sketched in Figure 17.

In the West Greenlandic fjord basically three different kinds of waters exists:

- Relative warm and saline waters of Atlantic origin (mixed Irminger Water).
- Cold and relative fresh water of polar origin (mixed Polar Water).
- Fresh surface water from land, either as melting of the Greenland Ice Sheet or from precipitation (surface water). The amount of this water is highly variable depending on the time of the year. The water is mixed with the surrounding surface waters, which is Polar Water. This mixing is continues going on along the coast, and the watermass keeps close to the coast. In the following it is named Coastal Polar Water.

### 4.1. Bredefjord and Skovfjord

Two fjords were measured in the Julianehaab Bight between the Cape Farewell and Cape Desolation sections (Figure 35). Bredefjord has by far the deepest sill of more than 400 m, whereas Skovfjord has a shallower sill depth of about 150–200 m. The two fjords are connected about 50 km inside by the Narssaq Sound with sill depth of about 100 m. In consequence, the top ~100 m has similar salinities and temperatures at Narssaq. A temperature minimum at about 100 m depth could be the core of Polar Water from outside the fjords, but it is more likely winter convected Coastal Polar Water, as it has lower salinities than the Polar Water outside the fjord. At the surface a strong halocline was found at about 15–20 m due to runoff from the numerous of glaciers that enter mainly Bredefjord. This surface layer was heated due to solar radiation.

The bottom water in Bredefjord below sill depth is filled with slightly diluted Atlantic Water with salinities above 34.6 and temperature near 4°C. This watermass efficient prohibit winter convection to the bottom, as it is much denser than the surface waters at its freezing point.

The bottom water in Skovfjord has lower temperature and salinity compared to Bredefjord, caused by the shallower sill depth, which efficiently prohibit water to enter offshore below ~150–200 m and from Bredefjord below ~100 m. However, salinities close to 34 and temperatures above 1.8°C shows that the water is partly of Atlantic origin, although diluted. The density is high enough to prevent winter convection to the bottom, as the surface water is less dense even at its freezing point. However minor changes in the salinity of the Coastal Polar Water above sill depth could change this.

In both fjords the watermass below sill depth is very stable. Despite vertical mixing, the minimal gradient in salinity and temperature indicates differences in the density of the inflowing waters over time. In Bredefjord both salinity and temperature increase marginally towards the bottom, where the least diluted Atlantic Water is found. This is to be expected, as the Atlantic Water is both the warmest and most saline watermass. In Skovfjord the salinity marginally increase below sill depth towards the bottom while the temperature decrease. This reflects the changes in the Coastal Polar Water characteristic over time, which is mixed into the Atlantic Water found at the bottom.

### 4.2. Godthaab (Nuuk) Fjord

Godthaab (Nuuk) Fjord were measured twice in 2006 (Figure 36–Figure 38). The fjord system has a sill depth of 200 m close to Godthaab Fjord station 1. Another major sill exists northwest of Nuuk town close to, but before, station 4. Between these two sills the water depth is about 400 m and forms a narrow channel. Strong tidal forcing mix the water column especially inshore station 2, which can be seen in especially the temperature but also the salinity profiles, where the isolines becomes vertical.

The main fjord system consists of three “arms”. Within these arms, several of “sub-sills” exists, as a result of the movement of the glacier back in time. The northwestern arm is believed to be the deepest of more than 600 m with a sub-sill just offshore station 6 of 350 m. The northern arm has been depth-measured using a multi-beam sonar until station 9, whereas the two other arms are only partly (or not) depth measured. The middle arm is shallow especially at its inner part, whereas the southeastern arm is supposed to be shallower than the northwestern arm, but this is uncertain. The inner part of the fjord (st.10 −> st.13 and further inside) ends in a floating glacier and some side braches which supply the surface layers with a significant amount of fresh water and keeping up a pressure gradient along the fjord.

The deep sills (200m/250m) permit “warmer” water masses to enter the fjord, which is part of the reason for ice-free conditions during wintertime except for the very inner parts. The bottom water was about 1.3−2.5°C and has salinities of about 33.67−33.80 - warmest and most saline in the inner part (st.10−13). This water is a mixture of Atlantic origin (Irminger Water) and Polar Water that enter the fjord from outside through the Fylla Bank Channel.

It is surprising, that the warmest and most saline bottom water was found in the inner parts (st.10−13), which is slightly denser than the bottom water closer to the entrance to the fjord. Three different explanations can be given:

1. The dense water enters the inner parts through the southeastern arm of the fjord – not the northwestern as original supposed. A vertical gradient in temperature and salinity between station 9 and 10 below about 350 m depth suggest an obstacle (sill), that do not permit the densest water from the southeastern arm to enter the northwestern arm.
2. The less cold and less saline water between station 4 and 10 is water that has undergone winter-convection and thereby vertical mixing. The reason for slightly lower salinities is the lower salinities in the upper layers due to runoff, which is mixed away during winter. However, convection is prohibited in the inner parts of the fjord (station 10 and inward) due to ice-cover. A cold temperature minimum found at about 150-200 m support this.

3. Water of Atlantic origin, which has its maximal strength during autumn, has penetrated into the inner parts of the fjord. In the late winter/early spring Polar Water becomes more dominating and is penetrating inward. The temperature minimum at about 150‒200 m support this explanation.

The right answer is most likely a combination of all three. One or two CTD-casts in the southeastern arm at depths below 350‒400 m at the same time as the other stations are taken, will likely give us the right answer. Especially in combination with a 3D hydrodynamic model study of the fjord.

### 4.3. Fjords south of Sisimiut

Four fjords around Sisimiut were investigated (Figure 39–Figure 42). They represent two very different types of fjords: two with deep sills (Amerdloq, Ikertoq), one with shallow sills (Kangerdluarssuk). Itivdleq fjord has an intermediate sill depth, which categorizes it as a fjord with a shallow sill, which occasionally has properties as a fjord with a deep sill depth. None of the fjords are directly connected to the Greenland ice sheet, and so the fresh water supply added are limited to runoff from land. For all fjords, the fresh water added is of minor importance as can be seen directly from a topographic map, but also by the fact, that only a shallow fresh water cap was measured at the surface.

In the deep sill fjords, Amerdloq and Ikertoq fjord (Figure 39 and Figure 40), the sill depth is about 150–180 m. These sill depths allow relative warm and saline waters of Atlantic origin to enter the fjords close to the bottom. The density is higher than the Coastal Polar Water above, even at the freezing point of the Coastal Polar Water. Thereby winter convection to the bottom is prevented. The bottom water up to about sill depth remain saline and “warm” (1-3°C). Above sill depth the salinities are almost homogenous whereas the temperature is coldest just above the interface between the diluted Irminger Water and the Coastal Polar Water. This cold water could be a result of winter convection of Coastal Polar Water, or it is just the core of the Polar Water. Close to the surface a thin warm layer was found caused by the sun heating of runoff water from land.

Kangerdluarssuk fjord (Figure 41) can be considered as a fjord with shallow sill. Kangerdluarssuk fjord has a sill depth of about 50 m. The whole bottom layer below sill depth is filled with Coastal Polar Water and the salinity is very homogeneous. During winter the Coastal Polar Water are cooled and undergoes convection. As the water inside the fjord have homogenous salinities the whole water column are gradually cooled by winter convection and the water become totally homogenous (neutral stability). Therefore cold temperatures are measured below sill depth. The bottom temperature is below 0°C and the bottom salinity is around 33.6. The low salinity at depth indicates that the winter cooled water is actually Coastal Polar Water. At the surface relative warm water is found caused by the solar radiation during spring and summer. In the top a thin warm solar heated fresh water cap was found caused by runoff from land.

Itivdleq fjord (Figure 42) has a sill depth about 100 m, which most of the year prohibit the relative “warm” and saline water of Atlantic origin to enter. However, occasionally, the deep water is influenced by water from outside the fjord, which is denser and more saline than the water found in the fjord above sill depths. The bottom salinities are around 34 and temperatures below 1°C. A gradient in salinity with depth below sill depth shows, that winter convection to the bottom has not taken place in the last few years. The density of the water below sill depth is marginally higher than the surface water above, even at the freezing point of the water above sill depth. This exclude winter convection to the bottom, but only small changes in the properties of the Coastal Polar Water could change this. It is therefore believed, that winter convection occasionally takes place depending on the salinity of the Coastal Polar Water during winter. Part of the water at intermediate depths below sill depth could be Coastal Polar Water from outside earlier of the year, when it was colder. In the top near the mouth of the fjord a thin warm solar heated fresh water cap is found caused by runoff from land.

Figure 43 and Figure 44 displays the temporal evolution in the properties in the Amerdloq/Ikertoq fjords. Between 2003 and 2005 (no measurements in 2004) the bottom water has become slightly more saline (and denser) indicating increased influence of mixed Irminger Water. This is in agreement with the findings by Ribergaard and Buch (2005) showing record high salinities in 2004 west of Fylla Bank in 400–600m and with Ribergaard (2006) showing lower, but still high, salinities in 2005. From 2005 to 2006 the salinity (and density) decreased slightly, which is to be expected, as the sub-surface salinities in 2006 west of Fylla Bank was lower than in 2005 (Figure 16) indicating that no inflow to the bottom has taken place. The decrease in salinity and density are due to mixing within the fjords. In both fjords, the surface (around 150m) salinities decreased from 2005 to 2006 indicating an increased influence of Polar Water.

For Kangerdluarssuk fjord, the hydrographic conditions below sill depth are similar to what observed in 2003 and 2005 (Figure 45). However, as for Amerdloq and Ikertoq fjords, the salinities were marginally higher in 2005 and the surface salinity has become less saline in 2006. The bottom temperature was lowest in 2003 and has since become slightly warmer by ~0.2°C, but it is still below 0°C.

Itivdleq fjord was only observed in 2005 and 2006 (Figure 46). Both the bottom and surface salinity has become less saline and the density has decreased throughout the water-column from 2005 to 2006 and the temperature of the water below sill-depth has become slightly colder by about 0.25°C. This is a sign of increased influence of Polar Water in 2006 compared to 2005.

**Conclusions**

The oceanographic conditions off West Greenland during the summer 2006 was characterised by:

- Negative NAO index.
- The strength of the westerlies over the North Atlantic has decreased, caused by weakened Icelandic low and the Azores high.
- The wind conditions over the East Greenland shelf and the Denmark Strait area was about normal.
- Anomalies warm air over most of the North Atlantic sector with strongest anomalies over the Davis Strait.
- Nuuk air temperature was about 1.5°C higher than normal.
- Medio June water temperature on top of Fylla Bank was about 0.9°C above average while the salinity were the third lowest observed during the 56 year time series.
- Normal inflow of Polar Water and normal or slightly above normal inflow of Irminger Water reflected by the facts that:
    - Normal concentration of multi-year-ice (“Storis”).
    - Low saline Polar Water lid throughout all the sections extending towards the interior of the Labrador Sea.
    - Well defined cold Polar Water core was observed west of Fylla Bank.
    - Low salinity on top of Fylla Bank, but high temperatures.
    - Pure Irminger Water could be traced at the Cape Desolation section (and maybe at the Paamiut section) and Modified Irminger Water could be traced up to the Maniitsoq section.
    - The Atlantic water component was warmer than normal, but the salinity was about normal indicating about normal strength of the Irminger Current.
    - West of Fylla Bank (st.4) the mean temperature in 400–600 m depth was high approximately 0.5°C above average, whereas slightly above normal salinities was observed.

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Table 1. Statistics for potential temperature and salinity at Fylla Bank st. 4. and values for 2006.

| Fylla Bank St.4 | Temperature [°C] | Salinity | 2006 | |
|---|---|---|---|---|
| | Mean ± std | Mean ± std | Tpot | S |
| 0–50 m | 1.87 ± 0.87°C | 33.20 ± 0.33 | 3.01°C | 33.17 |
| 50–150 m | 1.04 ± 0.86°C | 33.63 ± 0.27 | 1.48°C | 33.65 |
| 150–400 m | 2.56 ± 0.87°C | 34.28 ± 0.17 | 3.22°C | 34.40 |
| 400–600 m | 4.16 ± 0.58°C | 34.81 ± 0.08 | 4.67°C | 34.84 |

Table 2. Statistics for potential temperature and salinity Fylla Bank st. 2. The actual measured temperature in 2006 was 1$^{o}$C higher, but the timeseries are corrected for annual variations in order to get the temperature in mid-June. This correction value stems for the mean of temperatures measured in July minus temperatures measured in June.

| Fylla Bank St. 2 | Temperature [°C] | Salinity | 2006 | |
|---|---|---|---|---|
| | Mean ± std | Mean ± std | Tpot | S |
| 0–40 m | 1.78 ± 0.77°C | 33.41 ± 0.25 | 2.69°C | 33.06 |
| | | | | |

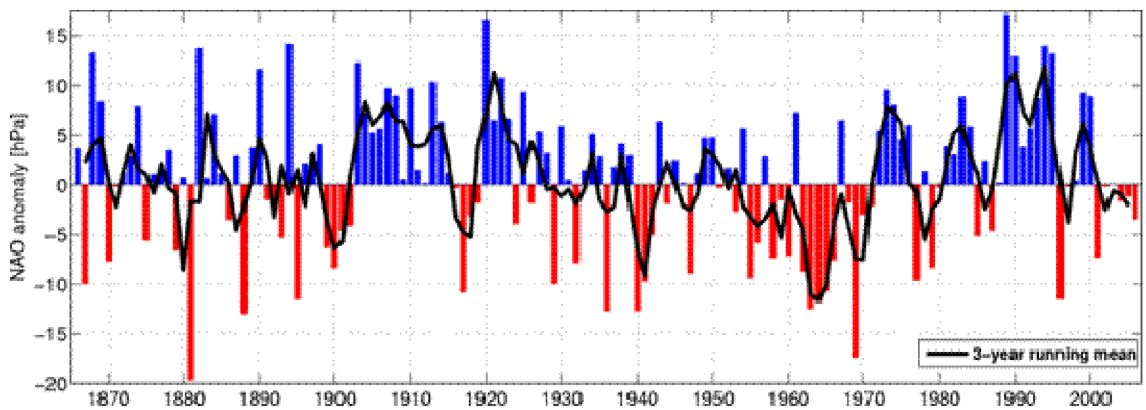


Figure 1. Time series of winter (December–March) index of the NAO from 1866–2006. The heavy solid line represents the meridional pressure gradient smoothed with a 3-year running mean filter to remove fluctuations with periods less than 3 years. In the figure 1866 correspond to the period December 1865 – March 1866 etc.. Data updated, as described in Buch et al. (2004), from http://ww.cru.uea.ac.uk/cru/data/nao.htm.

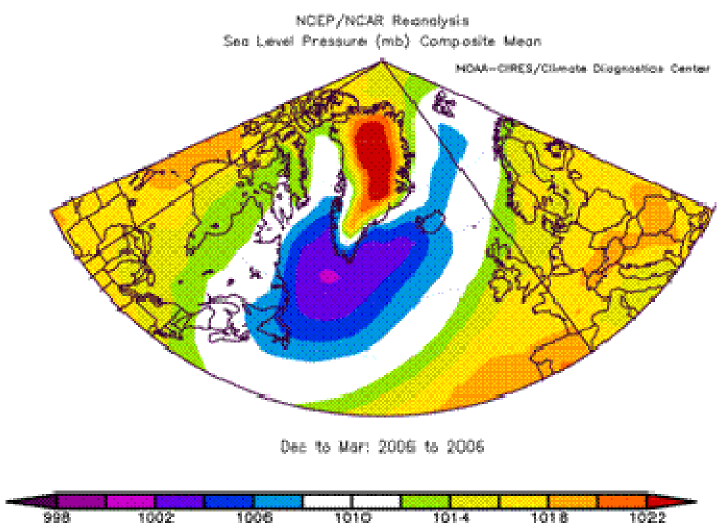


Figure 2. Winter (DJFM) sea level pressure for 2005/2006 in the North Atlantic region. NCEP/NCAR re-analysis (taken from http://www.cdc.noaa.gov).

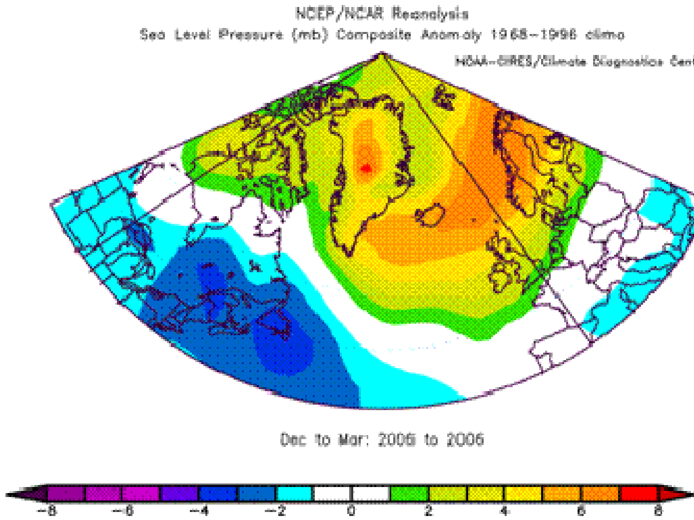


Figure 3. Winter (DJFM) sea level pressure anomaly for 2005/2006 in the North Atlantic region. NCEP/NCAR re-analysis (taken from http://www.cdc.noaa.gov).

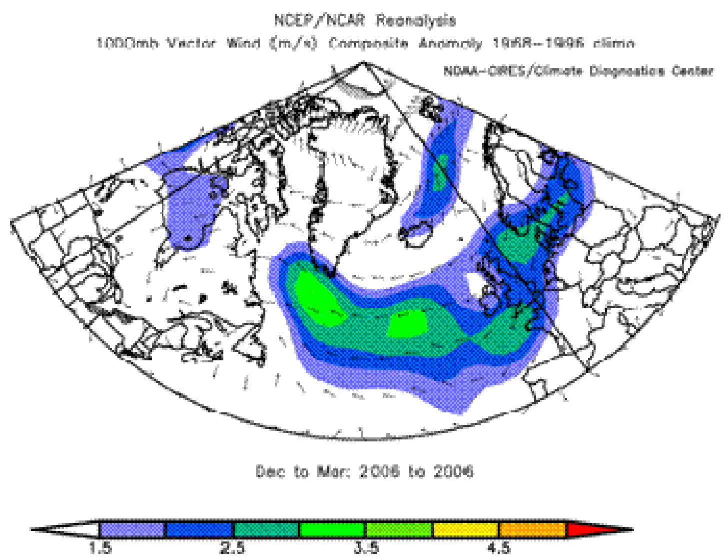


Figure 4. Winter (DJFM) wind anomaly for 2005/2006 in the North Atlantic region. NCEP/NCAR re-analysis (taken from http://www.cdc.noaa.gov).

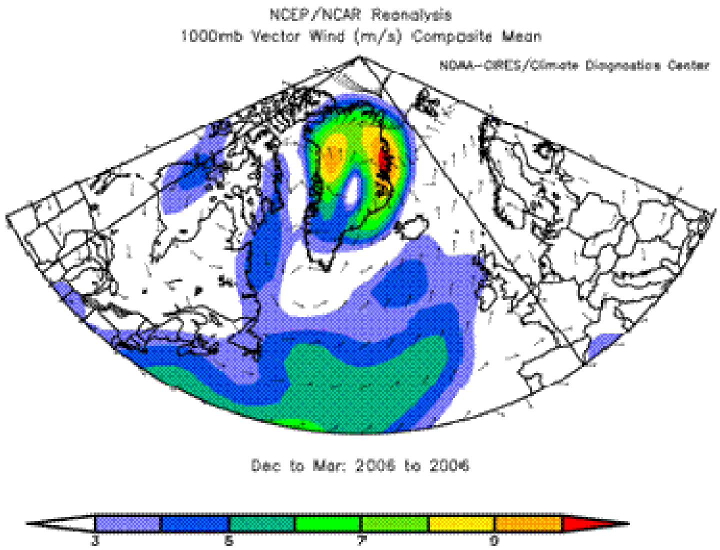


Figure 5. Winter (DJFM) wind for 2005/2006 in the North Atlantic region. NCEP/NCAR re-analysis (taken from http://www.cdc.noaa.gov).

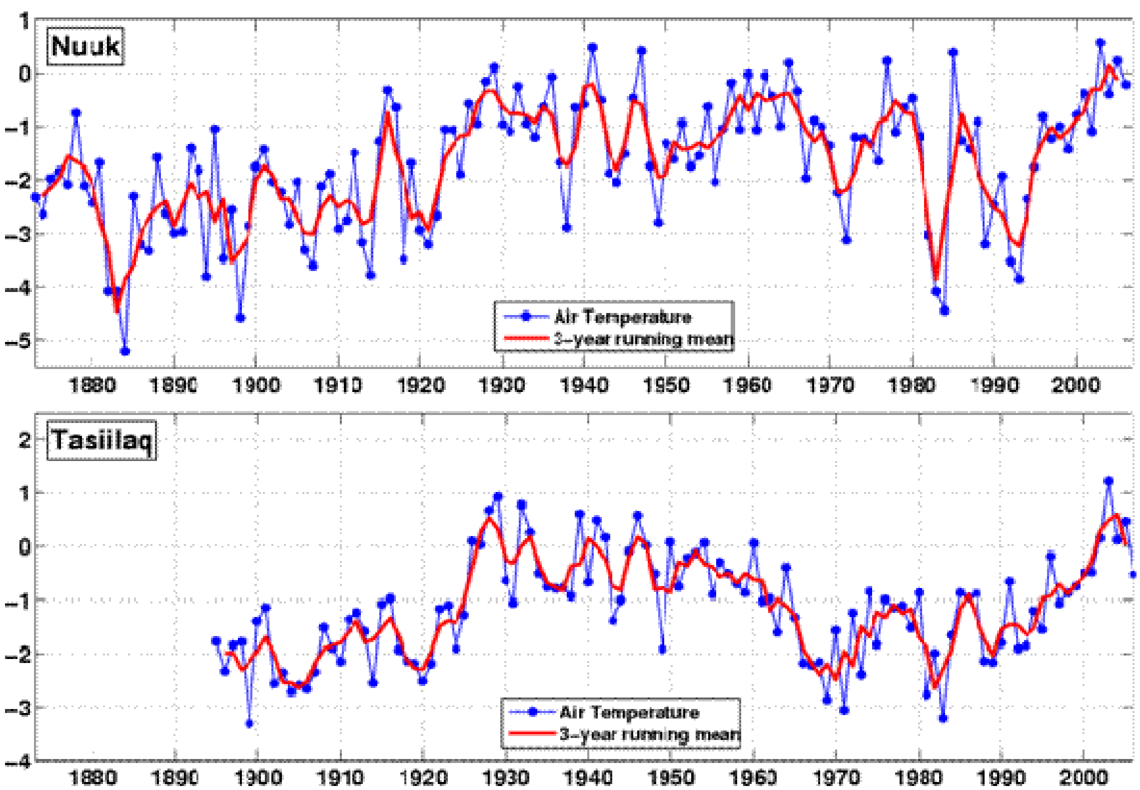


Figure 6. Annual mean air temperature observed at Nuuk and Tasiilaq for the period 1873–2006. The mean and standard deviation is -1.69 ± 1.21 °C for Nuuk and -1.15 ± 0.99 °C for Tasiilaq.

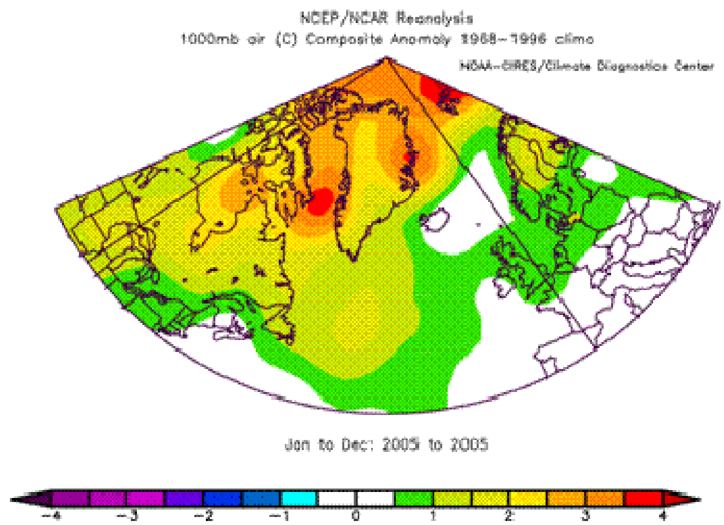


Figure 7. Anomalies of the mean air temperature for 2006 in the North Atlantic region. NCEP/NCAR re-analysis (taken from http://www.cdc.noaa.gov).

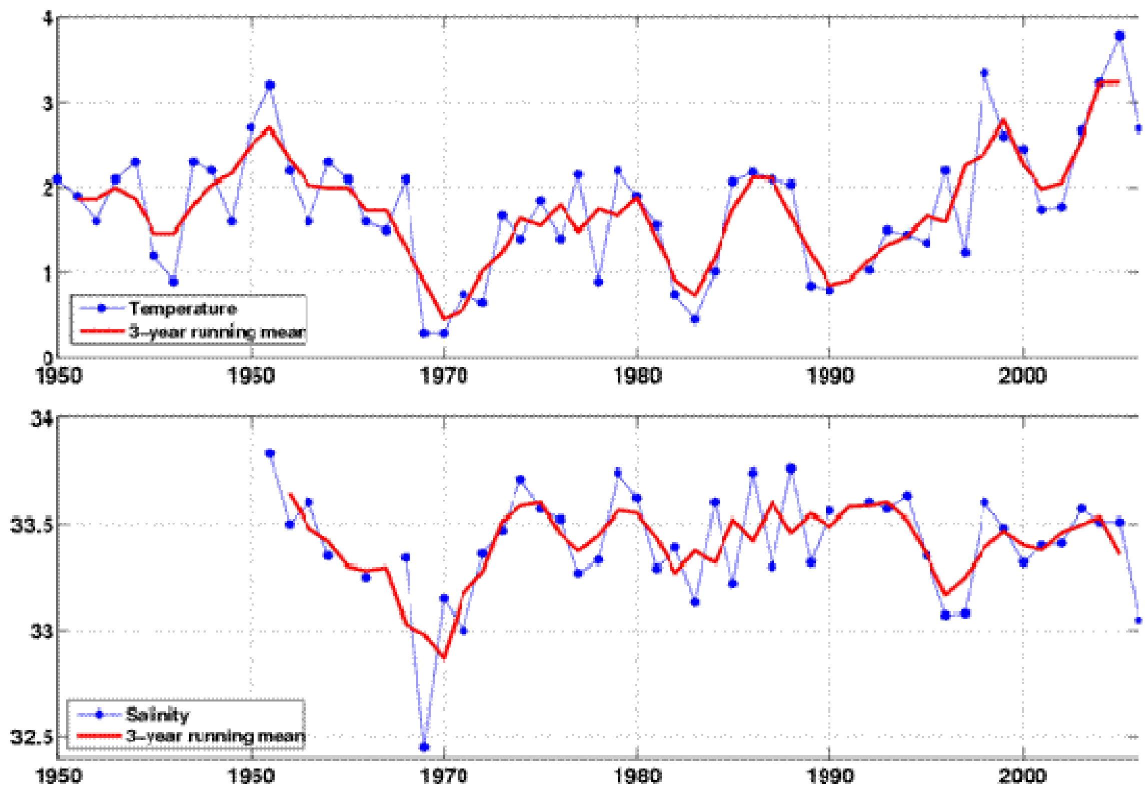


Figure 8. Timeseries of mean temperature (top) and mean salinity (bottom) on top of Fylla Bank (0–40 m) in the middle of June for the period 1950–2006. The mean and standard deviation is 1.78 ± 0.77°C for temperature and 33.41 ± 0.25 for salinity. The red curve is the 3 year running mean value.

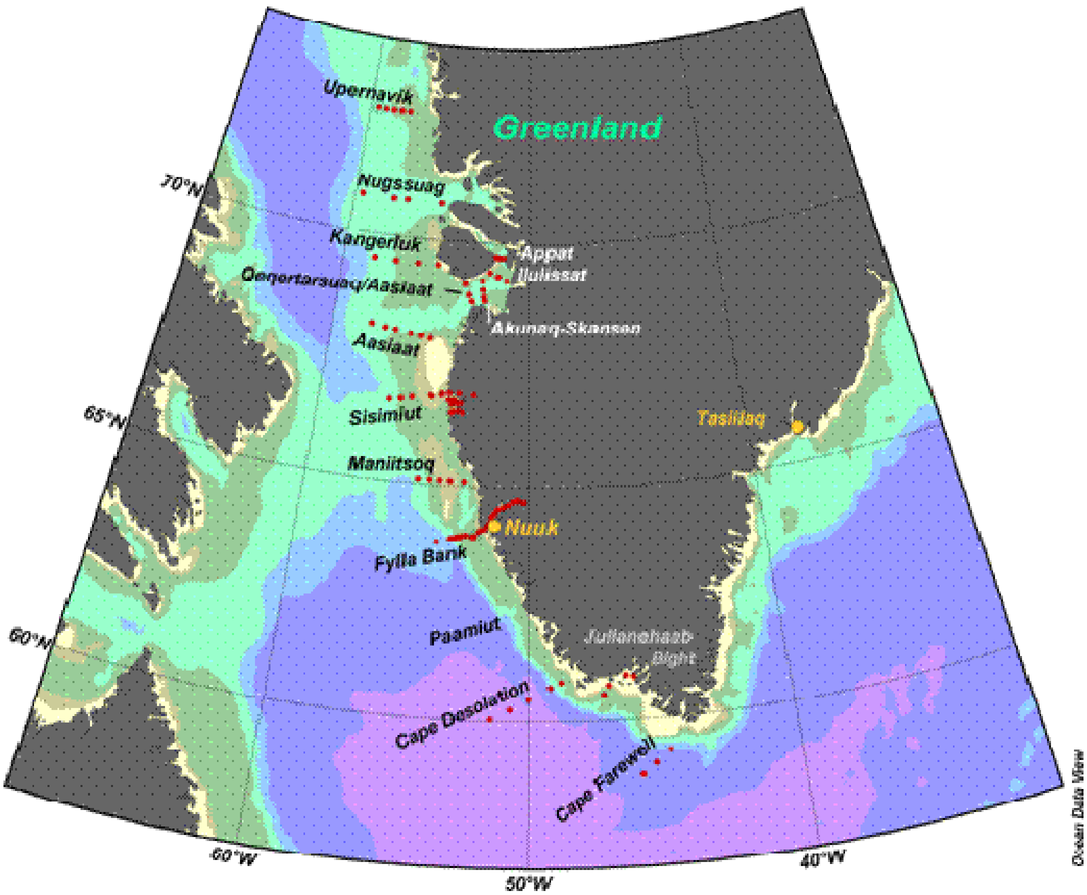


Figure 9. Position of the oceanographic sections off West Greenland where measurements were preformed in 2006. The fjord sections at Sisimiut, Nuuk Fjord, Bredefjord and Skovfjord in the Julianehaab Bight are *not* standard sections, but part of the sections was measured in 2006 (see Figure 10 – Figure 12). Due to stormy weather, no stations were taken on the Paamiut section and the two innermost stations on the Cape Farewell sections were skipped due to multi-year-ice, fog and swells. Map produced using Ocean Data View (Schlitzer, 2007).

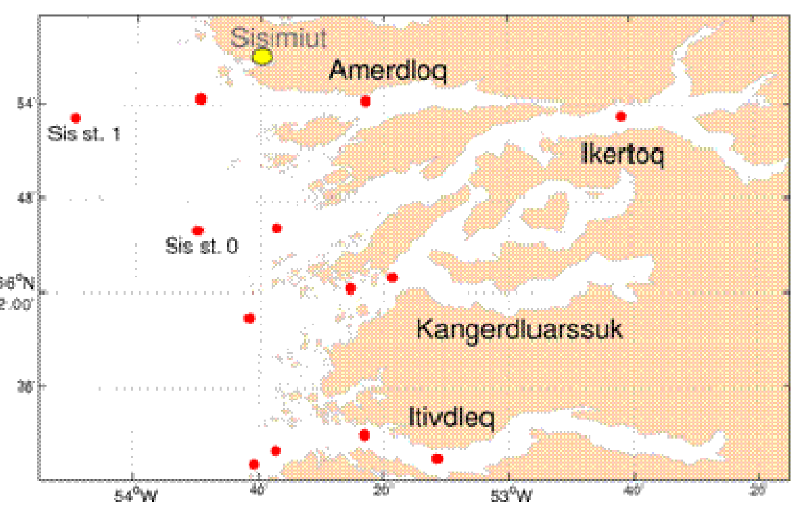


Figure 10. Position of the oceanographic fjord sections around Sisimiut where measurements were preformed in 2006. See Figure 9 for position of all sections measured in 2006.

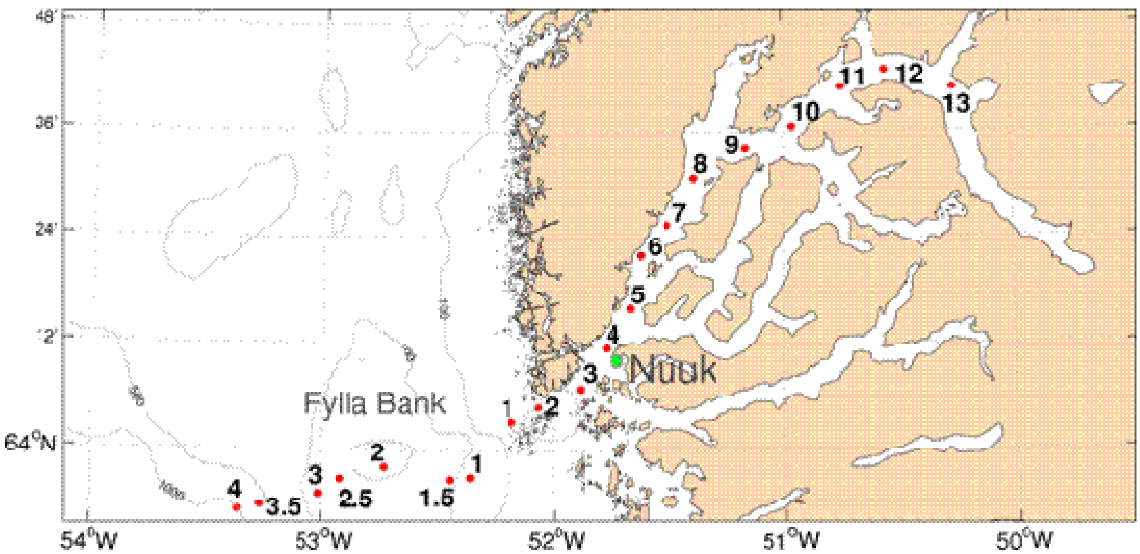


Figure 11. Position of the oceanographic fjord sections at Nuuk (Godhaab) Fjord where measurements were preformed in 2006. See Figure 9 for position of all sections measured in 2006.

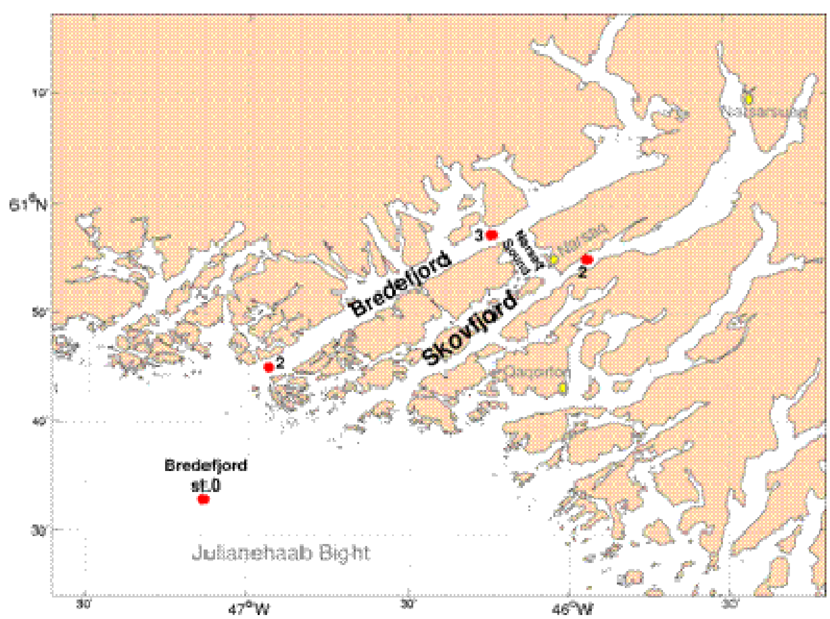


Figure 12. Position of the oceanographic fjord sections at Bredefjord and Skovfjord, where measurements were preformed in 2006. See Figure 9 for position of all sections measured in 2006.

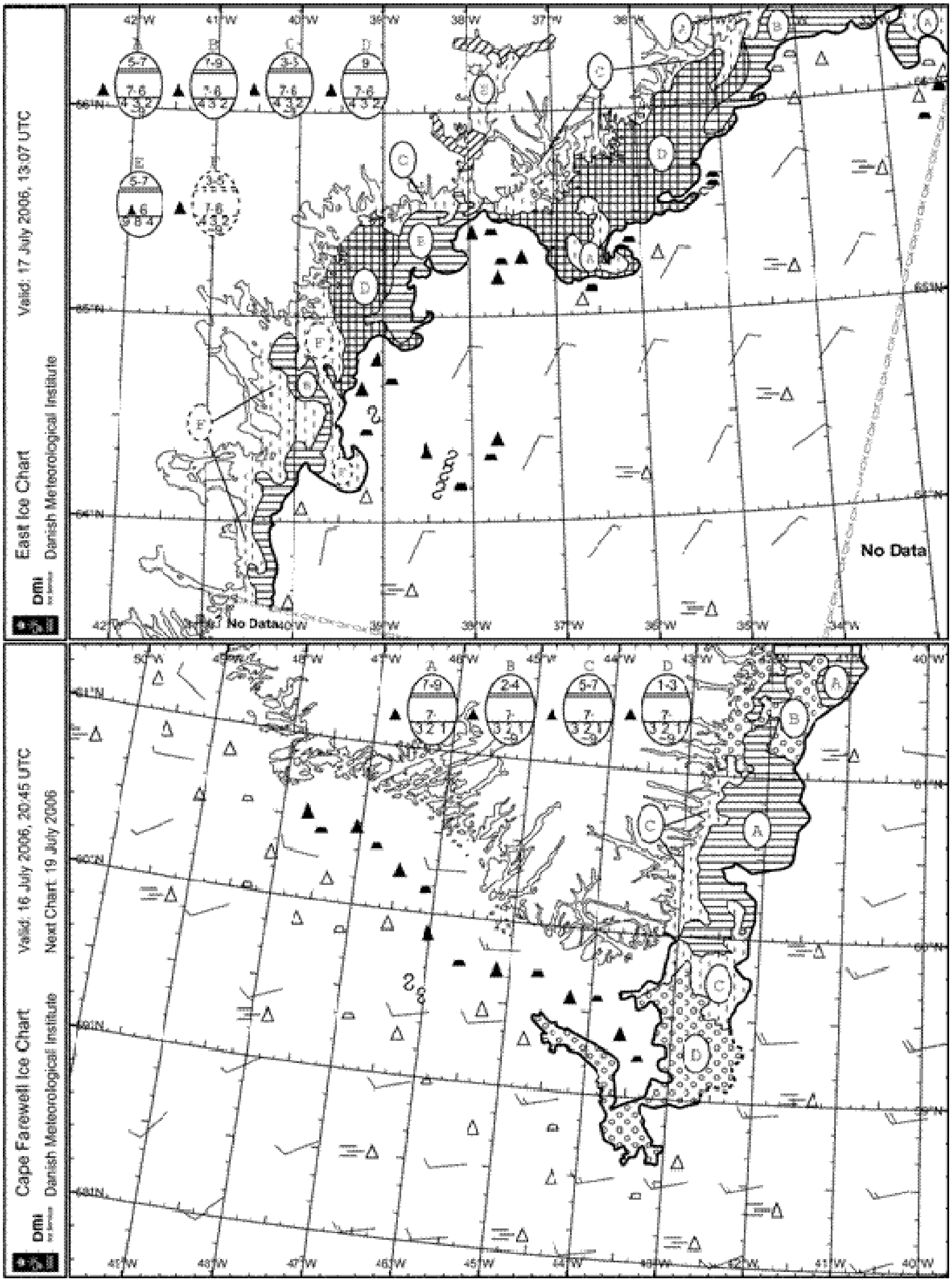


Figure 13. Distribution of sea ice in the Amerssalik region valid at 17. July 2006 (top) and in the Cape Farewell region valid at 16. July 2006 (bottom).

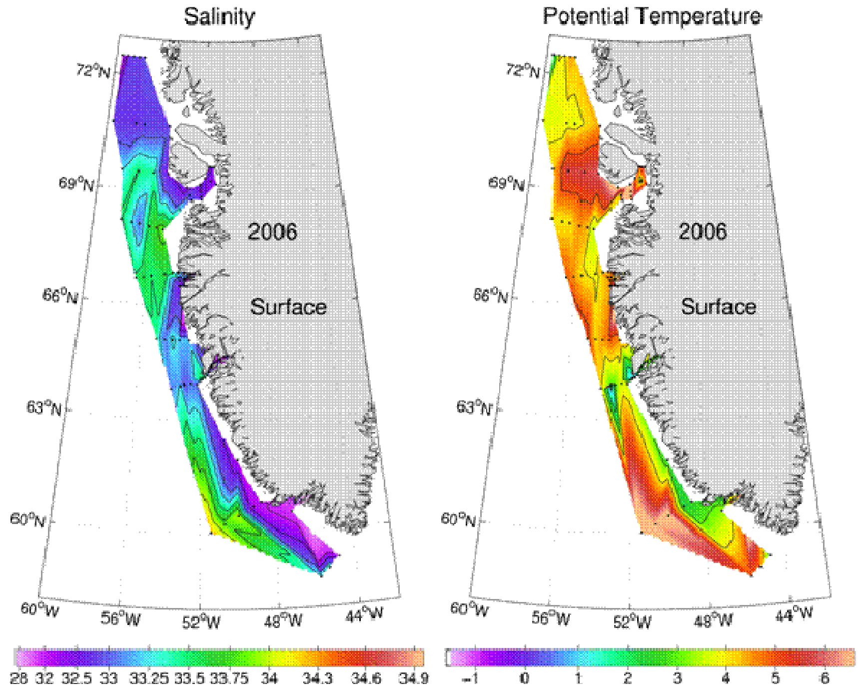


Figure 14. Salinity (left) and temperature (right) observed in 2006 at the surface (mostly 2–6 m). The data are all from July except for Nuuk Fjord in May. Note: As the Paamiut section was not taken, Cape Desolation st.1 has been copied to the location of Paamiut st.1 in order to make the Polar Water follow the coast more naturally in the plot.

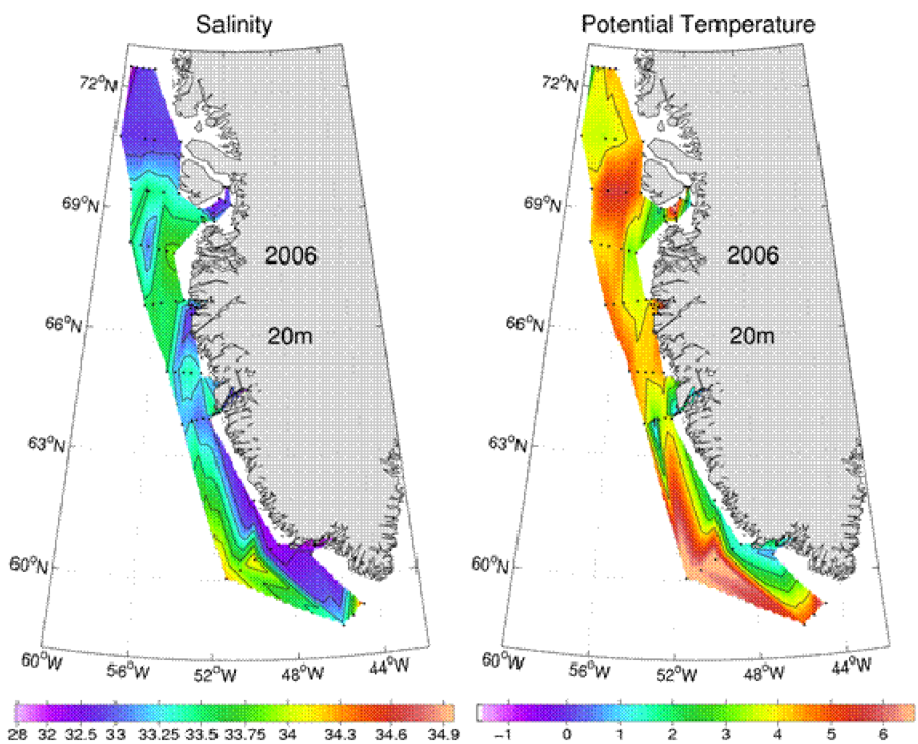


Figure 15. As Figure 14, but for 20 m depth.

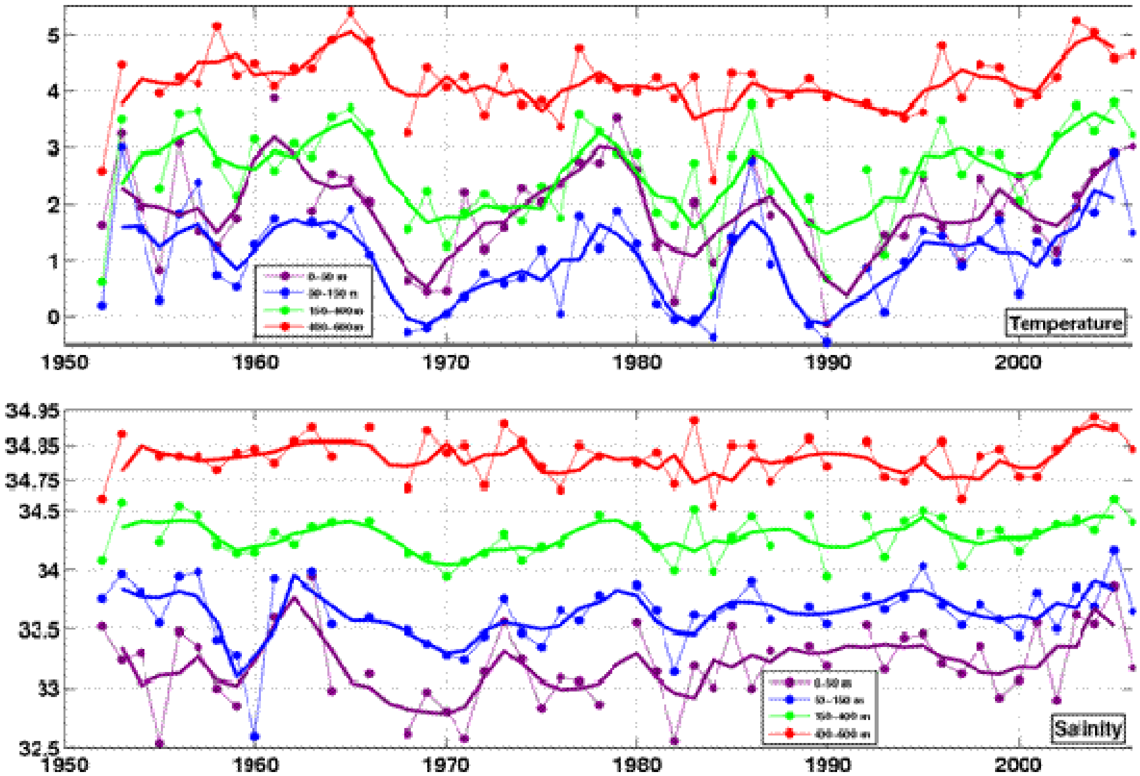


Figure 16. Timeseries of mean temperature (top) and mean salinity (bottom) for the period 1950–2006 in four different depth intervals west of Fylla Bank (st.4) over the continental slope. The thick curves are the 3 year running mean values. Note the change in scales at 34.75 for salinity.

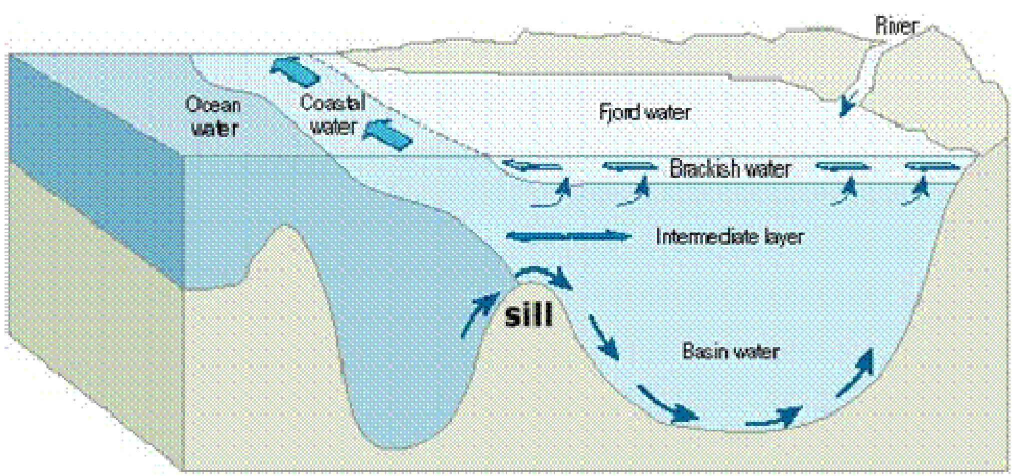


Figure 17. Sketch of the circulation in a fjord (modified from http://www.amap.no/maps-gra/show.cfm?figureId=58).

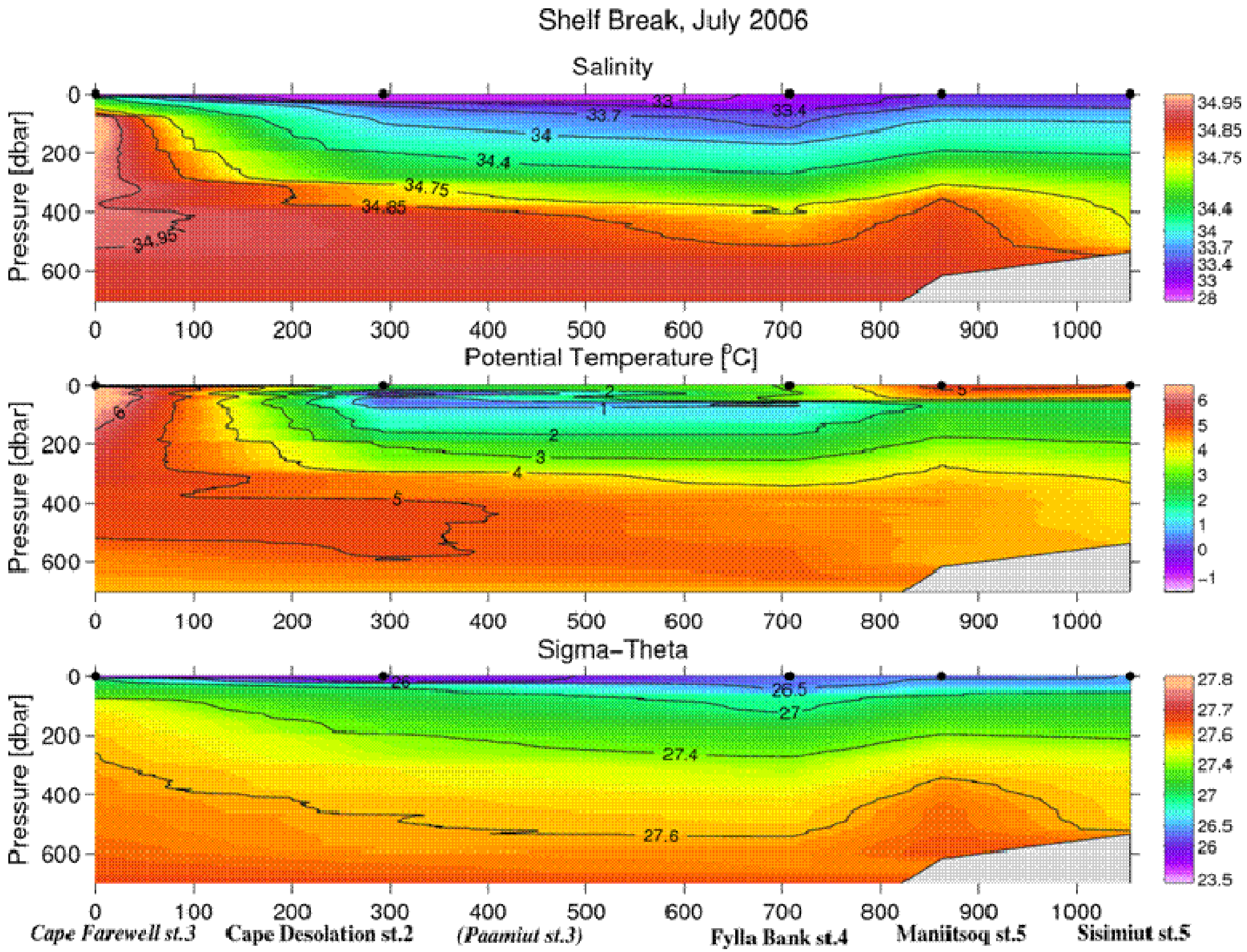


Figure 18. Vertical distribution of temperature, salinity and density over the continental shelf break from Cape Farewell to Sisimiut, June 16–24, 2006. Note: Cape Farewell st.3 is used instead of Cape Farewell st.2 as in Ribergaard (2006), and Paamiut st.3 was not measured.

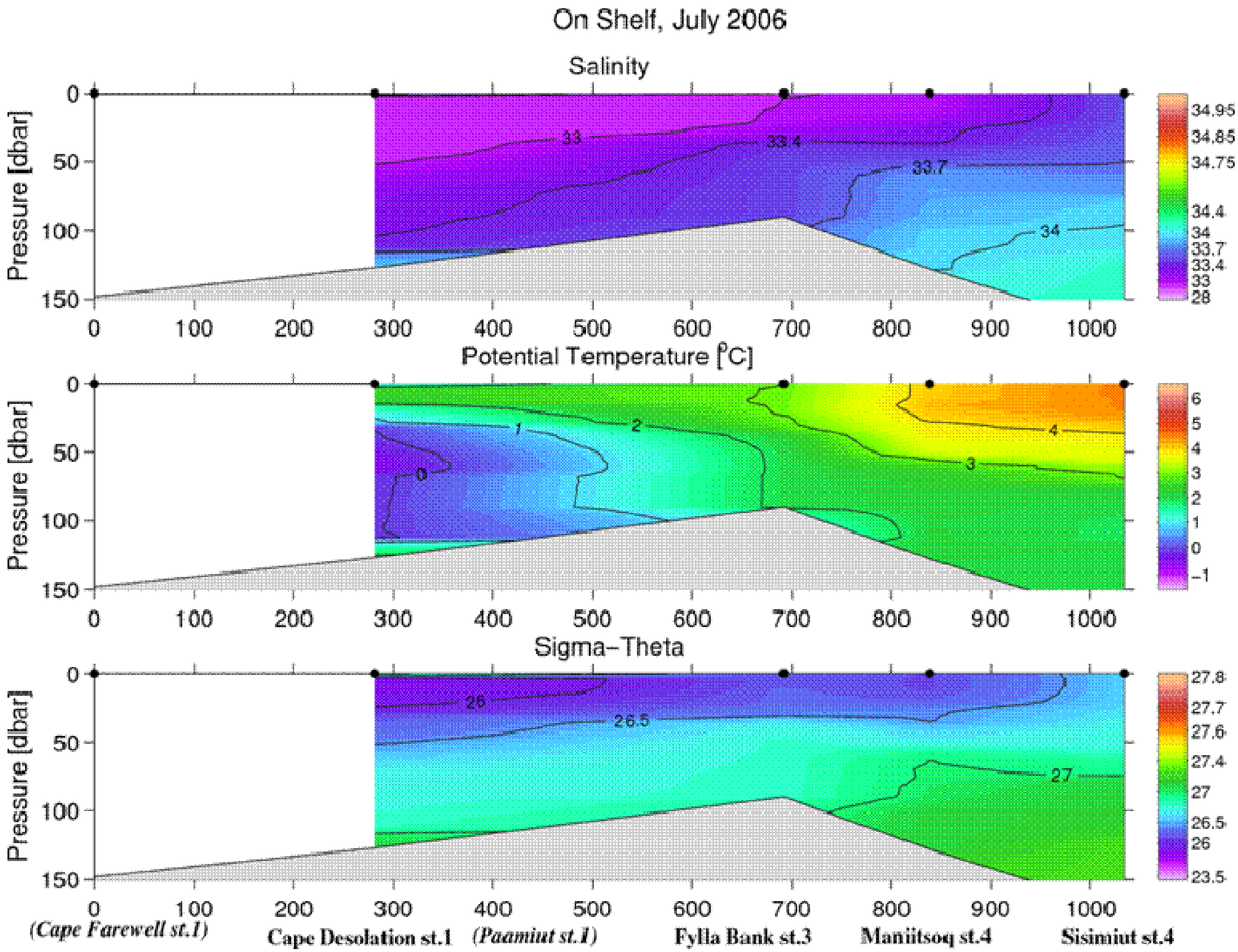


Figure 19. Vertical distribution of temperature, salinity and density over the shelf banks from Cape Farewell to Sisimiut, July 16–24, 2006
Note: Cape Farewell st.1 and Paamiut st.1 was not measured.

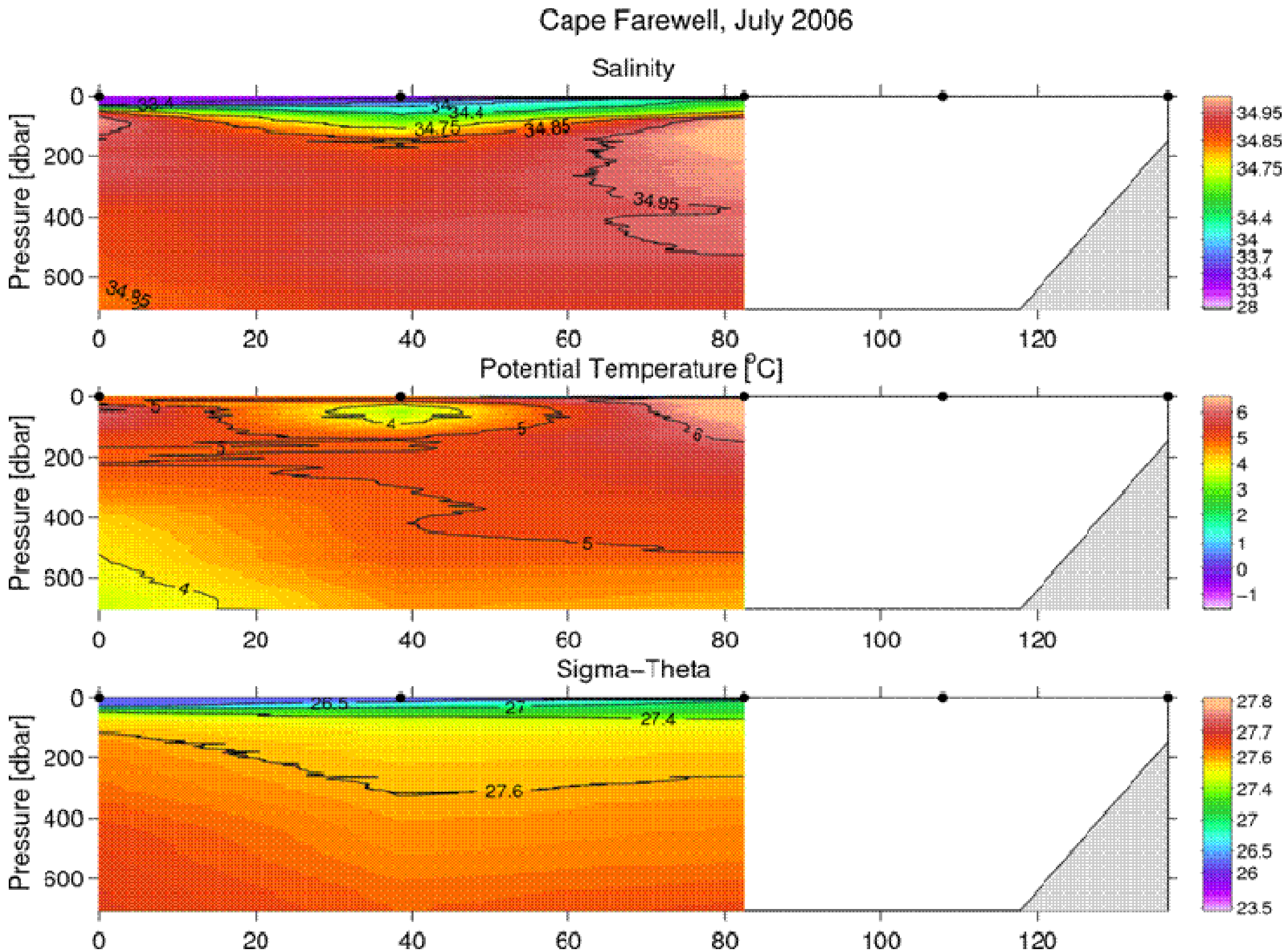


Figure 20. Vertical distribution of temperature, salinity and density at the Cape Farewell section, July 16, 2006. The two innermost stations was not measured due to multi-year-ice. Note, the low temperature and salinity in the upper 150m at st.4, which could be a cold-core eddy.

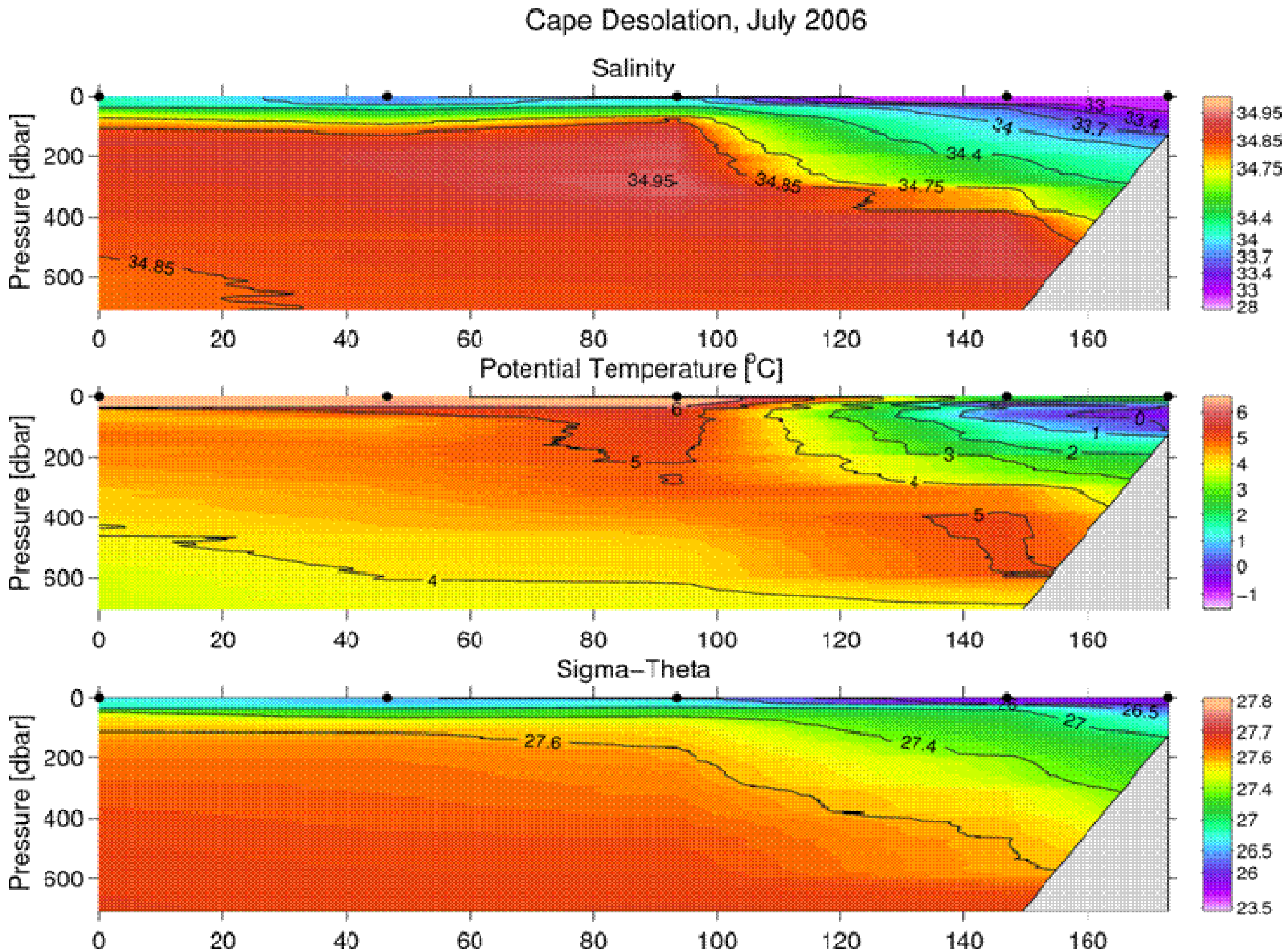


Figure 21. Vertical distribution of temperature, salinity and density at the Cape Desolation section, July 17, 2006.

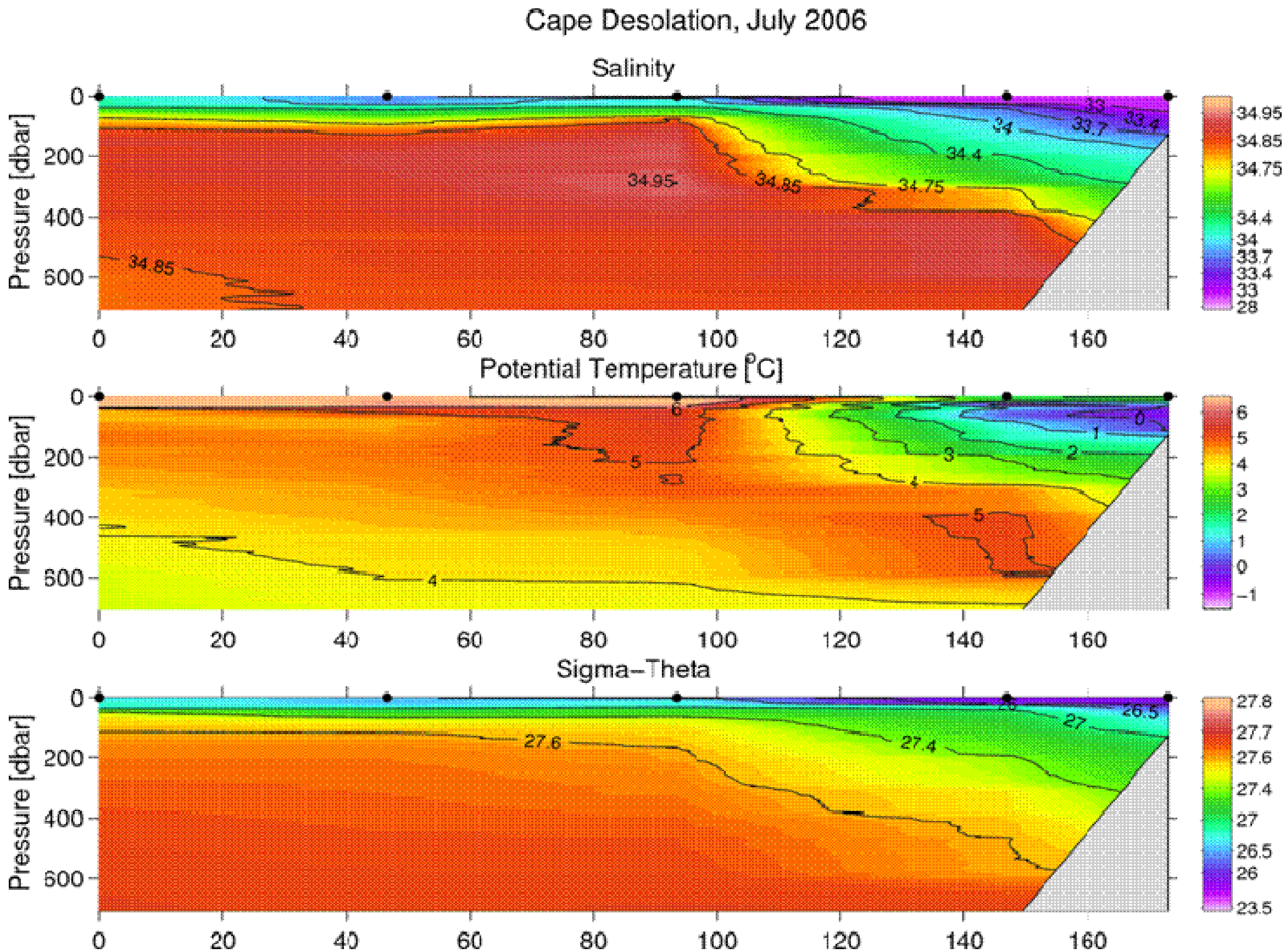


Figure 22. Vertical distribution of temperature, salinity and density at the Fylla Bank section, May, 2006. Fylla Bank st. 5 from July (identical to Figure 23).

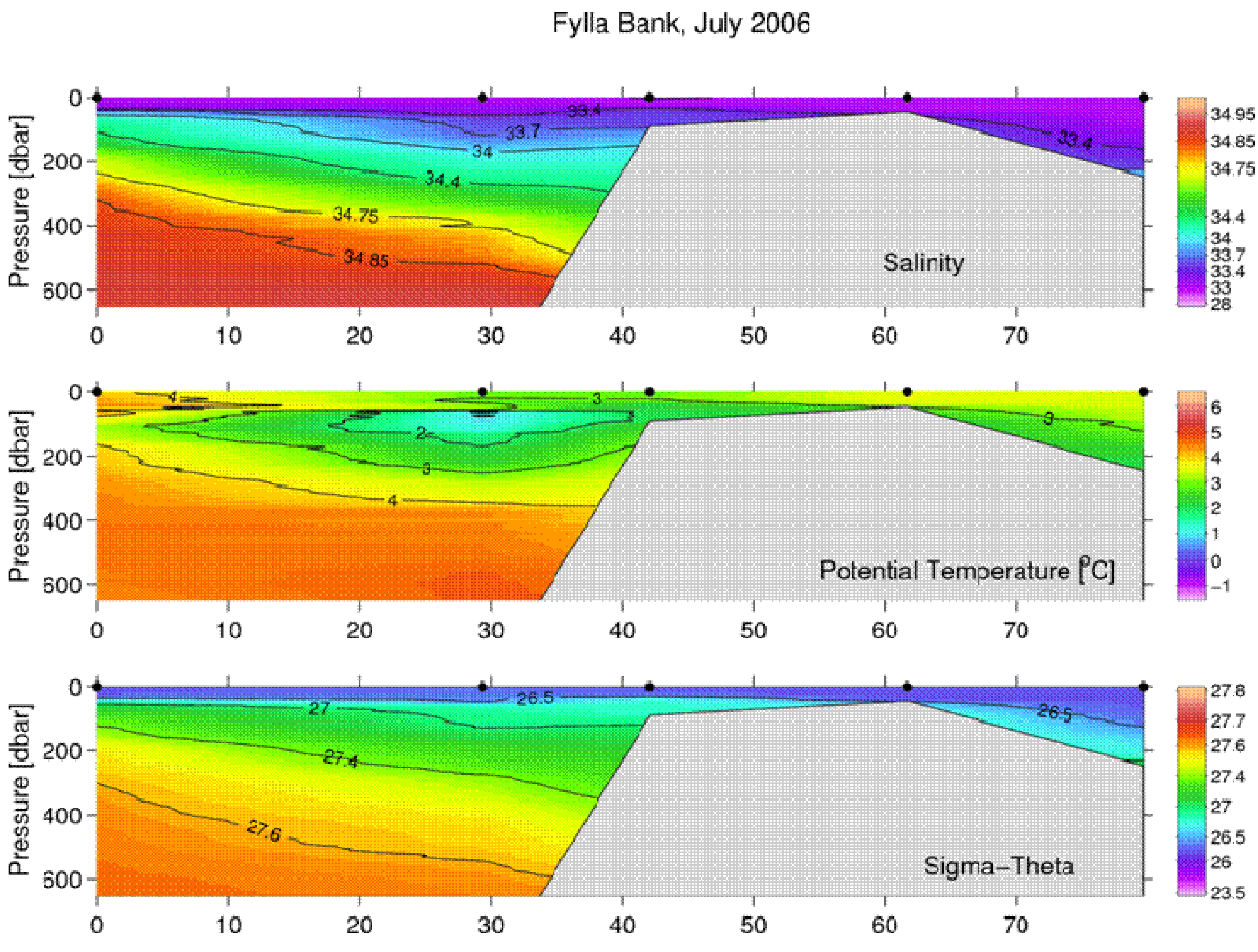


Figure 23. Vertical distribution of temperature, salinity and density at the Fylla Bank section, July 22, 2006.

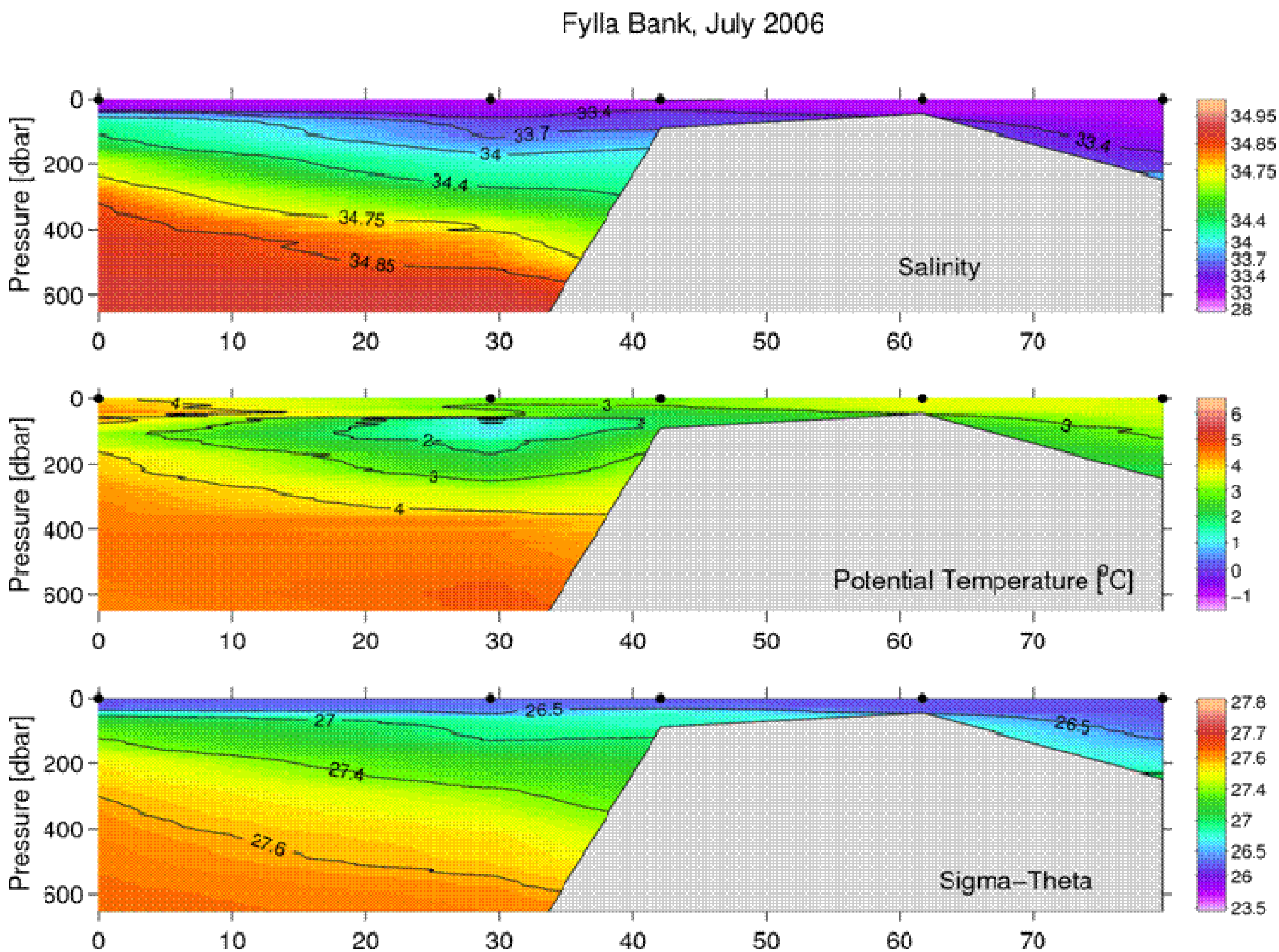


Figure 24. Vertical distribution of temperature, salinity and density at the Maniitsoq (Sukkertoppen) section, July 22–24, 2006.

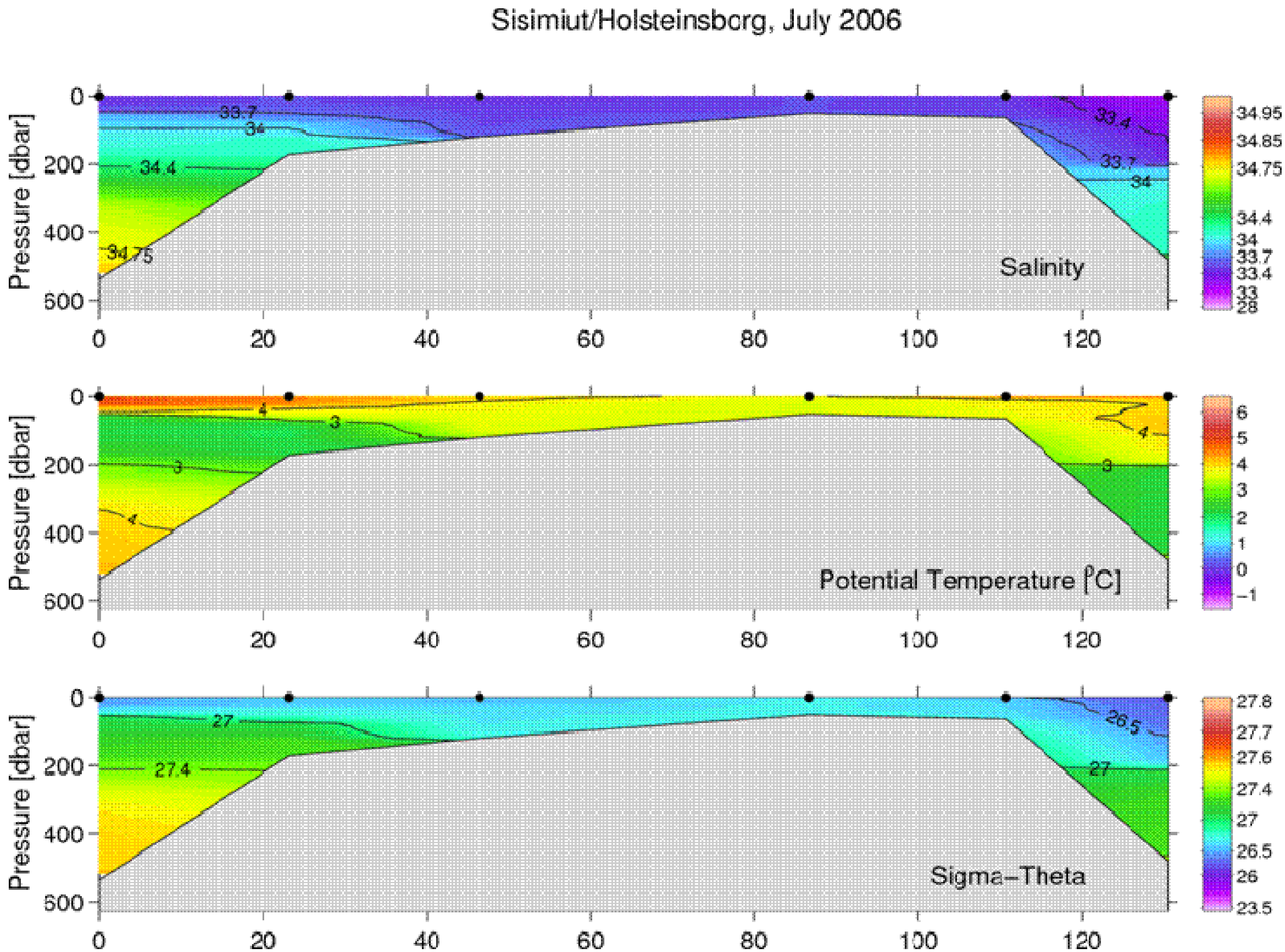


Figure 25. Vertical distribution of temperature, salinity and density at the Sisimiut (Holsteinsborg) section, July 24–25, 2006. Sisimiut st. 0 right.

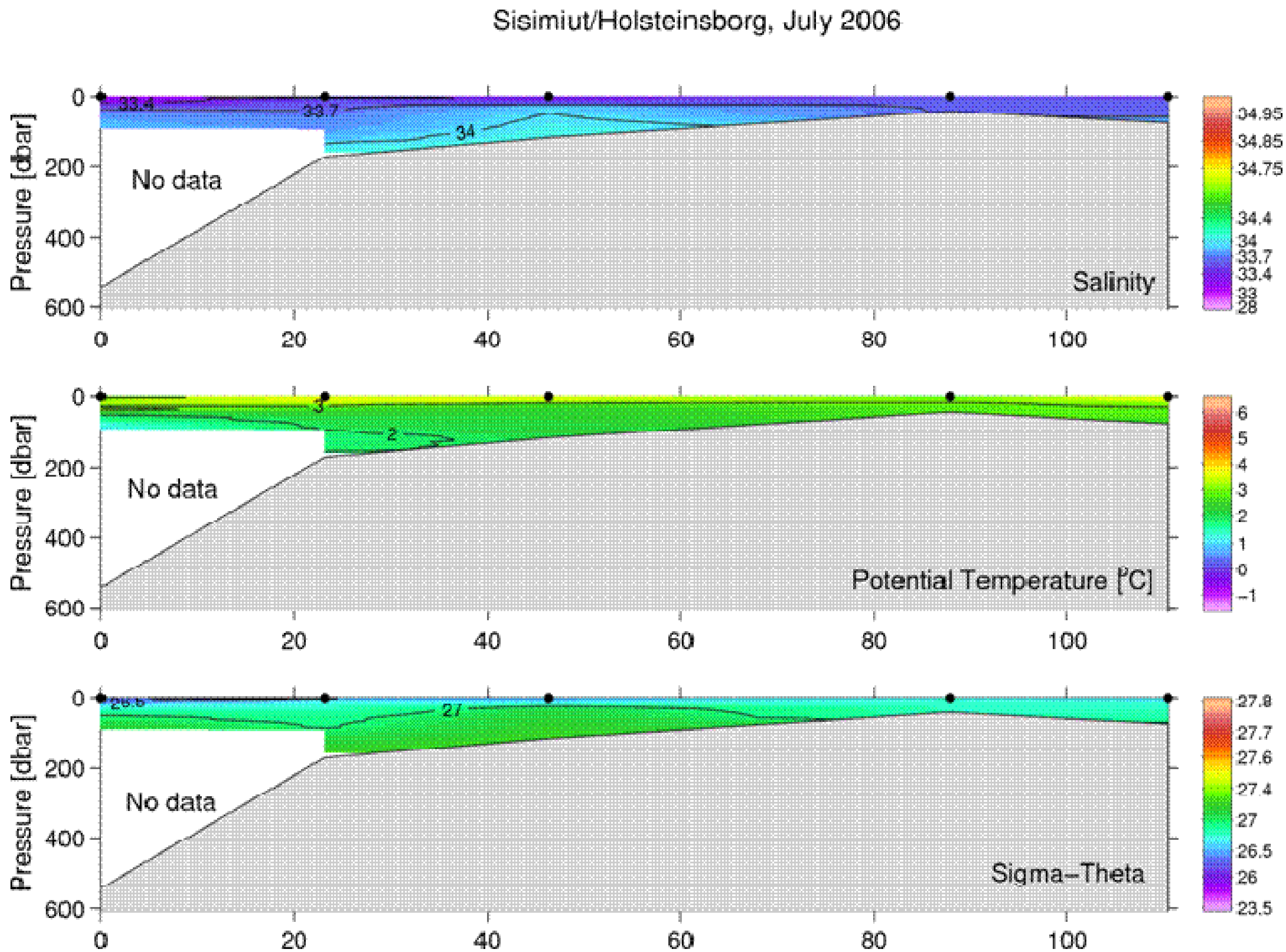


Figure 26. Vertical distribution of temperature, salinity and density at the Sisimiut (Holsteinsborg) section, July 3–4, 2006. Unfortunately, data from the deepest station (st.5) was only available down to 90 m.

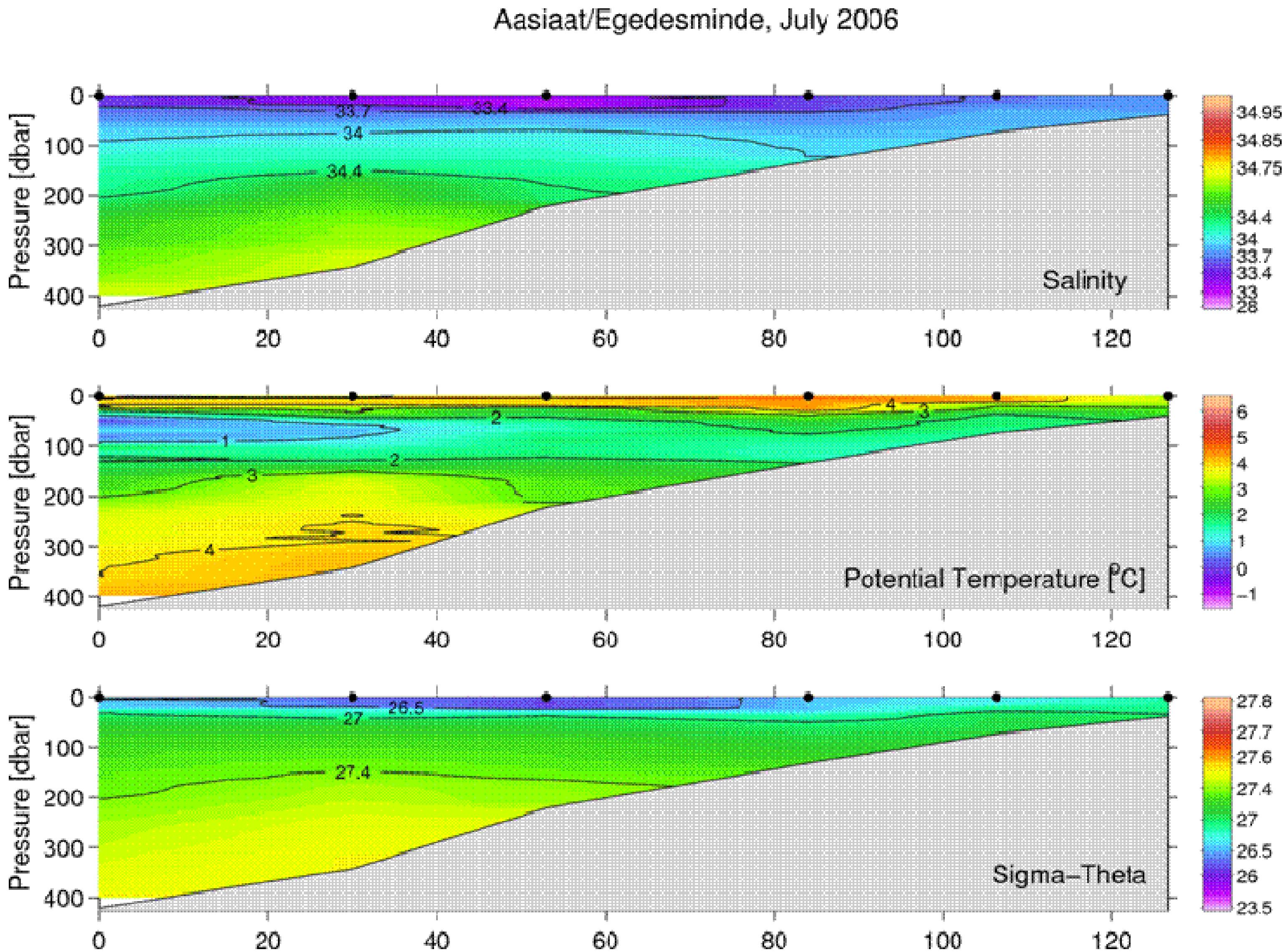


Figure 27. Vertical distribution of temperature, salinity and density at the Aasiaat (Egedesminde) section, July 8–11, 2006.

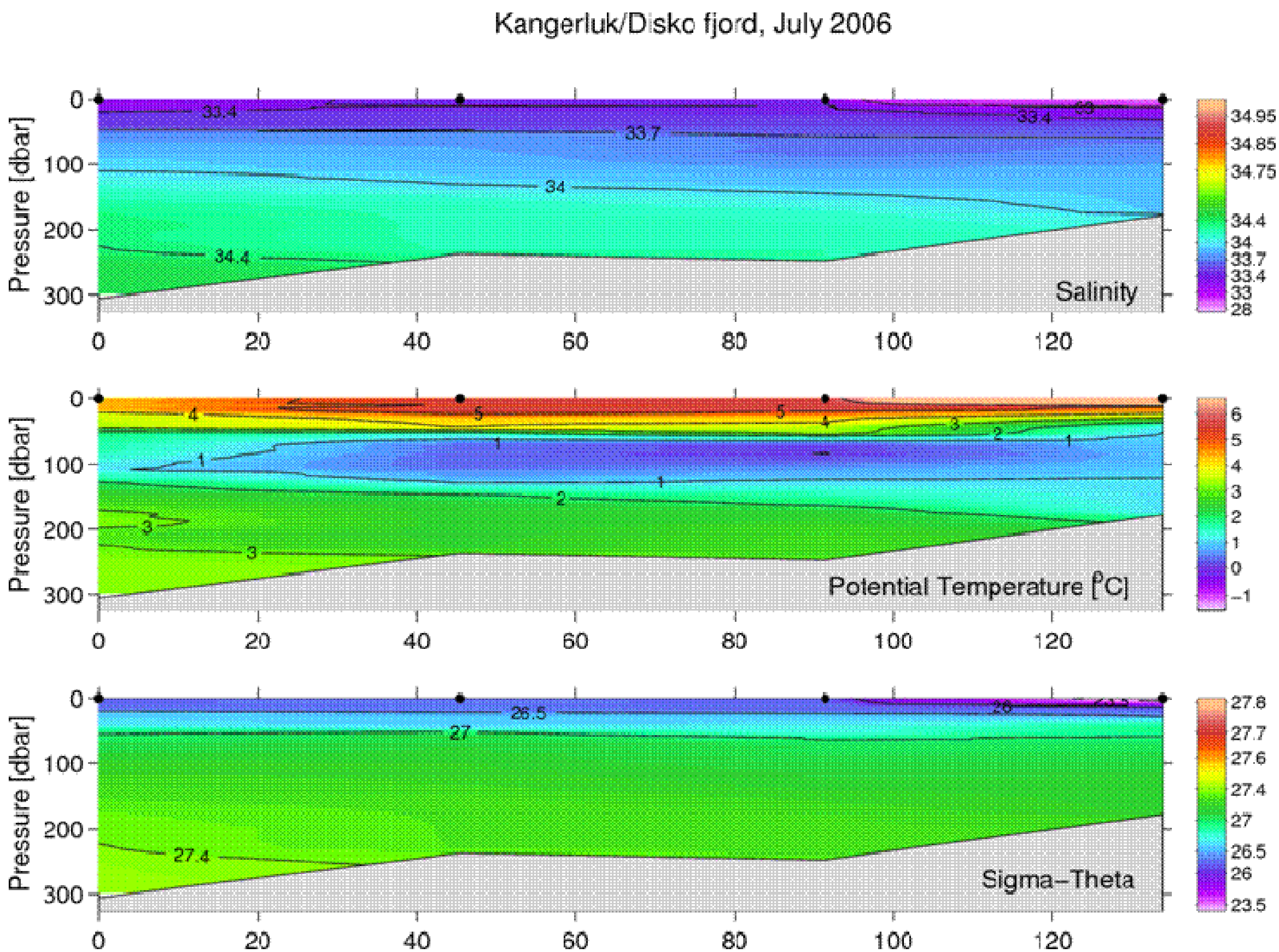


Figure 28. Vertical distribution of temperature, salinity and density at the Kangerluk (Disko Fjord) section, July 29–30, 2006.

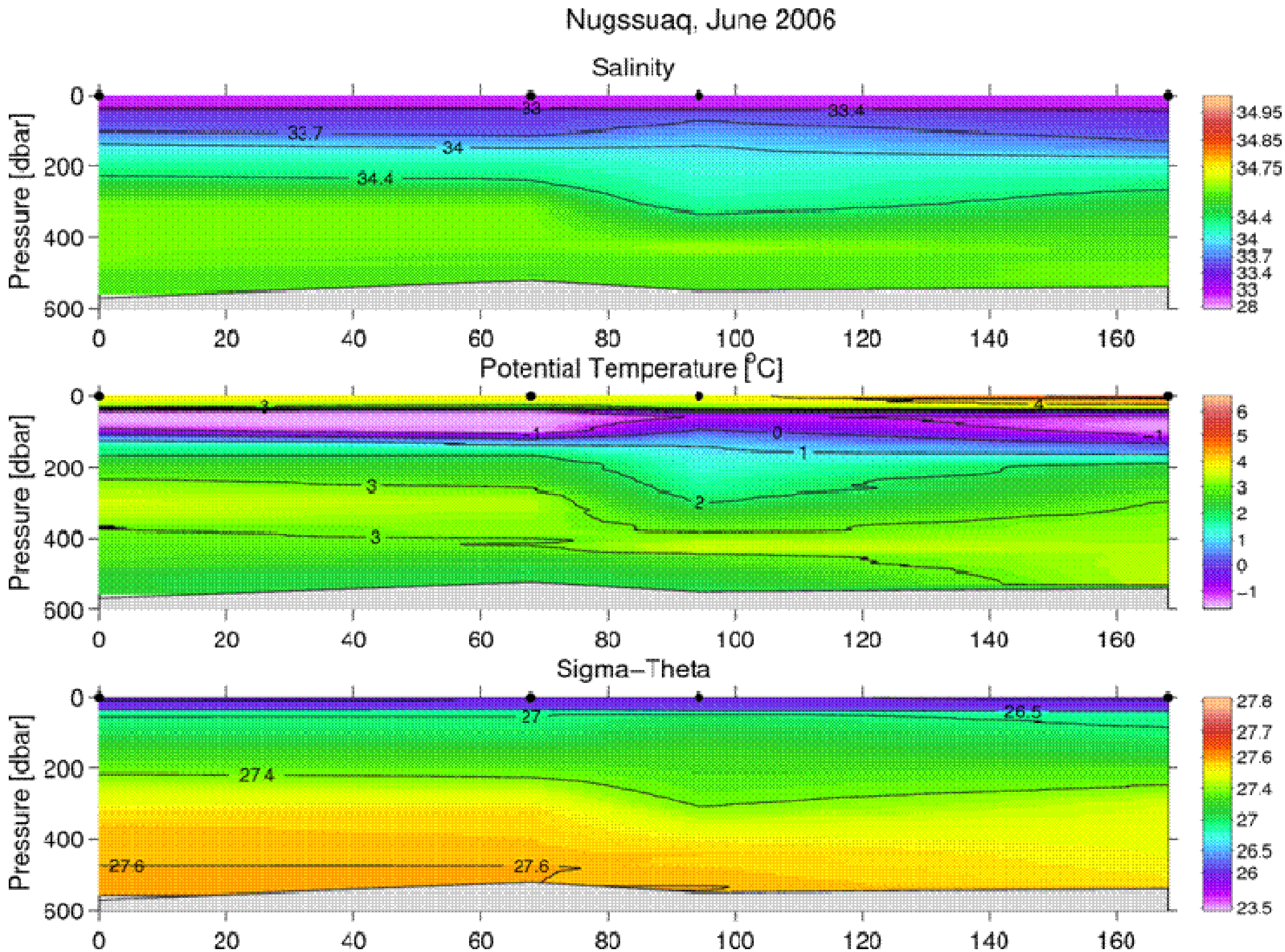


Figure 29. Vertical distribution of temperature, salinity and density at the Nugssuaq section, July 26–27, 2006. Station 2 was not taken.

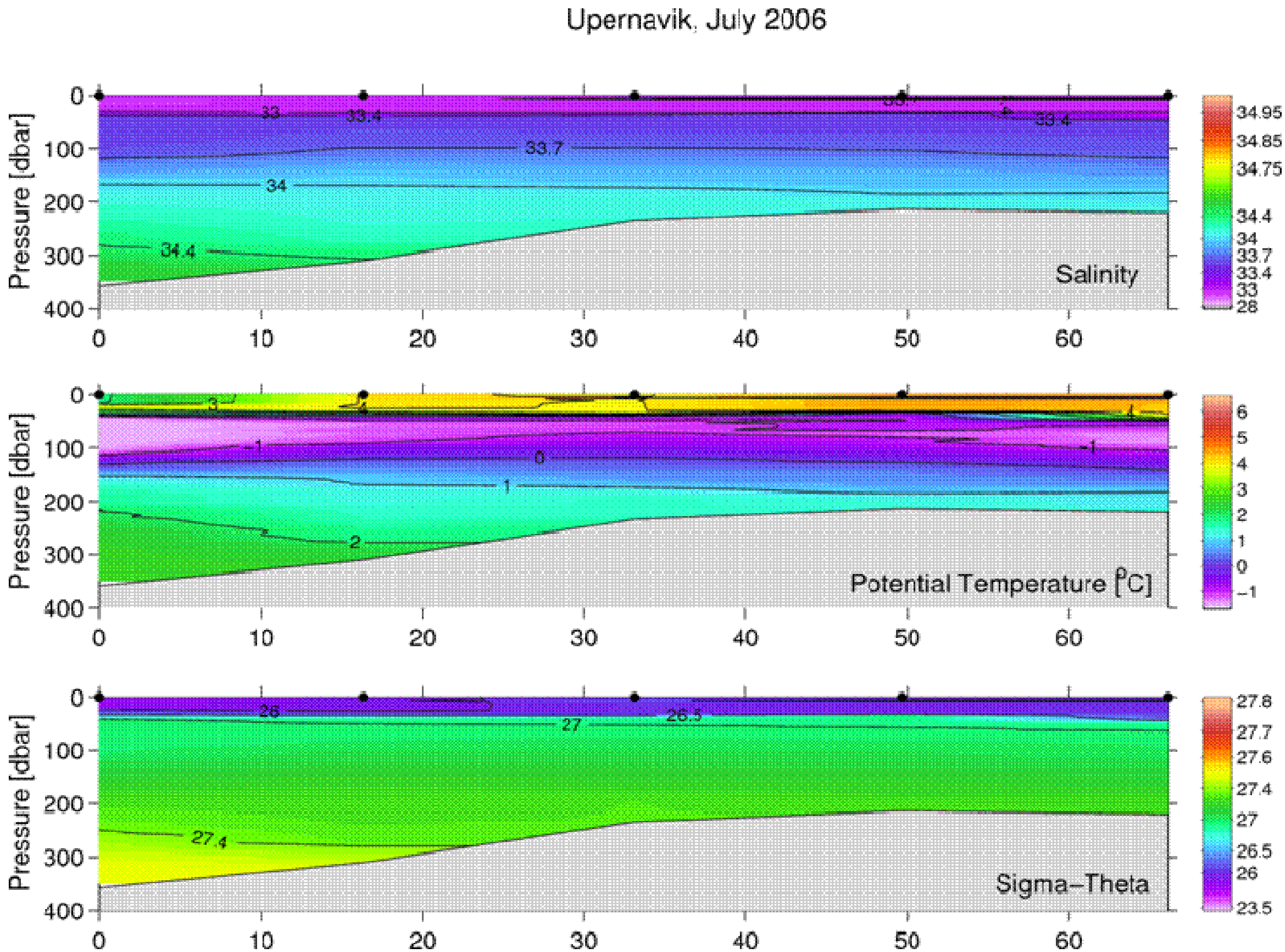


Figure 30. Vertical distribution of temperature, salinity and density at the Upernavik section, July 24–25, 2006.

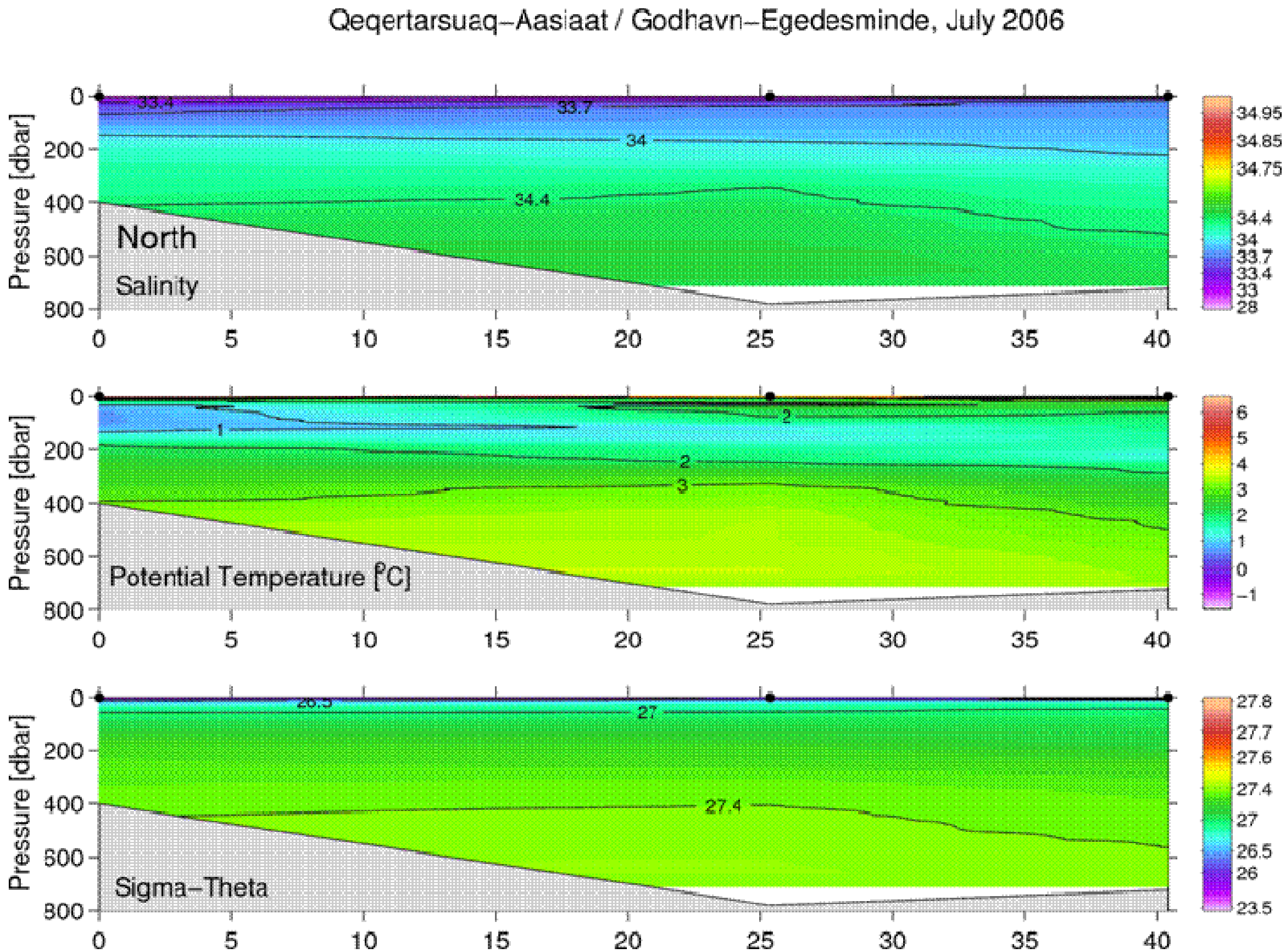


Figure 31. Vertical distribution of temperature, salinity and density at the Aasiaat–Qeqertarsuaq (Egedesminde–Godhavn) section, July 13–14, 2006.

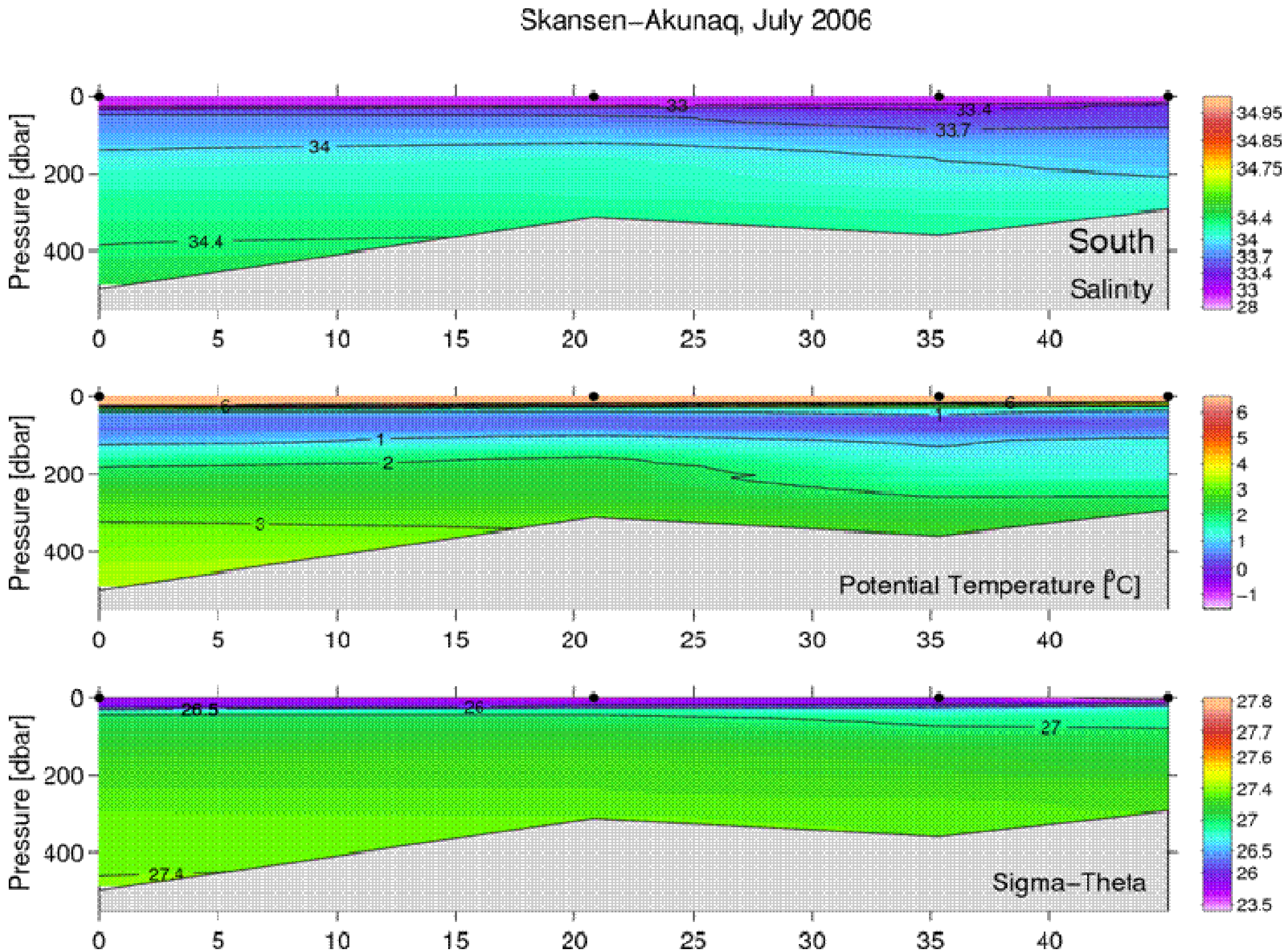


Figure 32. Vertical distribution of temperature, salinity and density at the Skansen–Akunaq section, July 14–15, 2006.

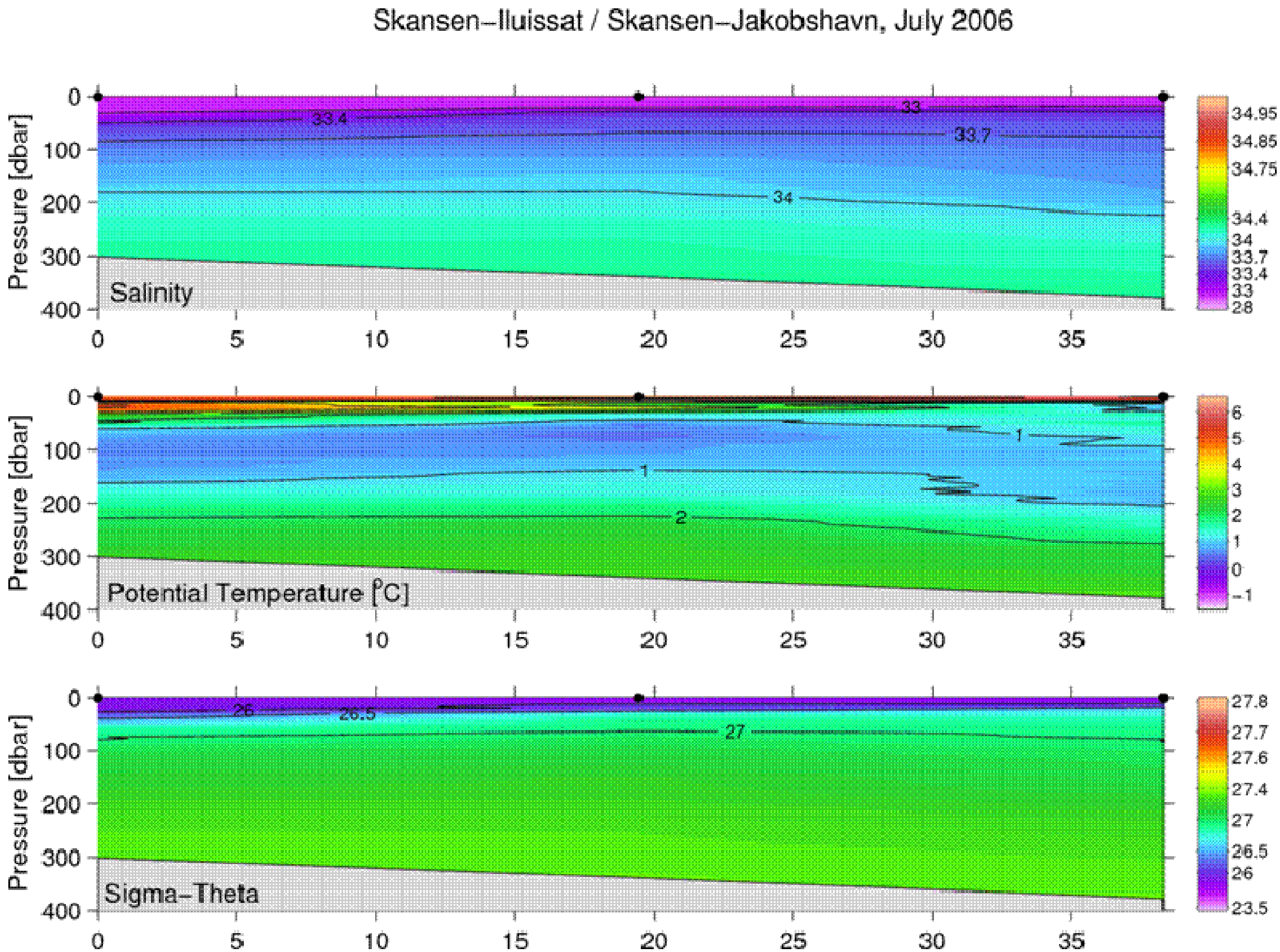


Figure 33. Vertical distribution of temperature, salinity and density at the Skansen–Iluissat (Skansen–Jakobshavn) section, July 15, 2006.

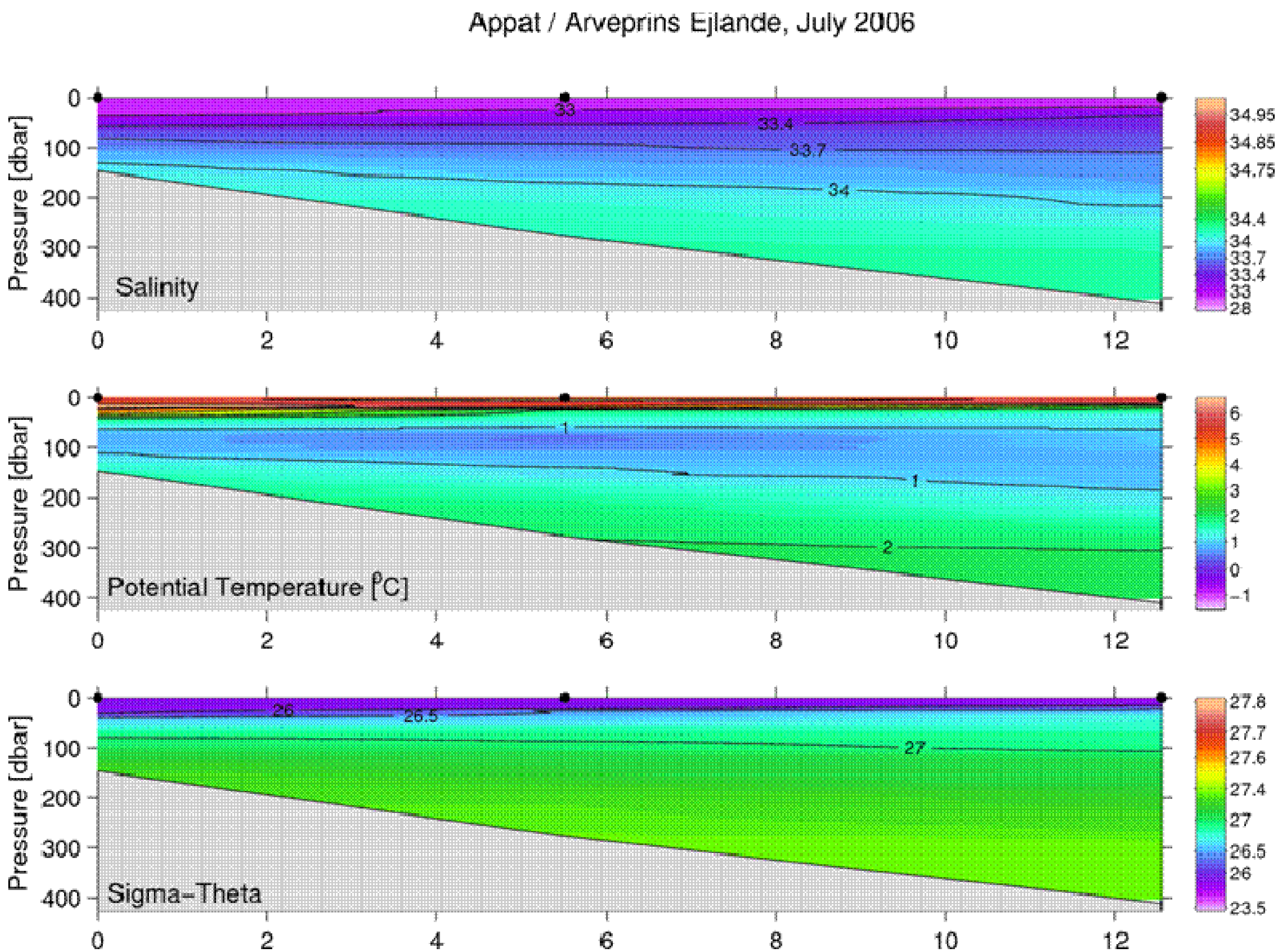


Figure 34. Vertical distribution of temperature, salinity and density at the Appat (Arveprins Ejlande) section, July 19, 2006.

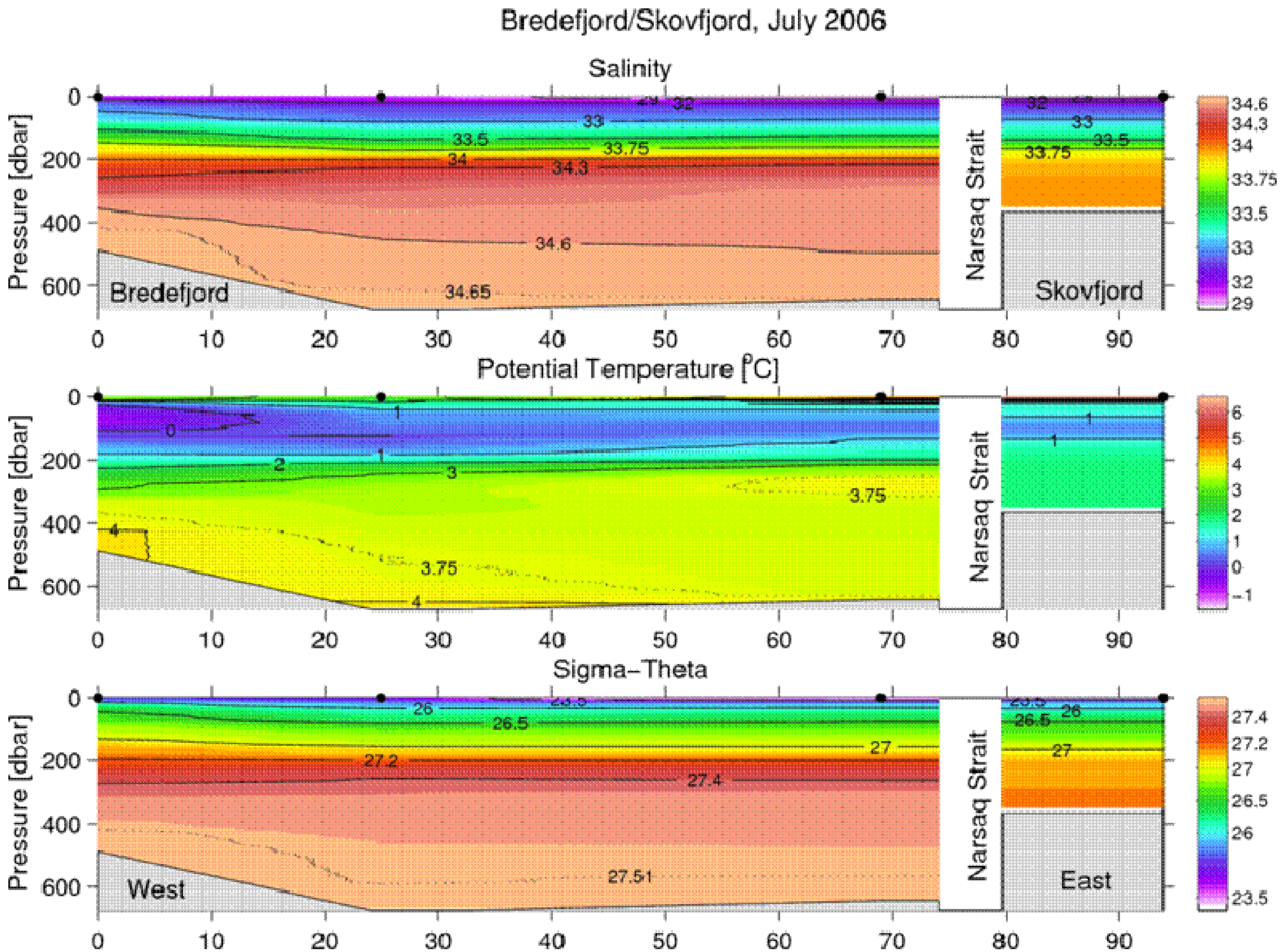


Figure 35. Vertical distribution of temperature, salinity and density at Bredefjord and Skovfjord, July 15–20, 2006. The most westerly station is just outside the sill.

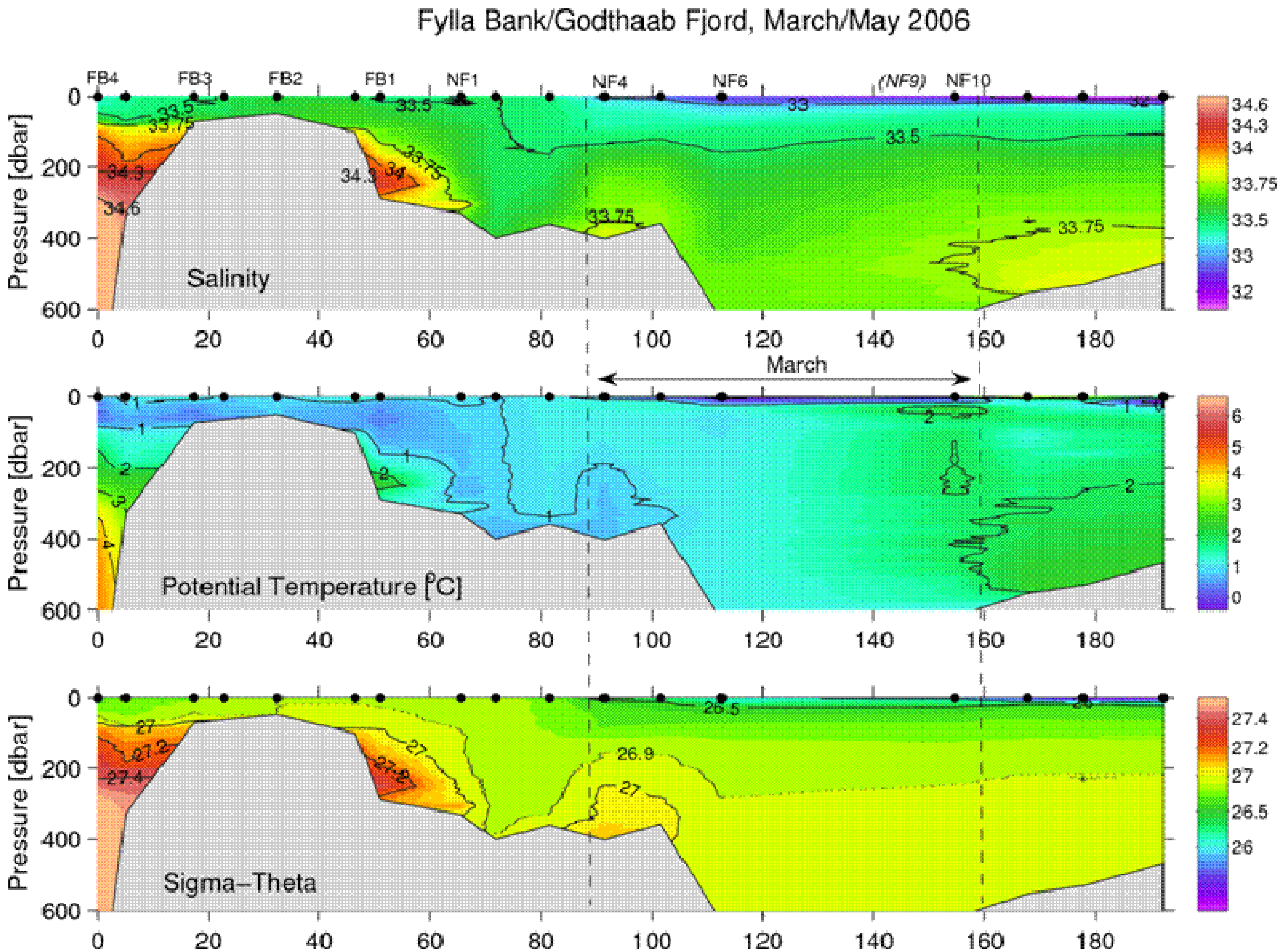


Figure 36**.** Vertical distribution of temperature, salinity and density at Godthaab (Nuuk) Fjord and Fylla Bank, March 23–26 (Godthaab Fjord st.4,5,6,10) indicated by the vertical stippled lines. The rest is from May 15–20, 2006 and identical to Figure 37.

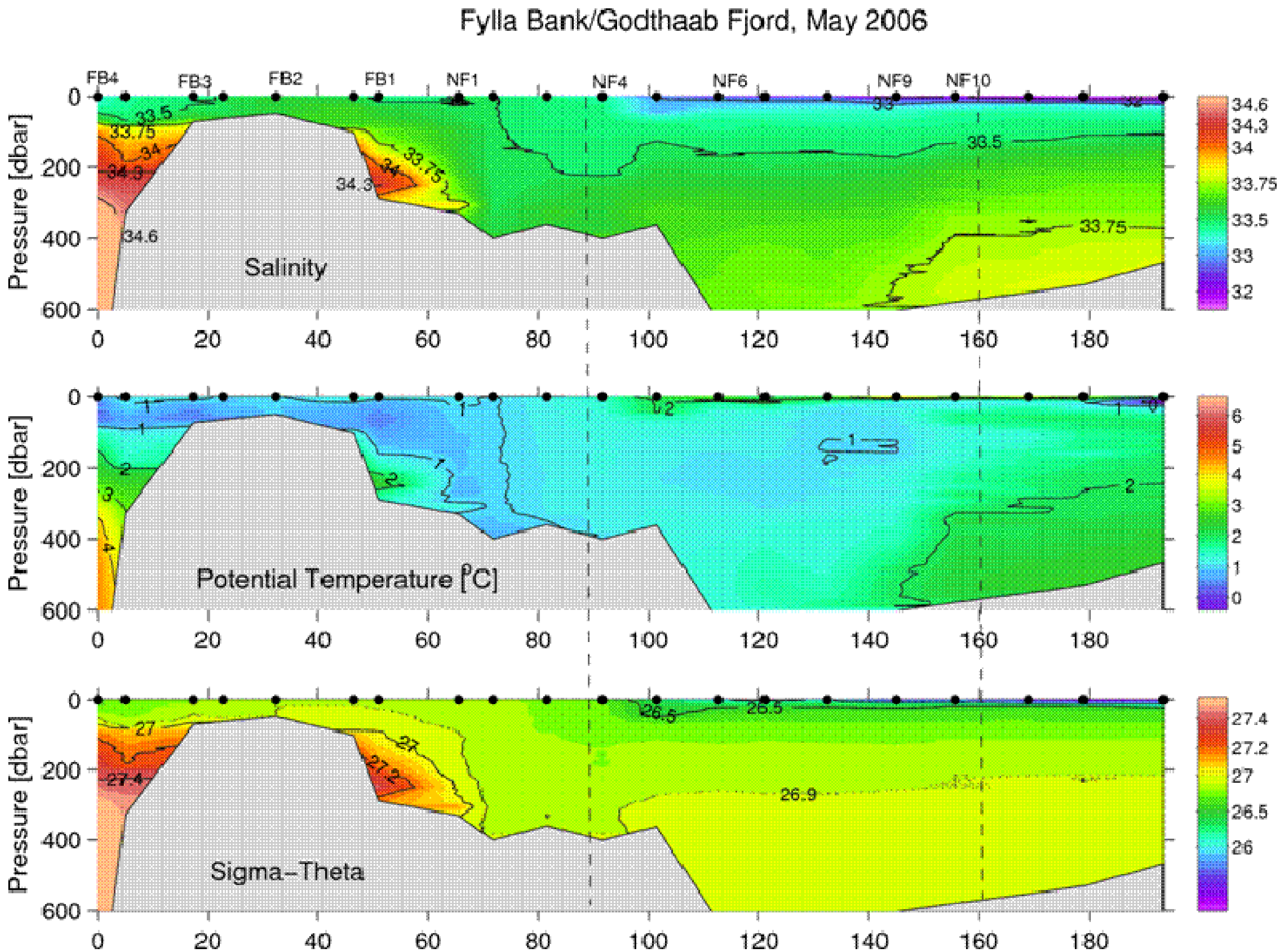


Figure 1. Vertical distribution of temperature, salinity and density at Godthaab (Nuuk) Fjord and Fylla Bank, May 15–20, 2006. The vertical stippled lines is placed identical to Figure 36 (March) for comparison.

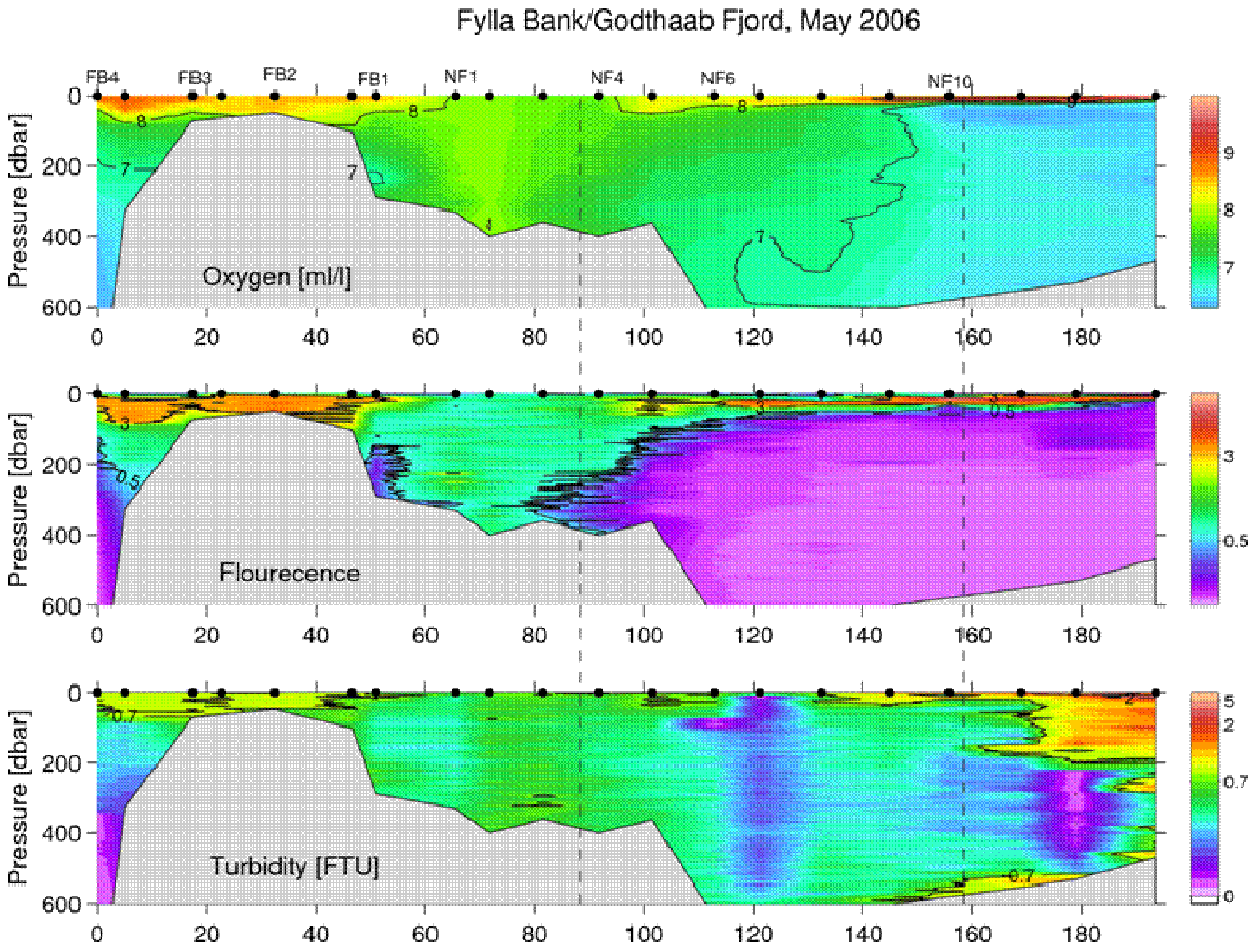


Figure 2**.** Vertical distribution of Oxygen, Flourecence and Turbidity at Godthaab (Nuuk) Fjord and Fylla Bank, May 15–20, 2006. The vertical stippled lines is placed identical to Figure 36 (March) for comparison.

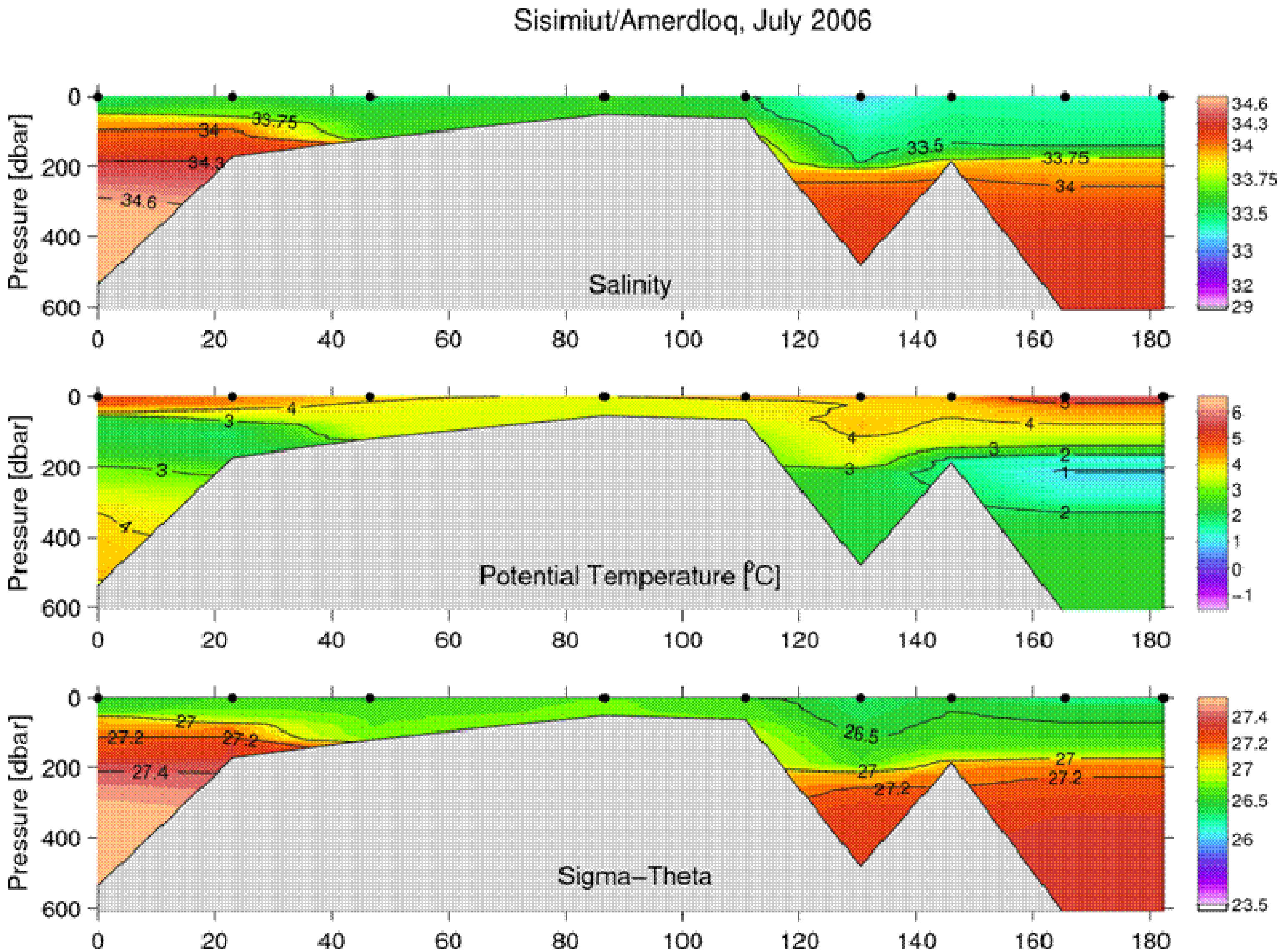


Figure 39**.** Vertical distribution of temperature, salinity and density at the Amerdloq fjord, July 24–25, 2006. Sisimiut section left (identical to Figure 23). Note, the innermost fjord station has been repeated in the plot.

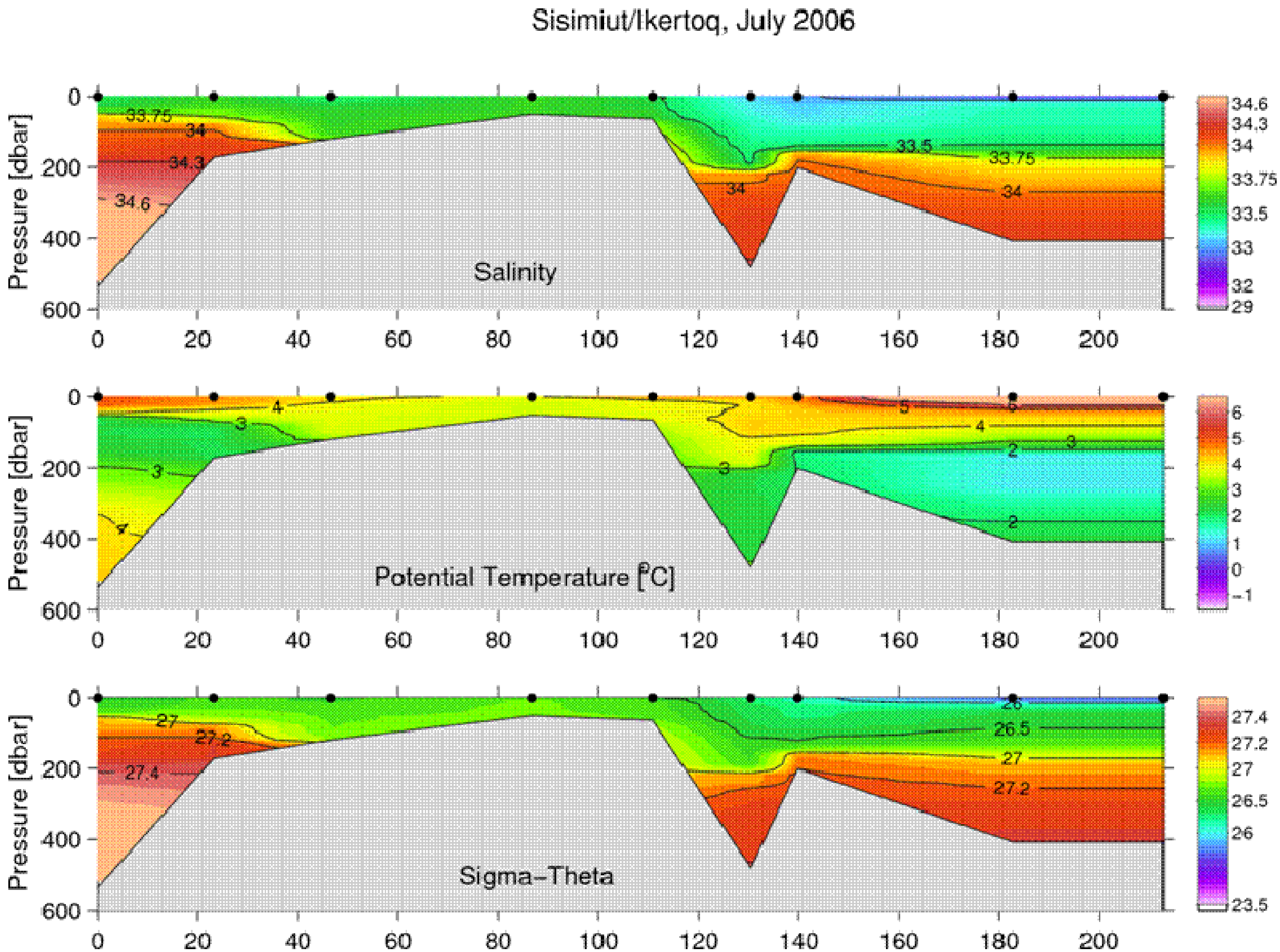


Figure 40**.** Vertical distribution of temperature, salinity and density at the Ikertoq fjord, July 24–25, 2006. Sisimiut section left (identical to Figure 23). Note, the innermost fjord station has been repeated in the plot.

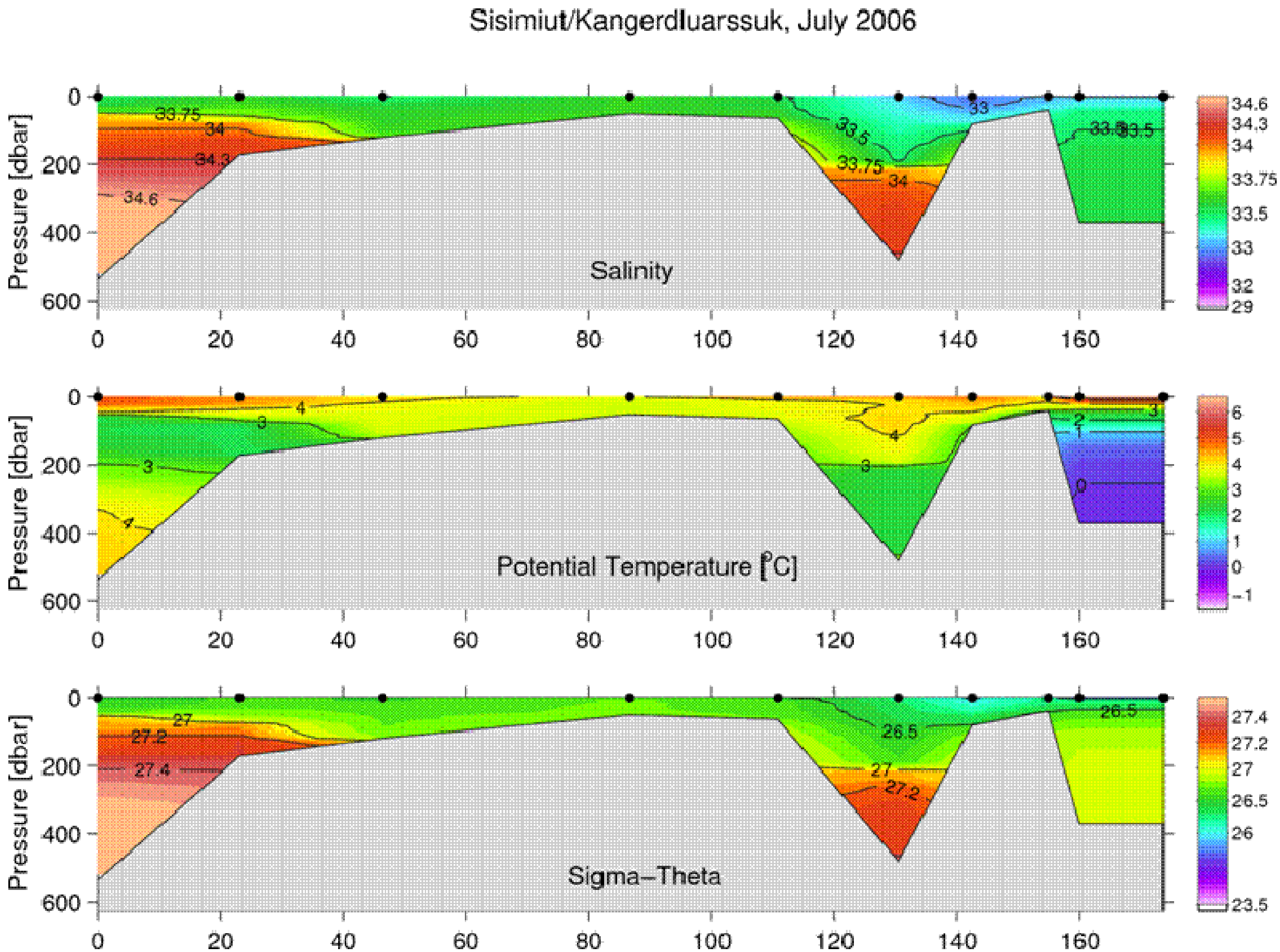


Figure 41. Vertical distribution of temperature, salinity and density at the Kangerdluarssuk fjord, July 24–25, 2006. Sisimiut section left (identical to Figure 23). Note, the innermost fjord station has been repeated in the plot.

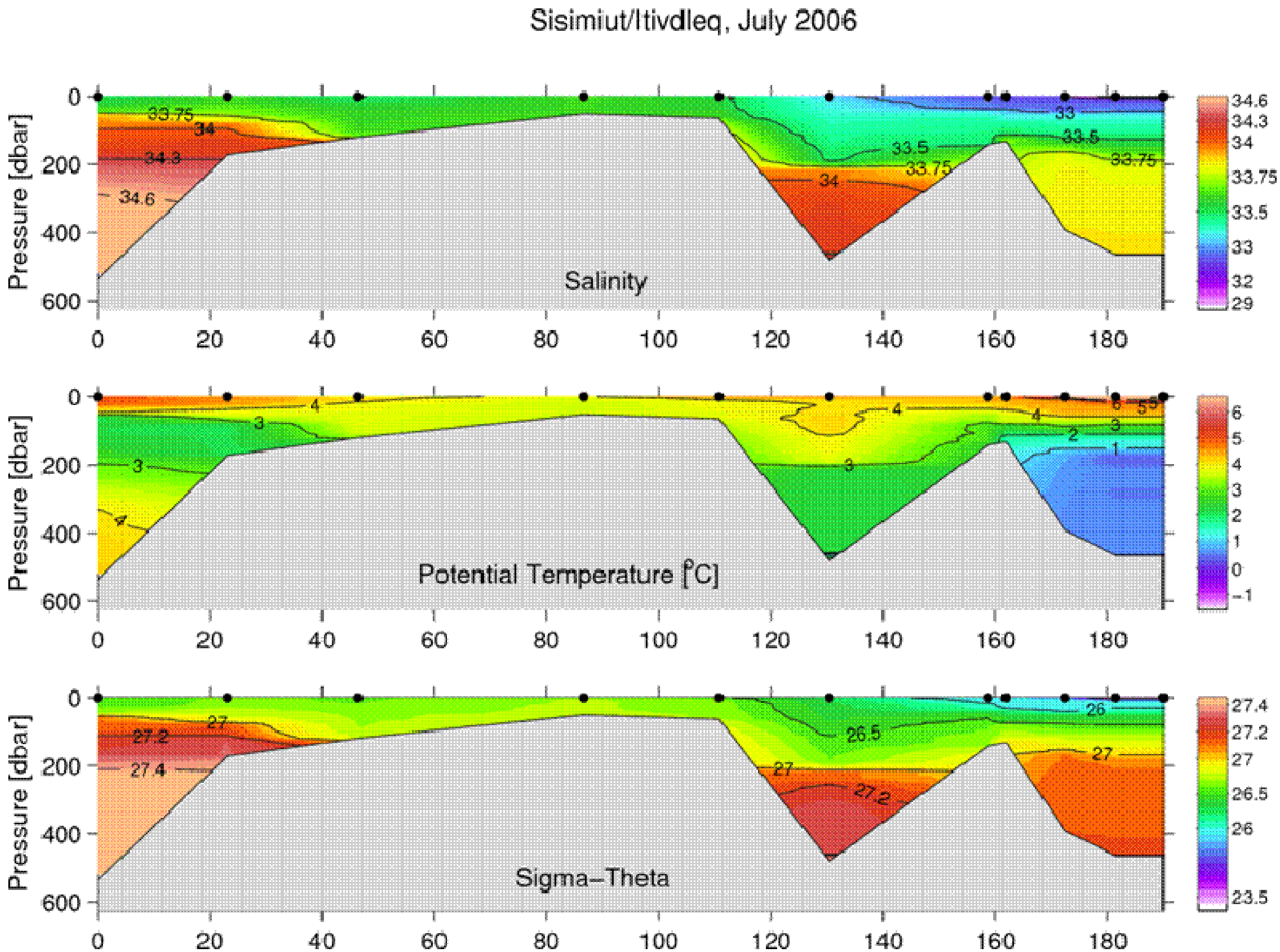


Figure 42**.** Vertical distribution of temperature, salinity and density at the Itivdleq fjord, July 24–25, 2006. Sisimiut section left (identical to Figure 23). Note, the innermost fjord station has been repeated in the plot.

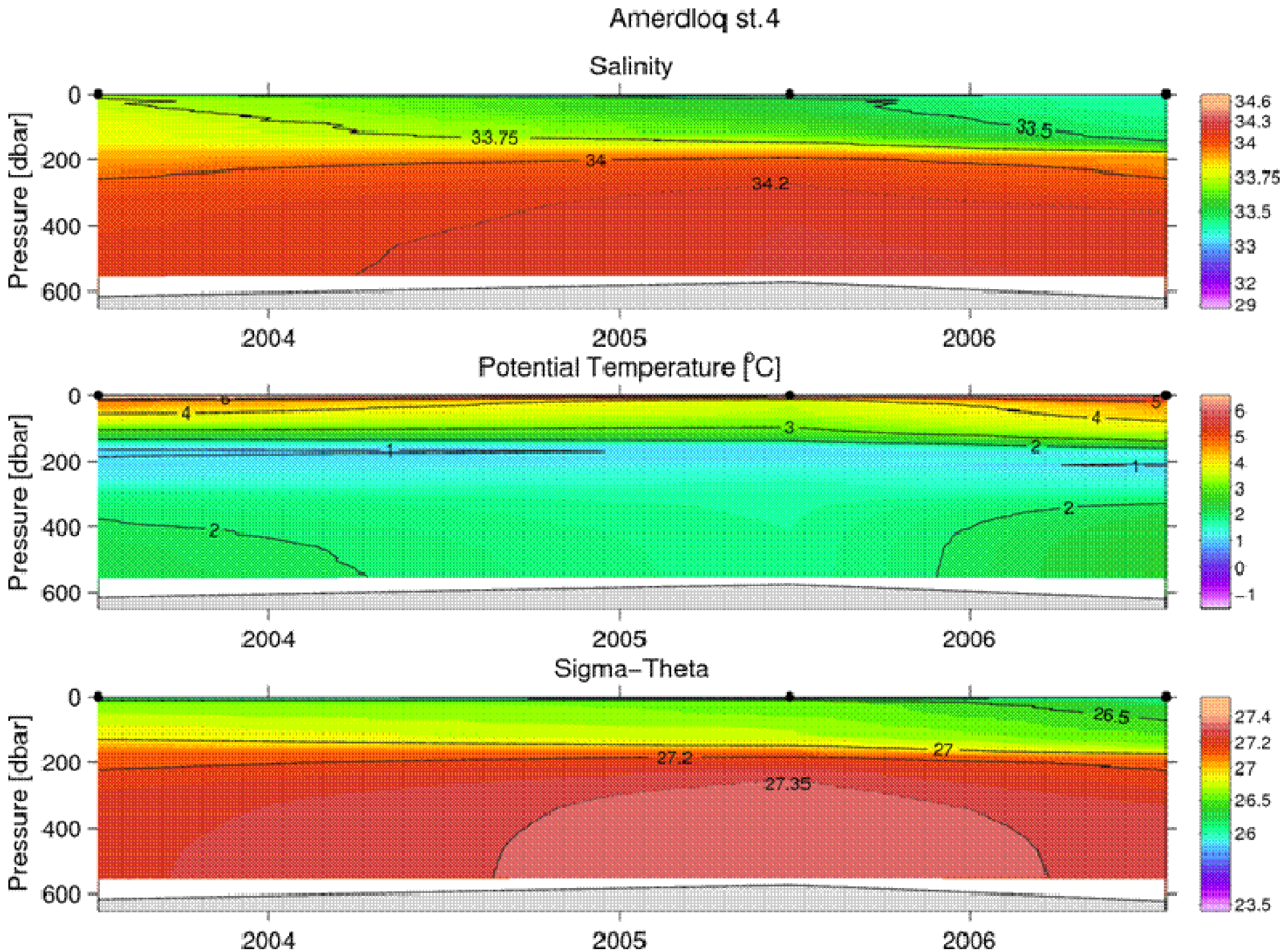


Figure 43**.** Hovmöller diagram of vertical distribution of temperature, salinity and density at the Amerdloq fjord st.4, late June/July 2003, 2005, 2006.

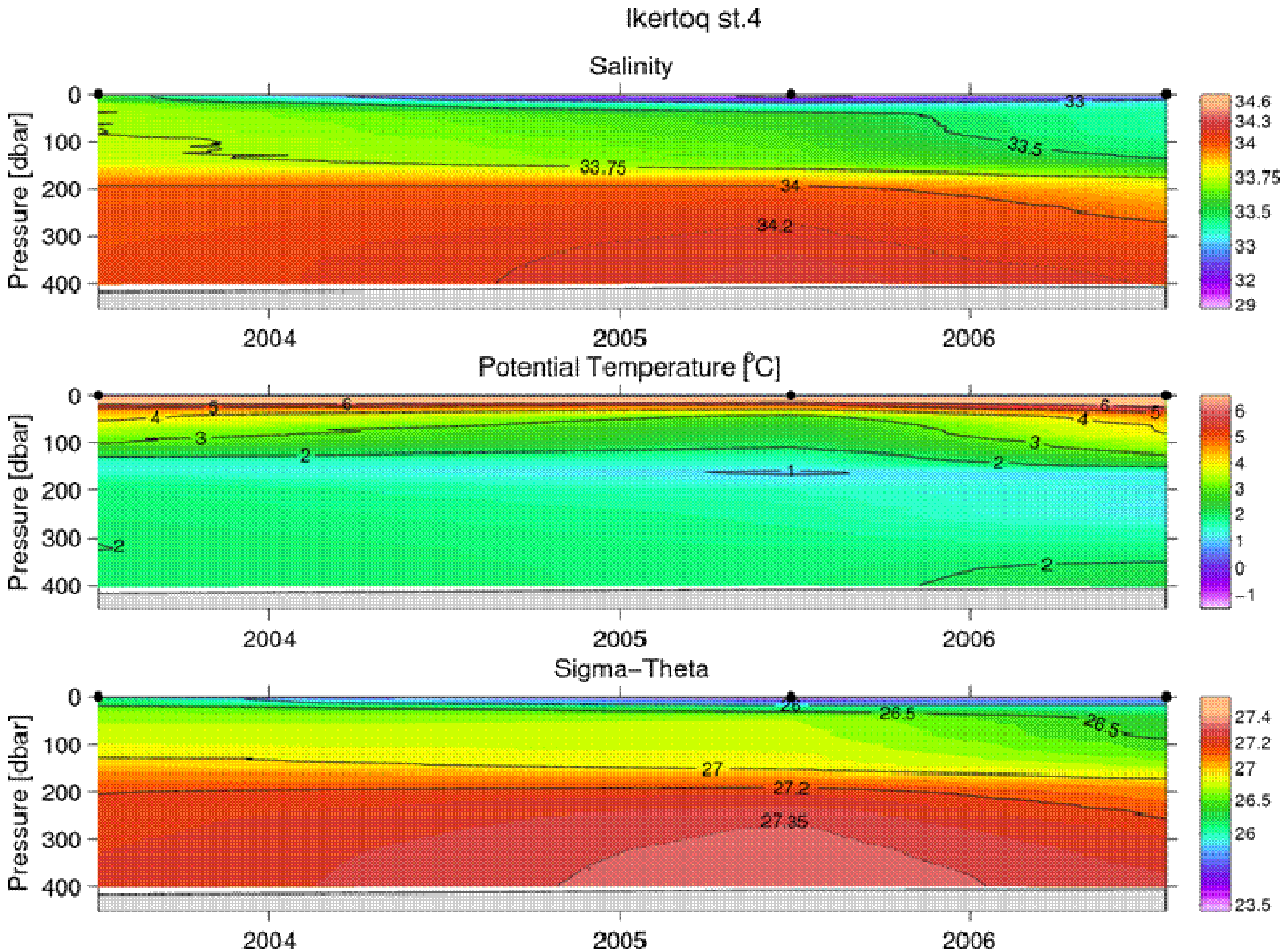


Figure 44**.** Hovmöller diagram of vertical distribution of temperature, salinity and density at the Ikertoq fjord st.4, late June/July 2003, 2005, 2006.

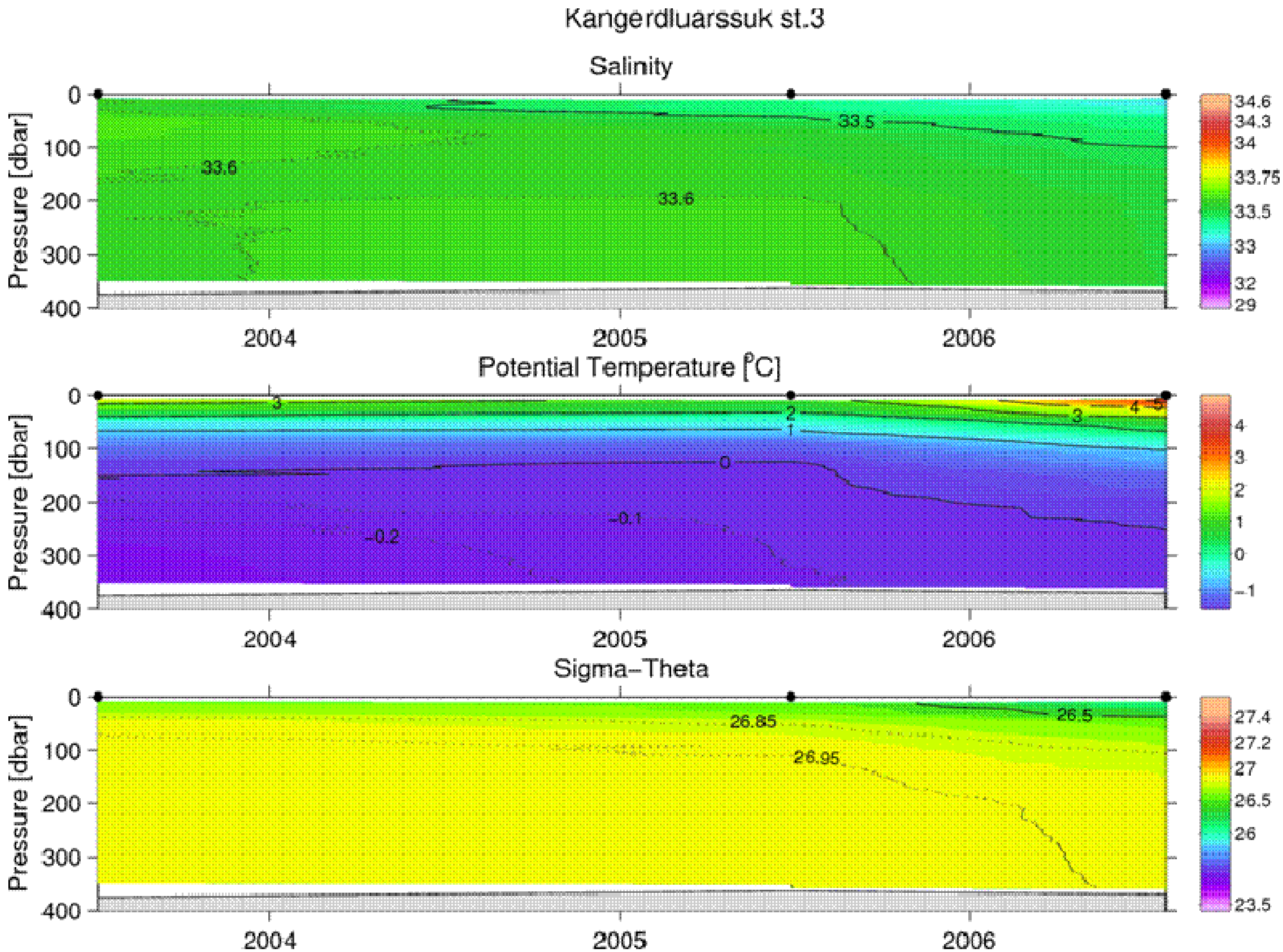


Figure 3**.** Hovmöller diagram of vertical distribution of temperature, salinity and density at the Kangerdluarssuk fjord st.3, late June/July 2003, 2005, 2006.

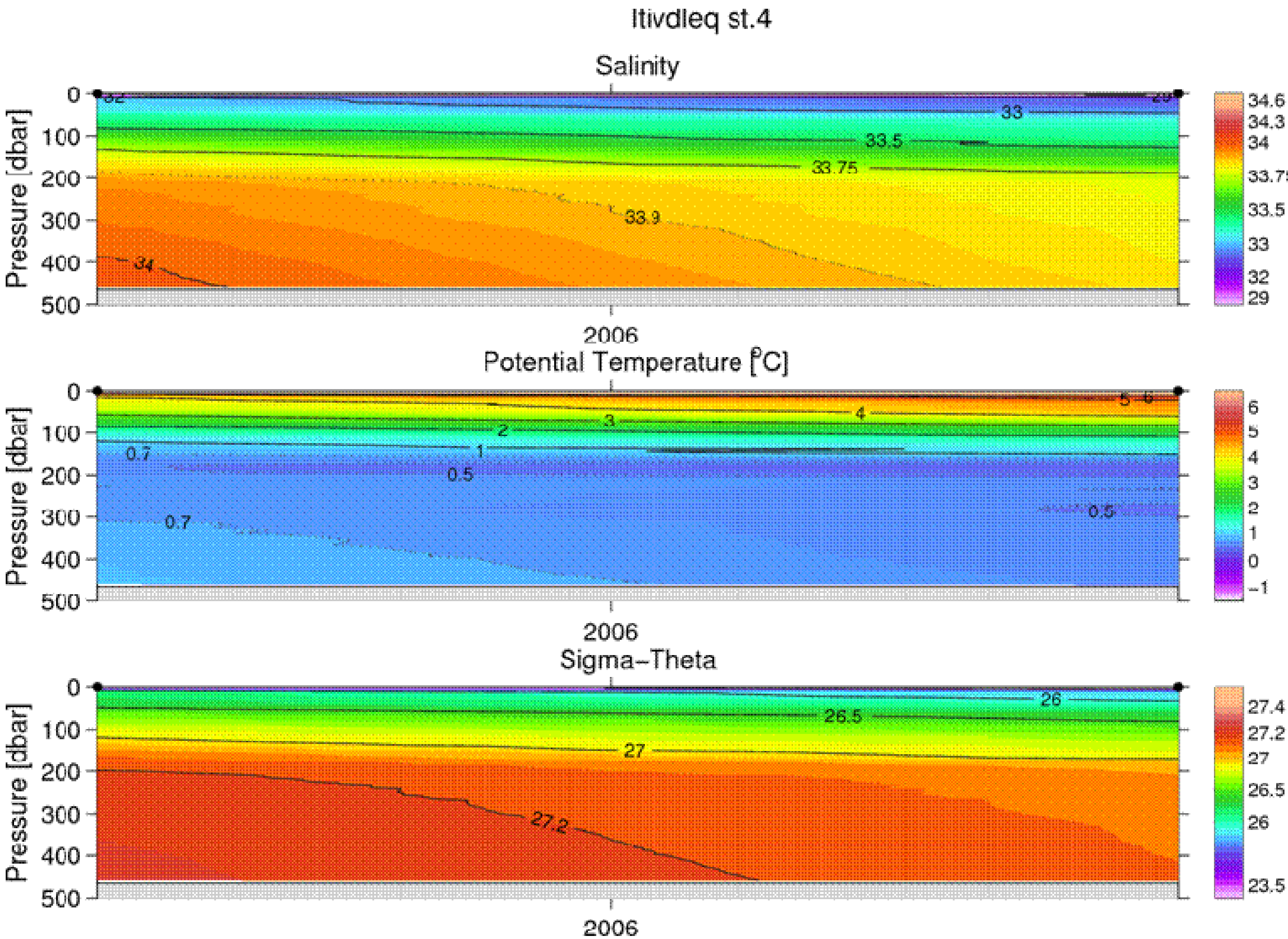


Figure 4. Hovmöller diagram of vertical distribution of temperature, salinity and density at the Itivdleq fjord st. 4, late June/July 2005, 2006.