Northwest Atlantic Fisheries Organization

**Serial No. N4357** **NAFO SCR Doc. 01/2**

**SCIENTIFIC COUNCIL MEETING – JUNE 2001**

# Oceanographic Investigations off West Greenland 2000

by

Erik Buch and Mads Hvid Nielsen
Division for Operational Oceanography
Danish Meteorological Institute
February 2000

**Abstract**

Results of the 2000 summer cruise to the standard sections along the west coast of Greenland are presented together with CTD data from gathered during trawl surveys.

Although the North Atlantic Oscillation (NAO) Index has been fairly positive, the climate over Greenland has in recent years been rather mild, which can be attributed to at eastward shift og the Icelandic Low. The oceanographic conditions in the surface showed temperatures around 1°C above normal on top of Fylla Bank, while the salinity was slightly below normal. The inflow of Polar water was above normal while the inflow of Irminger water was very limited in 2000.

## 1. Introduction

The North Atlantic marine climate is largely controlled by the so-called North Atlantic Oscillation or NAO, which is driven by the Azores High and the Iceland Low pressure cells. Following its long period of extreme positive values, the NAO index suddenly underwent a sharp decrease to a short-lived minimum in the winter of 1995-96. Since that temporary minimum, a steady recovery towards positive values of the winter NAO is observed, Fig. 1. However the recovery has so far been incomplete, a comparison of the Atlantic sea level pressure anomaly pattern for the early-1990s (1993-95) with those for winters 1999 and 2000 it is found that the recent NAO pattern is displaced slightly towards the east or northeast, ICES, 2000.

This subtle change has little effect on the subtropical gyre of the Atlantic and along its eastern boundary to the Barents Sea where evidence of the widespread warming that normally is associated with the positive NAO is found. However in the Northwest Atlantic, this slight eastward retraction of the "normal" NAO pattern has made an important difference to the marine climate. Instead of a chill and strong northwesterly airflow promoting cooling there, as it did in the early-1980s and 1990s, any northwesterly airflow is now mainly confined to the east of Greenland, while the Labrador Sea is occupied by light or southerly anomaly-winds, ICES 2000.

West Greenland lies within the area, which normally experiences cool conditions when the NAO index is positive. However, although the NAO index has been positive since 1996 and in the winter 1999/2000 recovered to the level of extreme positive values experienced in the early-1980s and especially in the early-1990s, conditions around Greenland remained warm. In 2000 the annual mean air temperature in Nuuk was –0.80°C, which is 1.03°C above normal, Fig. 2. This confirms the above-mentioned anomalous NAO pattern over the area.

Changes in the ocean climate in the waters off West Greenland generally follow those of the air temperatures. The relatively mild atmospheric conditions are reflected in the mean temperature on top of Fylla Bank in the middle of June, Fig. 3.

The 2000 temperature value (T = 2.45°C) is the fifth highest temperature observed since the start of the time series in 1950, and thereby also well above the average value of 1.67°C for the whole 50-year period

## 2. Measurements

The 2000 cruise was carried out according to the agreement between the Greenland Institute of Natural Resources and Danish Meteorological Institute during the period June 29-July 10, 2000 onboard the Danish naval ship **"TULUGAQ".** Observations was performed on the following stations (see also Fig. 4):

- Cape Farewell St. 1 - 5
- Cape Desolation St. 1 - 5
- Frederikshaab St. 1- 5
- Fylla Bank St. 1- 5
- Lille Hellefiske Bank St. 1 - 5
- Holsteinsborg St. 1 - 5

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 750 m was the maximum depth of observation.

The cruise was blessed with favourable weather and ice conditions. "Vestice" was not present at the Holsteinsborg section. Close to Cape Farewell "Storis" was present, Fig. 5; but fortunately not in quantities preventing the measuring program being carried out.

## 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 sensor of the CTD, water samples were taken at great depth on stations with depths greater than 500 m. The water samples were after the cruise analysed on a Guildline Portosal 8410 salinometer.

The CTD data were analysed using SEASOFT 4.217 software provided by SEABIRD.

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

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

## 4. Oceanographic Conditions off West Greenland in 2000

The surface temperatures and salinity's observed during the 2000 cruise are shown in Fig. 6. The cold and low salinity conditions observed off Southwest Greenland reflect the inflow of Polar Water carried to the area by the East Greenland Current. Water of Atlantic origin (T> 3°C; S> 34.5 psu) is found at the surface only at the three outermost stations on the Cape Farewell Section.

The sea surface temperatures are generally higher in 2000 compared to 1999 in the entire area with temperatures well above 5°C in certain regions.

The 2000 mean salinity value (33.32 psu) on top of Fylla Bank (Fig. 7) was slightly lower than in 1999, and below the average value of 33.40 psu.

Time series of the temperature and salinity conditions west of the Fylla Bank (Fylla Bank St. 4) at various depth intervals are presented in Fig. 8 a, b. The surface conditions as described above are also seen at this station. More interestingly it shall be noted that in 2000 a decrease in temperature as well as salinity compared to the previous years was observed at intermediate depth (the 50-150m and 150-400 m intervals). These two depth intervals are the domain of the Polar Water along the Southwest Greenland fishing banks. The relatively low temperature and salinity values therefore indicate increased inflow of polar water in 2000, which also can be seen in the vertical section plots displayed in Fig. 10-17.

At great depth (400-600 m) a relatively large decrease in temperature was observed in 2000 together with a slight decrease in salinity. This indicates that only Northwest Atlantic Mode Water was present at Fylla Bank in July 2000, which also can be seen in Fig. 14.

The vertical distribution of temperature, salinity and density as well as TS-relations at sections along the West Greenland coastline is given in Fig. 10-22. In addition to data from the six standard sections obtained during the TULUGAQ cruise in early-July, data from Fylla Bank in May and medio July are also presented together with data from the Disko Bay and further north obtained during the R/V PAAMIUT cruise in August.

In the surface layer relatively strong gradients between the cold, low-saline Polar Water and the warm, high-saline water of Atlantic origin was observed from Frederikshaab and southward. From Fylla Bank and northward the core of Polar Water was observed just west of the banks a depth of 50-150 m.

The development in time of the temperature and salinity conditions at Fylla Bank can be se seen in Fig. 13-15. Medio May rather cold conditions are found in the upper 150-200 m due to winter cooling. In July the surface temperatures has increased due to atmospheric heating; but the inflow of Polar Water dominates the 50-150 m depth interval just west of the bank.

At Egedesminde and northwards a cold layer is found between approximately 25 and 150 m with extreme low temperatures at around 100 m. This cold water most likely is Polar Water transported to the West Greenland waters by a side branch of the southward flowing Baffin Current.

Temperature and salinity observations at greater depth showed that pure Irminger Water ($T \sim 4.5^{o}C$, $S > 34.95$ psu) was not present in the area during the summer of 2000 – not even at the southernmost section at Cape Farewell. Modified Irminger Water ($34.88 < S < 34.95$) was, however, present in great quantities and was observed as far north as to the region between Little Hellefiske Bank and the Holsteinsborg section.

Northwest Atlantic Mode Water ($3.5 < T < 4.5$; $34.5 < S < 34.88$) was observed at all sections from Cape Farewell to Nugssuaq.

## 5. Model Simulations

The Danish Meteorological Institute has set-up a 3D-ocean model for the Greenland Waters using the linear harmonic model Fundy (Lynch and Werner, 1987; Greenberg *et al.*, 1998). The main purpose of this model implementation is the production of ocean forcing fields to the Institutes operational ice forecasting model (Kliem, 2000). The model is, however, well suited for calculations current fields, temperature and salinity fields as well as drift patterns of passive objects like plankton, fish eggs etc.

Based on the temperature and salinity observations from the TULUGAQ cruise in July 2000 the current field along the west coast of Greenland has been calculated, Fig. 9.

The model simulation reflects the main features of the ocean circulation in the West Greenland area. The northward flow along the coast with strong currents in the southern part, the deflection towards the west around 64–65°N. It is of special interest to note the large-scale eddy north 66°N transporting cold Polar Water from the

Baffin Current towards West Greenland, since – as discussed above- this cold water was observed at the Egedesminde Section and further north in August 2000, Fig. 18; 21-22.

## 6. Conclusions

The oceanographic conditions off West Greenland during the summer 2000 was characterised by:

- High surface temperatures due to mild atmospheric conditions.
- Relatively high inflow of Polar Water.
- Pure Irminger Water was absent even in the Cape Farewell region

## References

GREENBERG, D. A., F. E. WERNER, and D. R. LYNCH. 1998. A diagnostic finite-element ocean circulation model in sperical-polar coordinates. *J. Atmos. Ocean. Technol*., **15**: 942-958.

ICES. 2000. The 1999/2000 ICES Annual Ocean Climate Status Summary. Prepared by the Working Group on Oceanic Hydrography. Editor: Bill Turrell. (http://www.ices.dk/status/clim9900/)

JONES P. D., T. JONSSON, and D. WHEELER. 1997. Extension to the North Atlantic Oscillation using early instrumental pressure observations from Gibraltar and South-West Iceland. *Int. J. Climatol*., **17**: 1433-1450.

KLIEM, N. 2000. A sea ice forecasting system for the Cape Farewell area. *DMI Tech. Report* 00-28.

LYNCH, D. R., and F. E.WERNER. 1987. Three-dimensional hydrodynamics on finite elements, Part I: Linearized harmonic model. *Int. J. Numer. Methods Fluids*, **7**: 871-909.

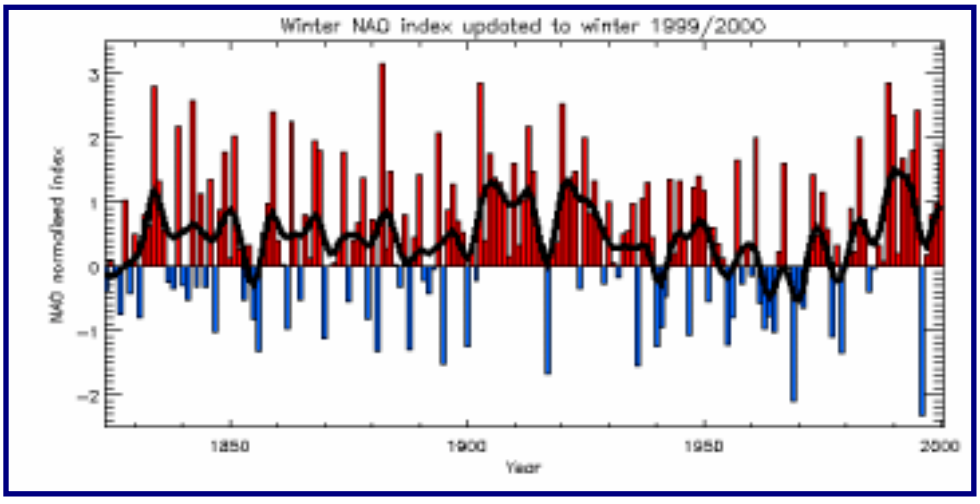



Fig. 1. Time series of the winter NAO (December to March average). After Jones *et al.* (1997) updated to the winter 1999/2000.

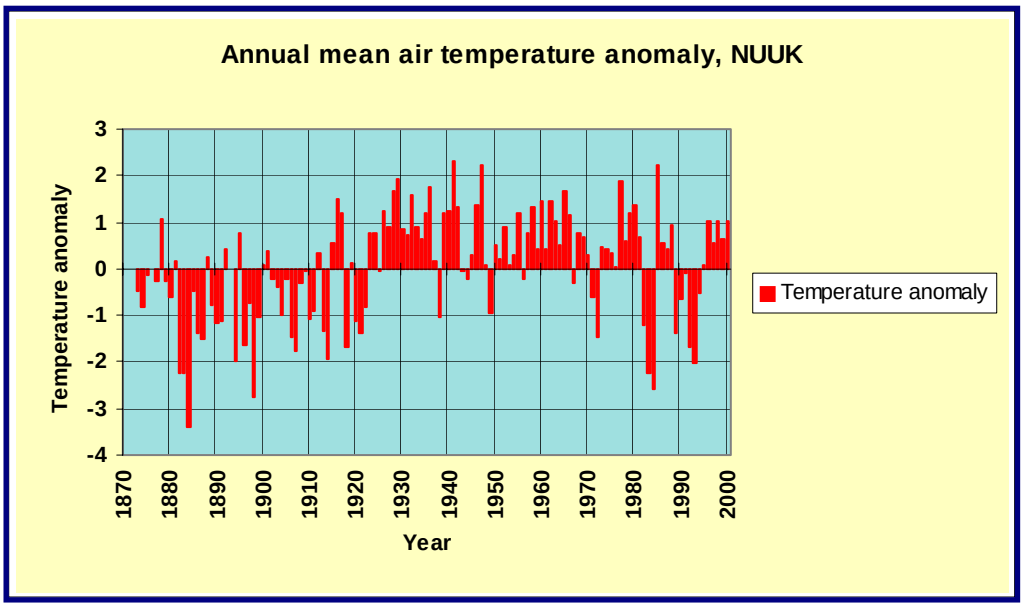



Fig. 2. Anomaly in the annual mean air temperature observed at NUUK for the period 1873 to 2000. (The anomaly is taken relative to the mean temperature for the whole period).

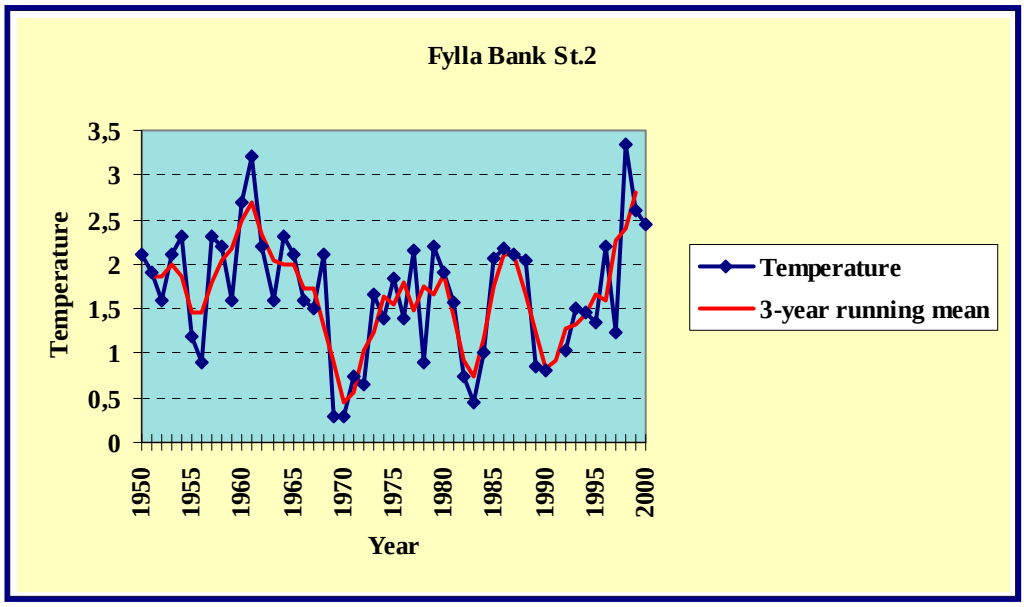



Fig. 3. Time series of mean temperature (observations and 3-year running mean) on top of Fylla Bank (0-40 m) in the middle of June.

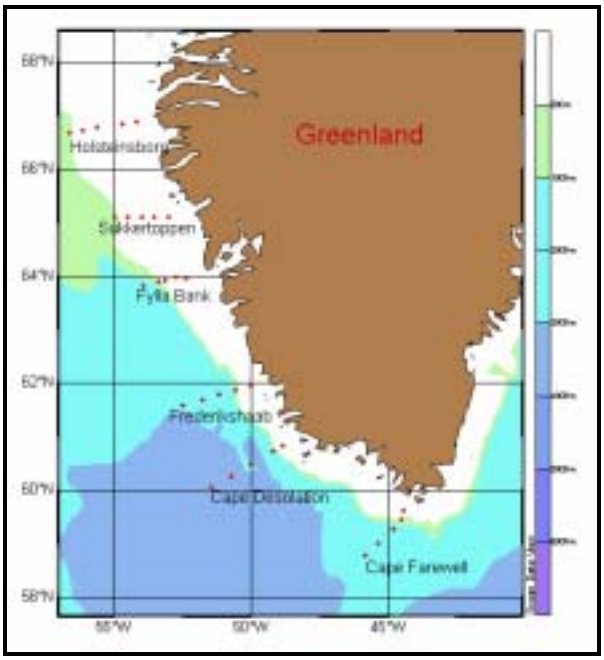



Fig. 4. Position of the standard sections off West Greenland.

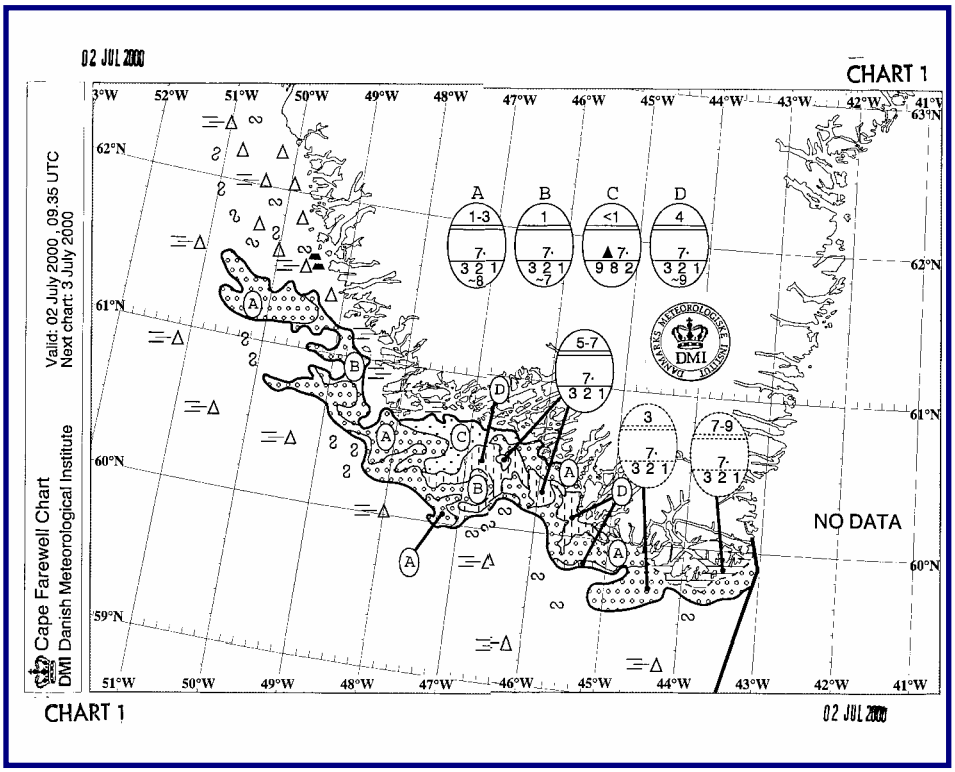



Fig. 5. Distribution of sea ice in the Cape Farewell region July 2, 2000.

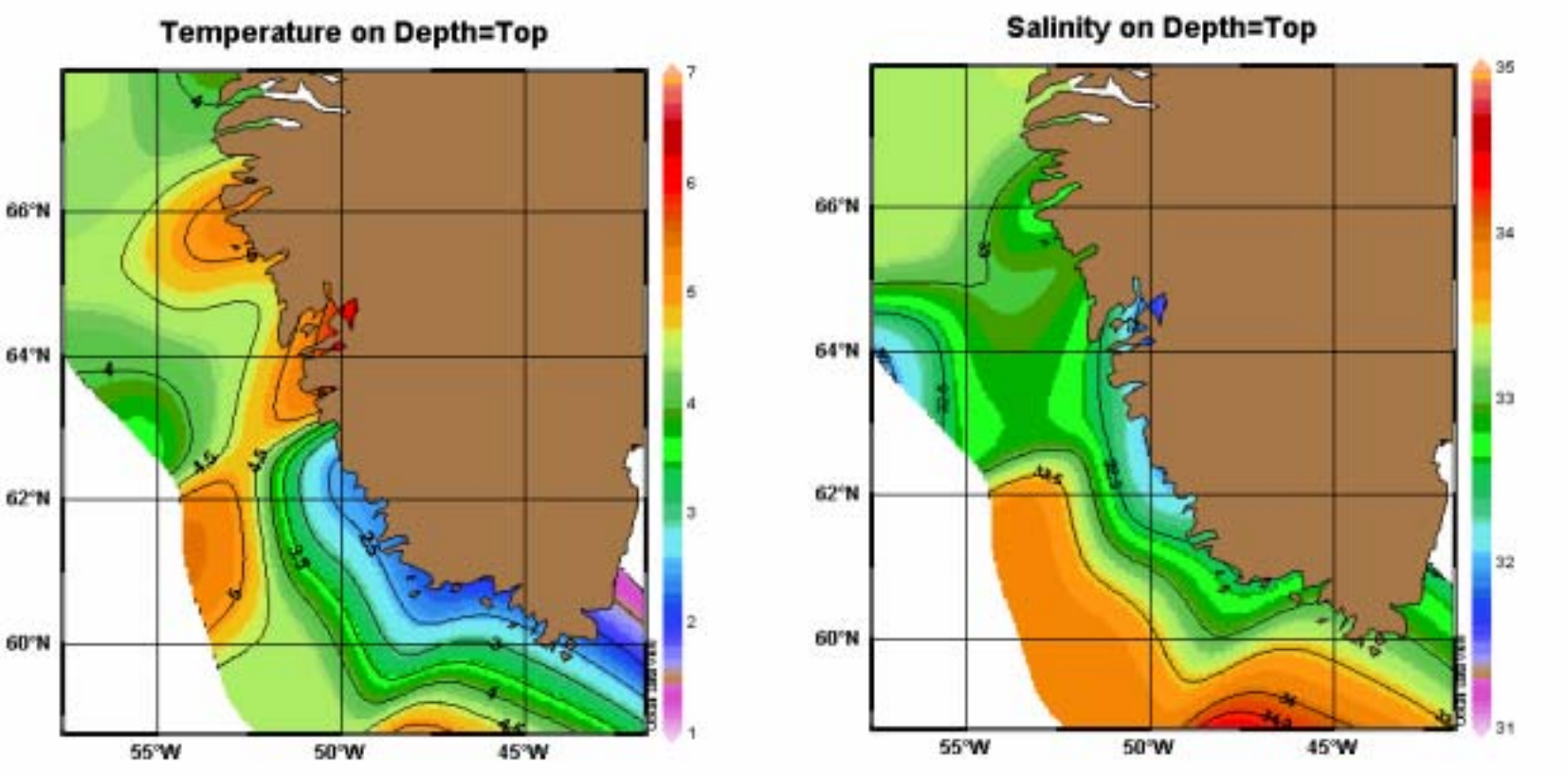



Fig. 6. Surface temperature and salinity, July 2000.

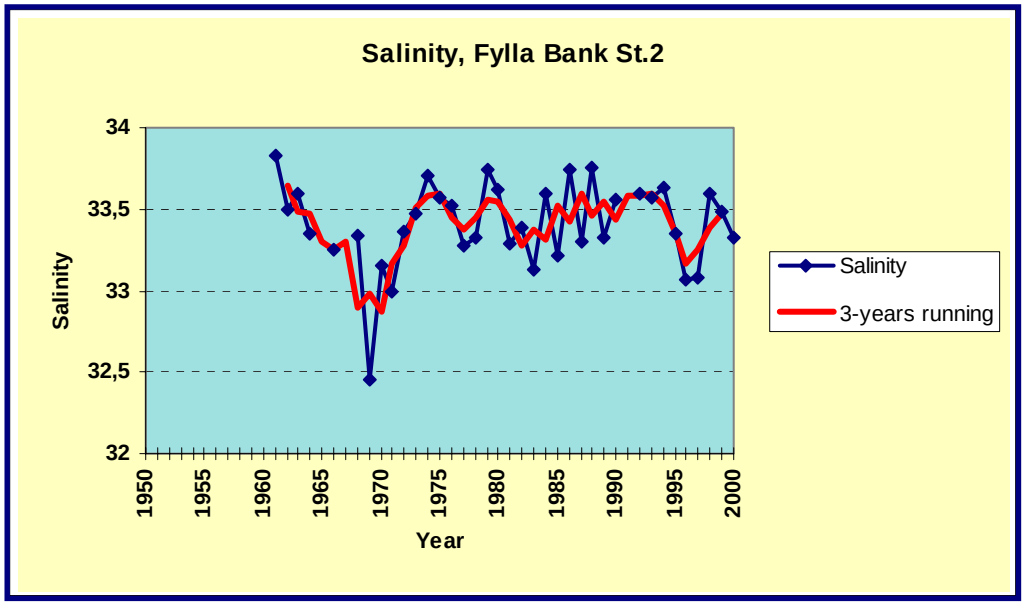
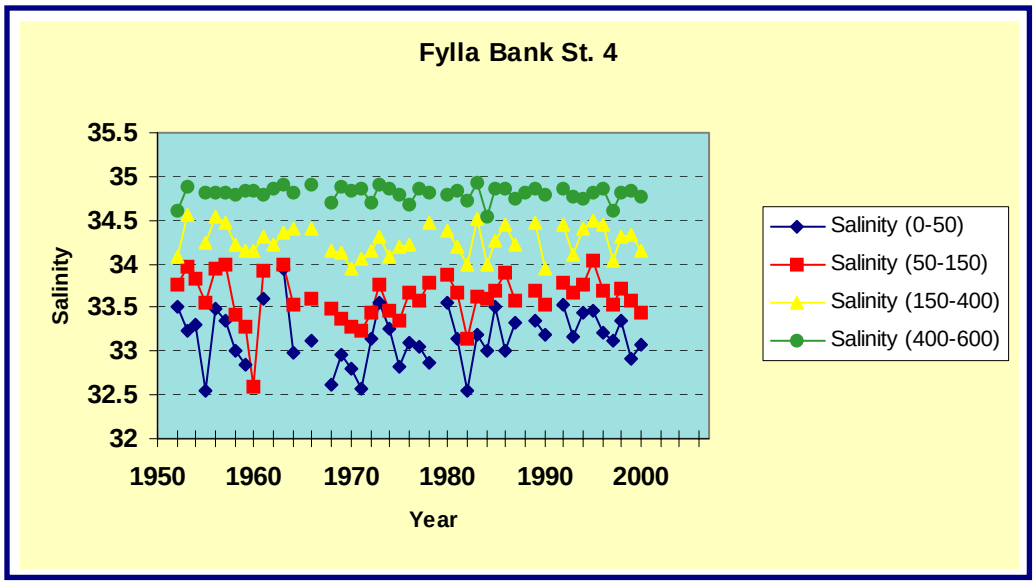



Fig. 7. Time-series of the mean salinity (observations and 3-year running mean) on top Fylla Bank (0-40m) in the middle of June.

a)




b)

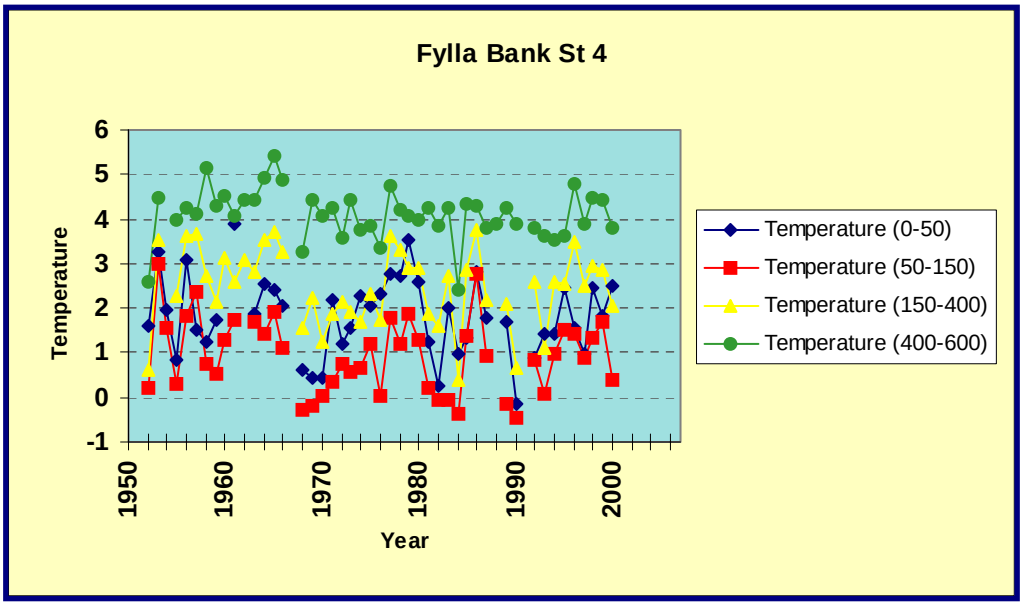



Fig. 8. Time-series of: a) mean temperature, and b) mean salinity in four depth intervals at Fylla Bank St. 4, primo July.

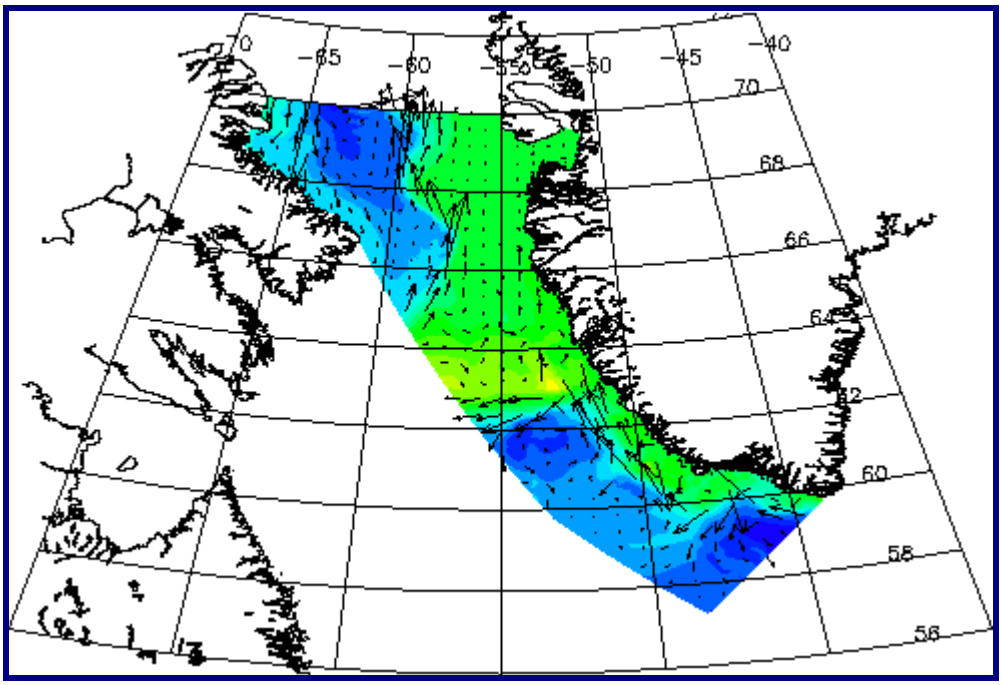



Fig. 9. Surface currents along the west coast of Greenland, first week of July 2000. The colour coding represents the surface elevation.

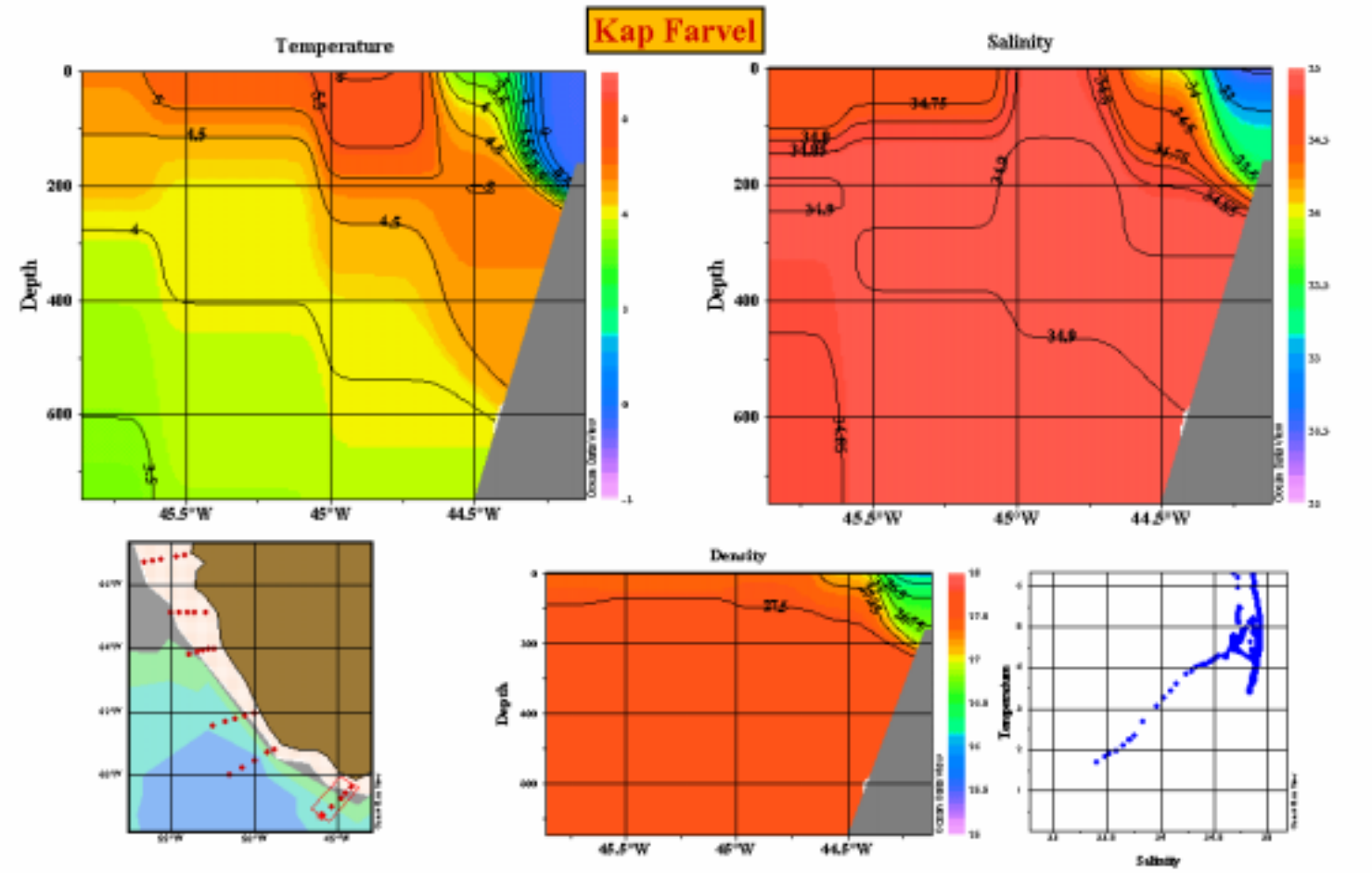



Fig. 10. Vertical distribution of temperature, salinity and density at the Cape Farewell section, June 29, 2000.

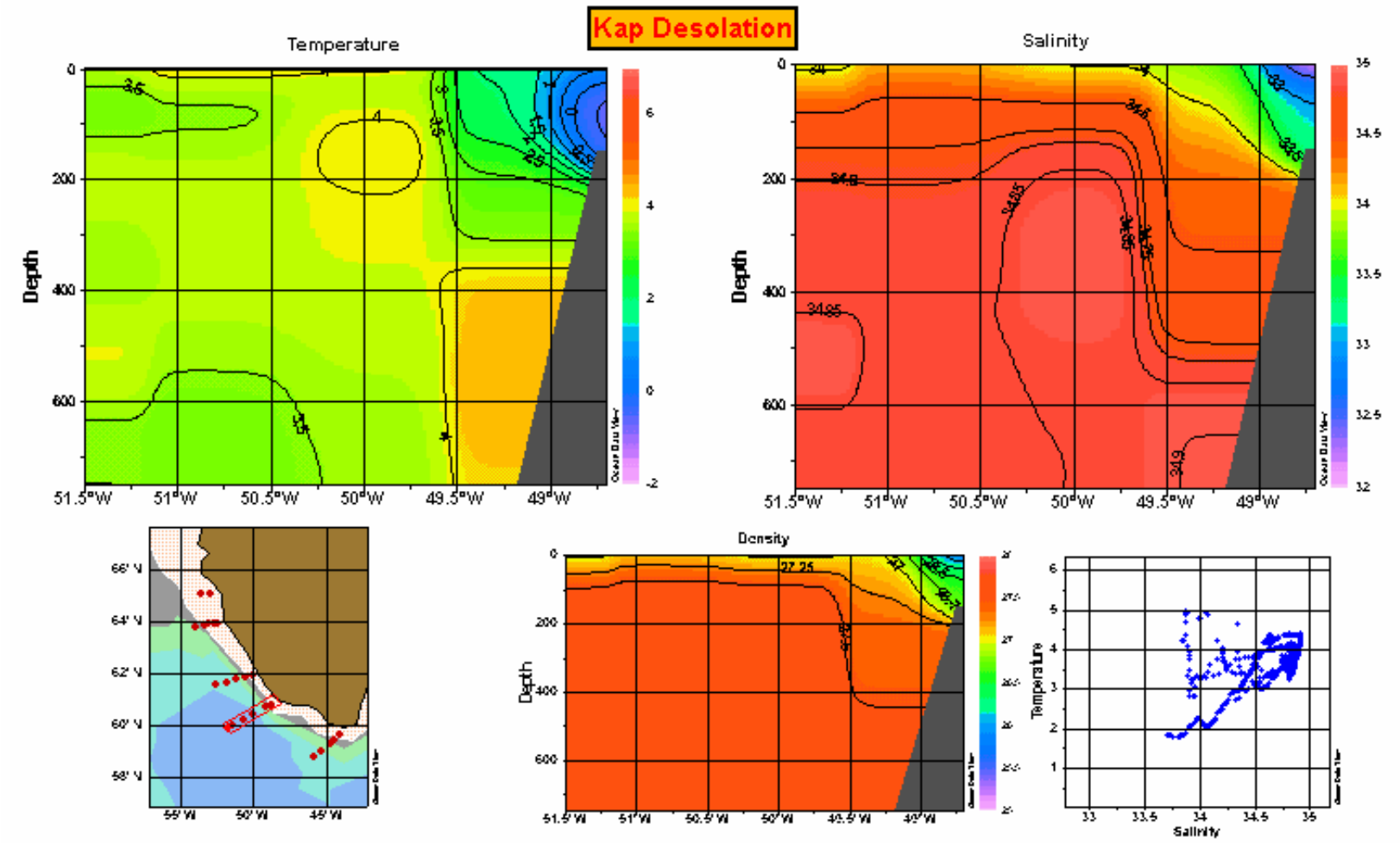



Fig. 11. Vertical distribution of temperature, salinity and density at the Cape Desolation Section, July 1, 2000.

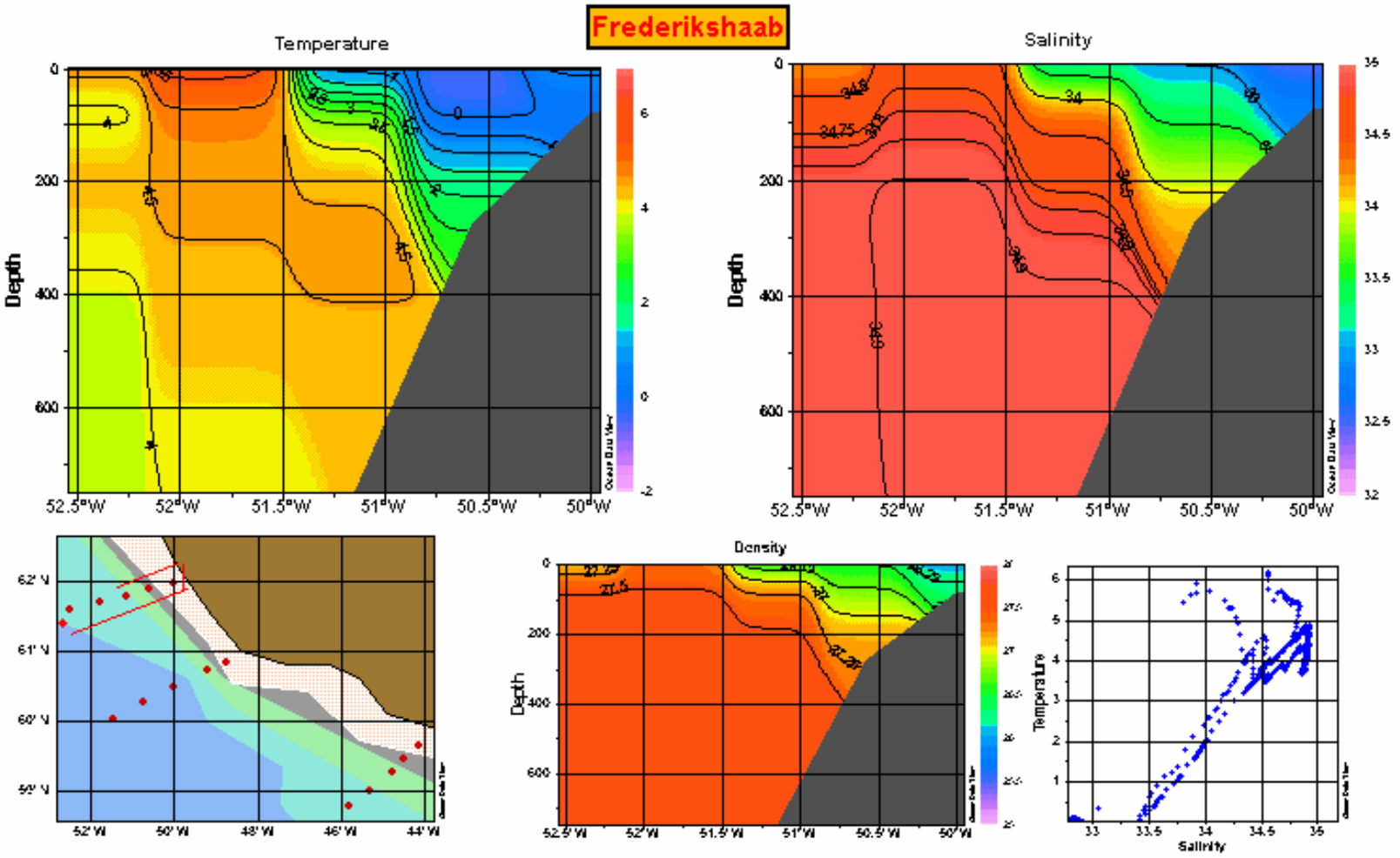



Fig. 12. Vertical distribution of temperature, salinity and density at the Frederikshaab Section, July 4, 2000.

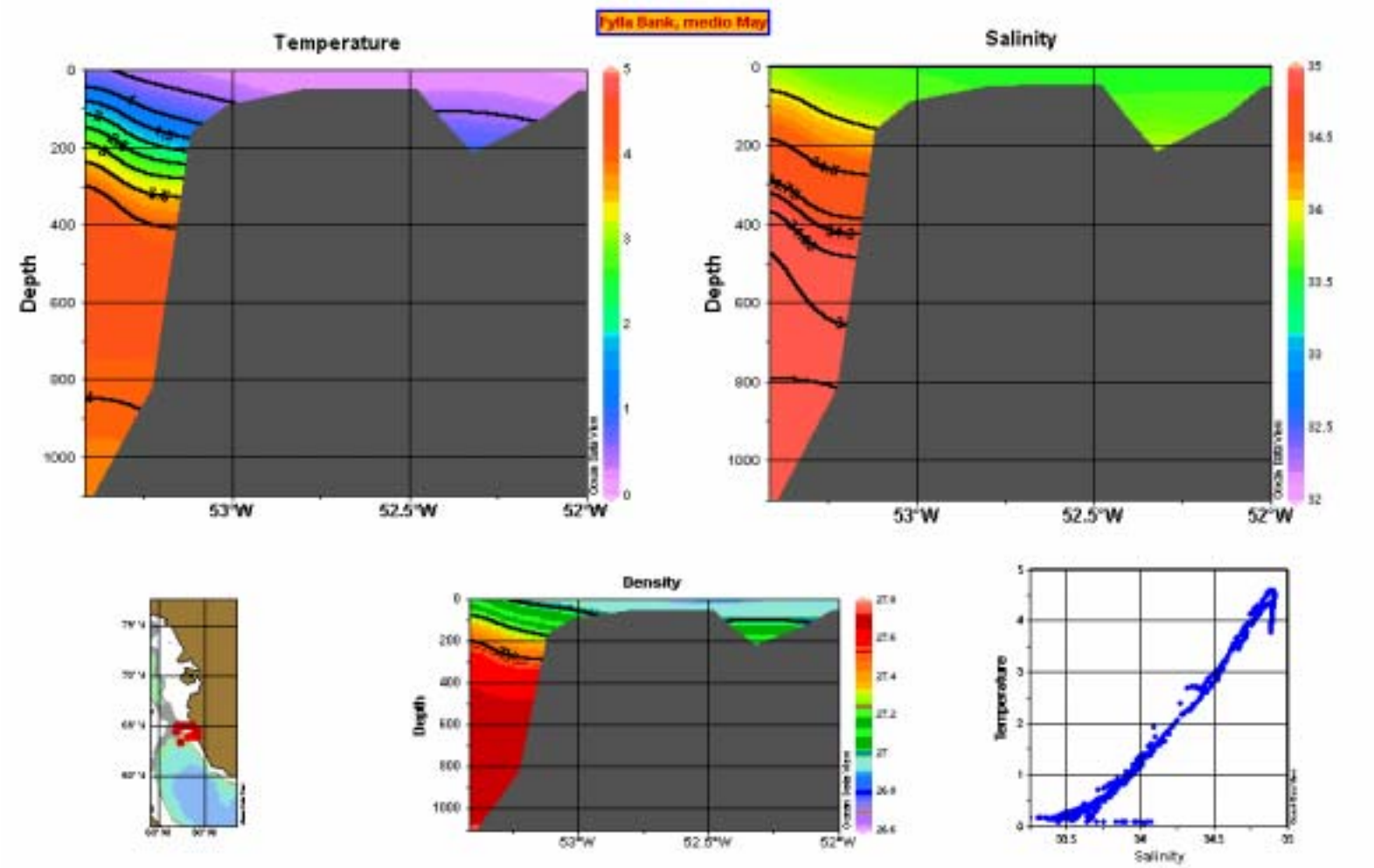



Fig. 13. Vertical distribution of temperature, salinity and density at the Fylla Bank Section, May 12, 2000.

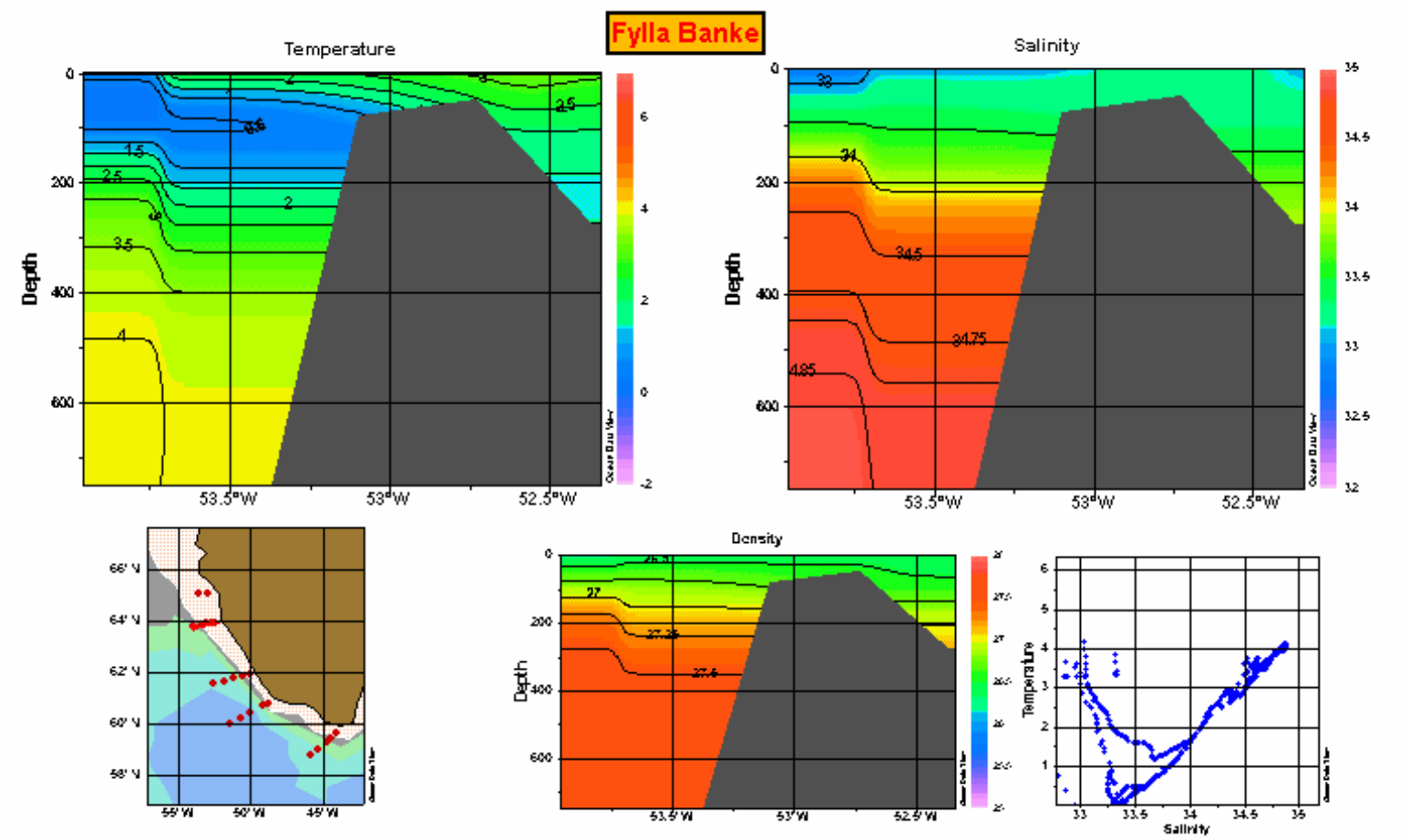



Fig. 14. Vertical distribution of temperature, salinity and density at the Fylla Bank Section, July 9, 2000.

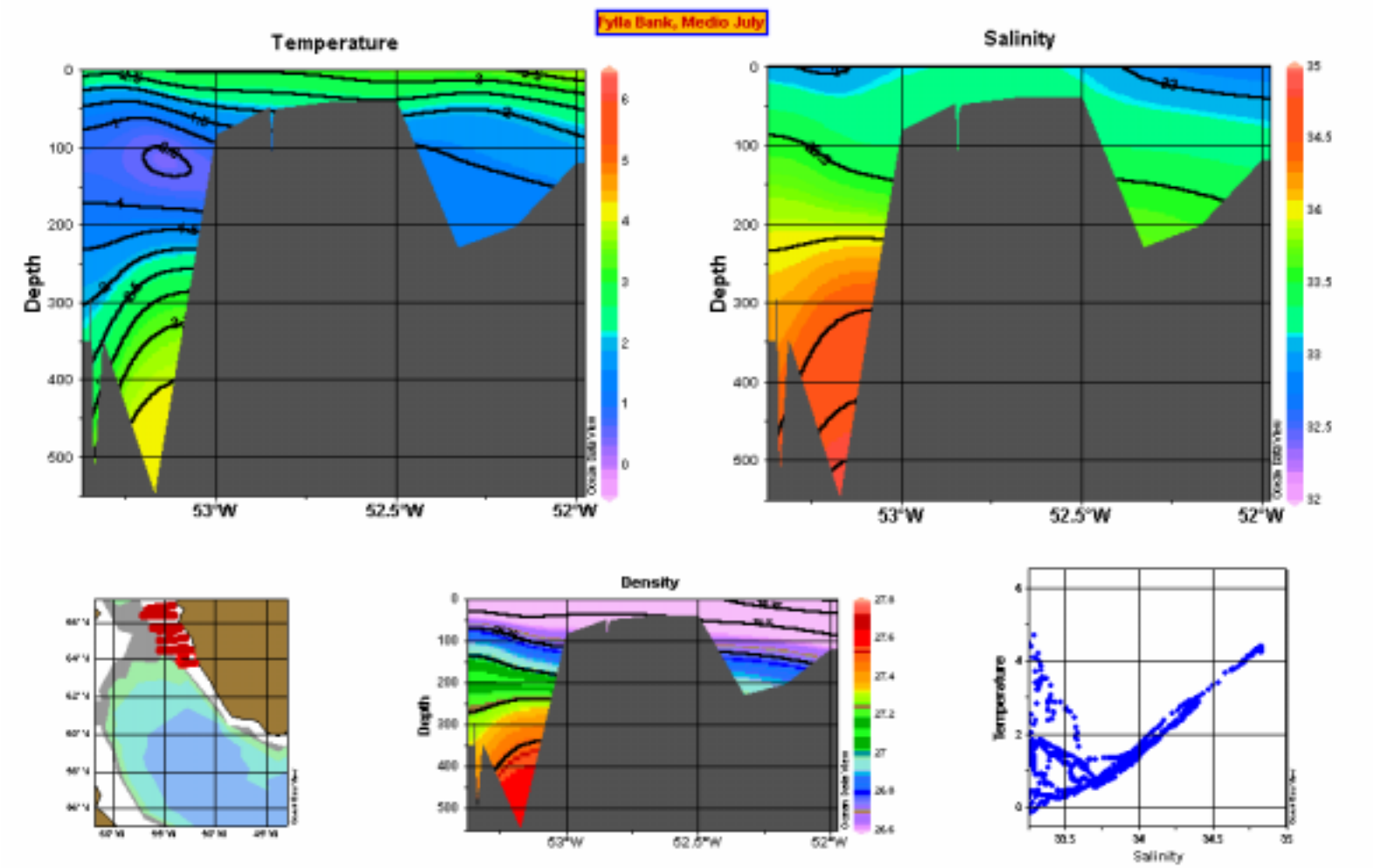



Fig. 15. Vertical distribution of temperature, salinity and density at the Fylla Bank Section, July 15, 2000.

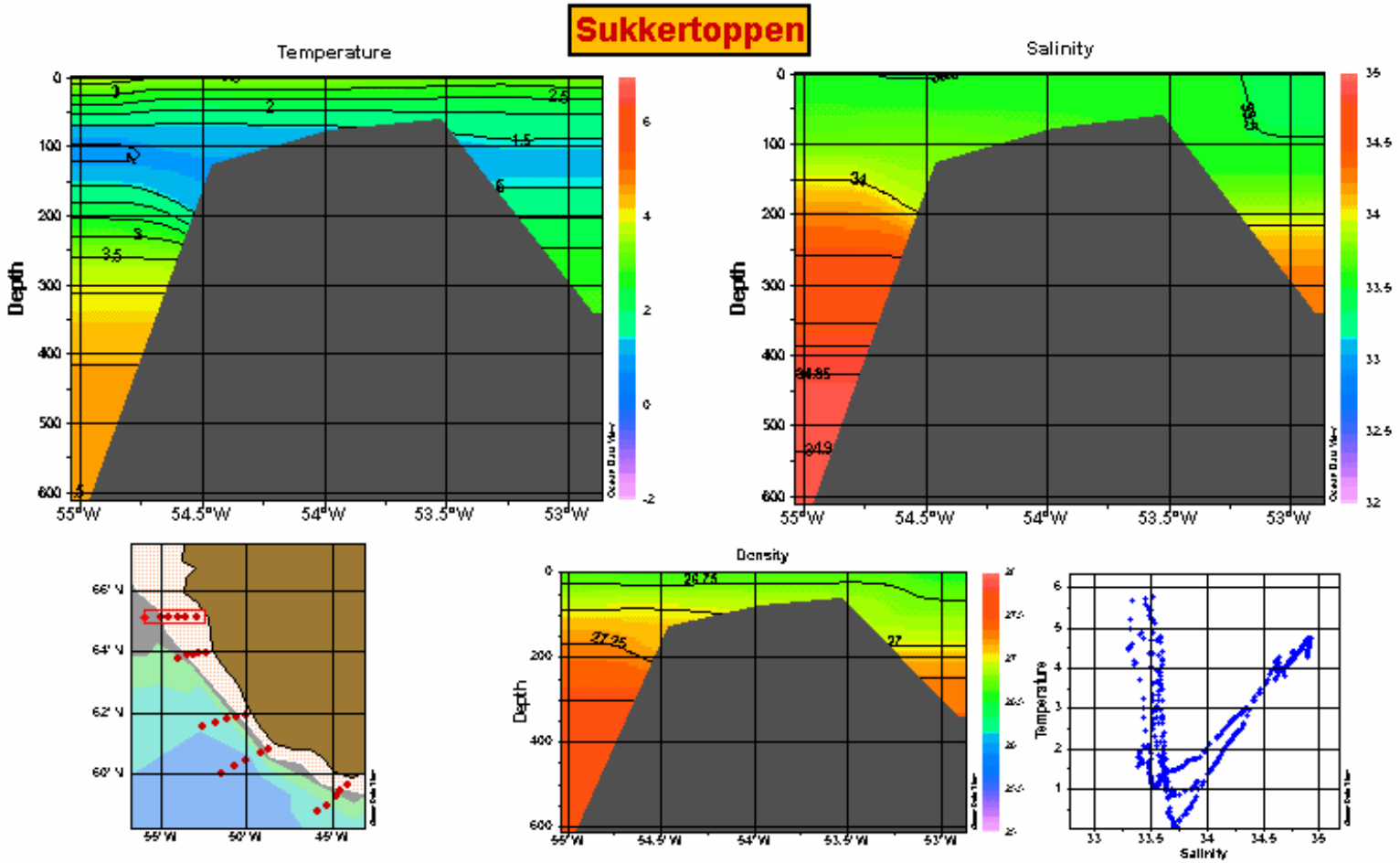



Fig. 16. Vertical distribution of temperature, salinity and density at the Lille Hellefiske Bank Section, July 9, 2000.

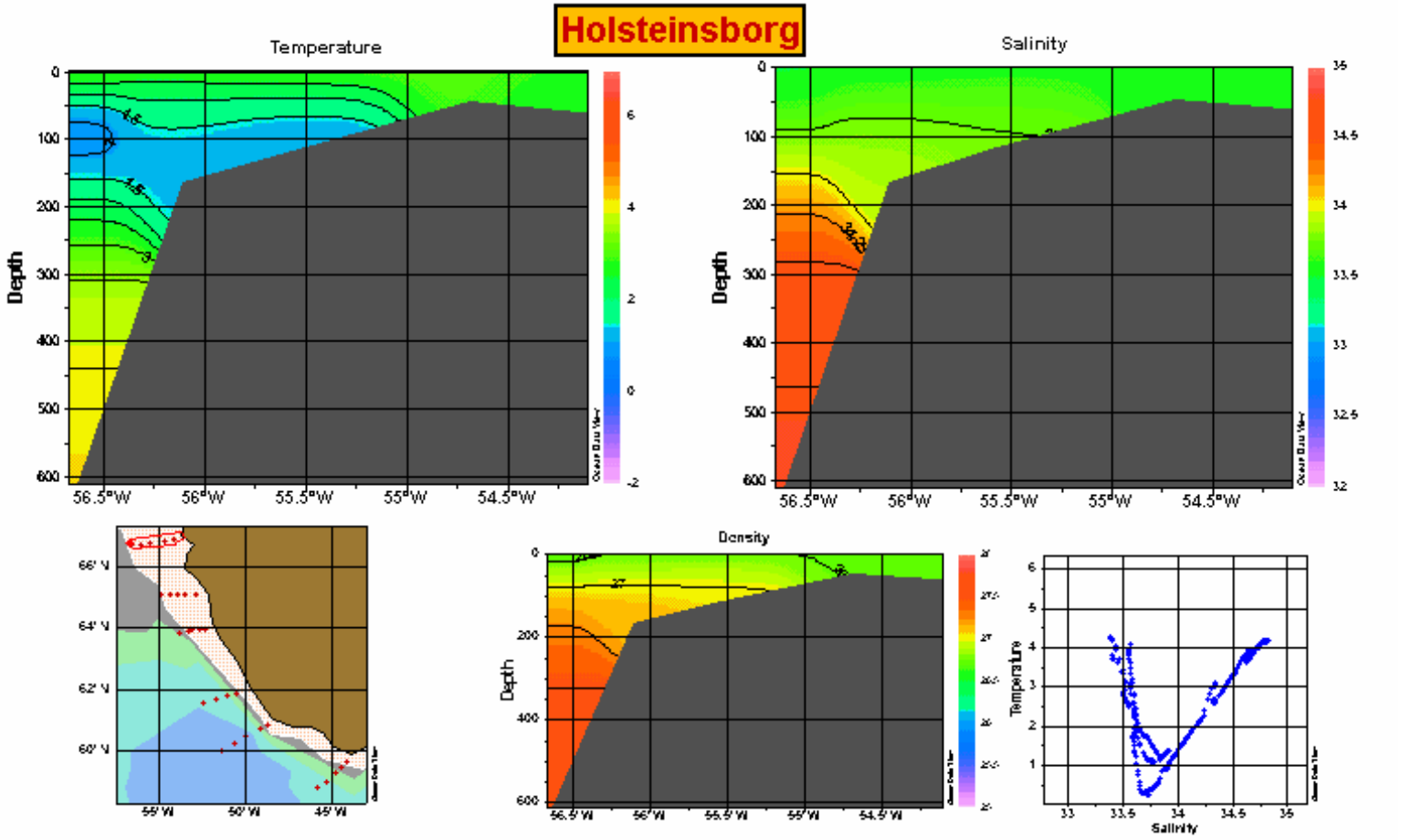



Fig. 17. Vertical distribution of temperature, salinity and density at the Holsteinsborg Section, July 10, 2000

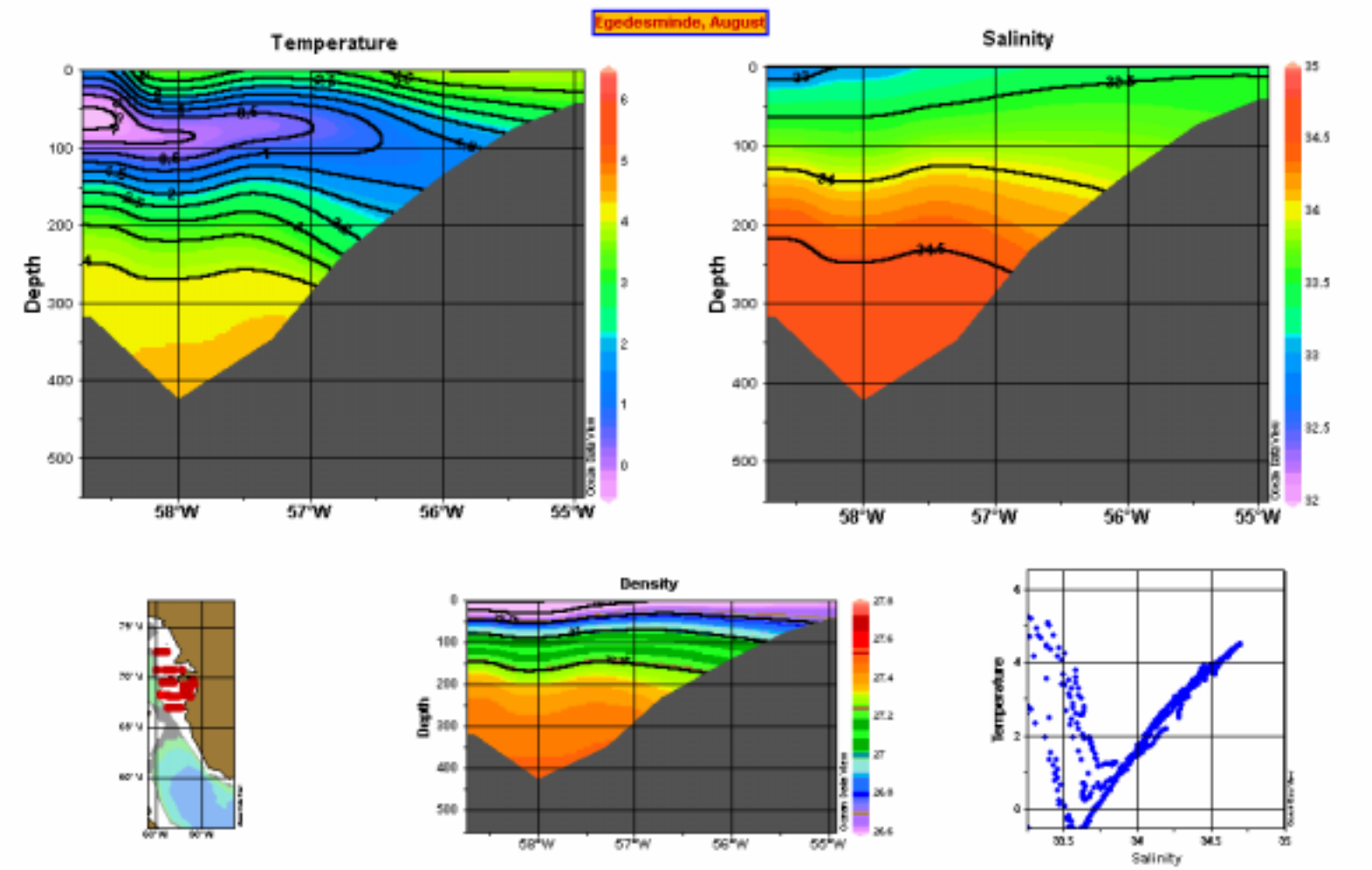



Fig. 18. Vertical distribution of temperature, salinity and density at the Egedesminde Section, August 6, 2000

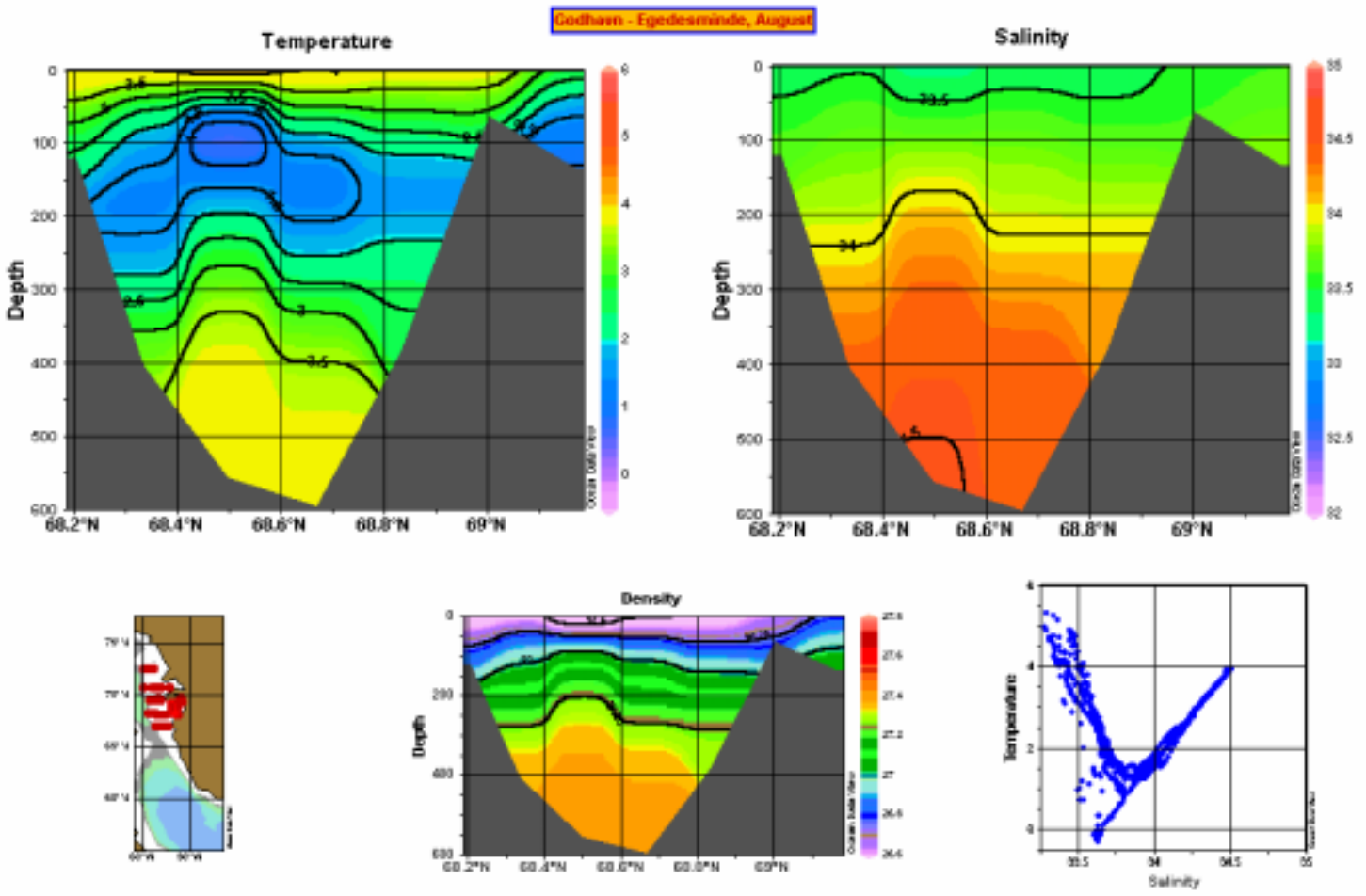



Fig. 19. Vertical distribution of temperature, salinity and density at the Godhavn-Egedesminde Section, August 14, 2000

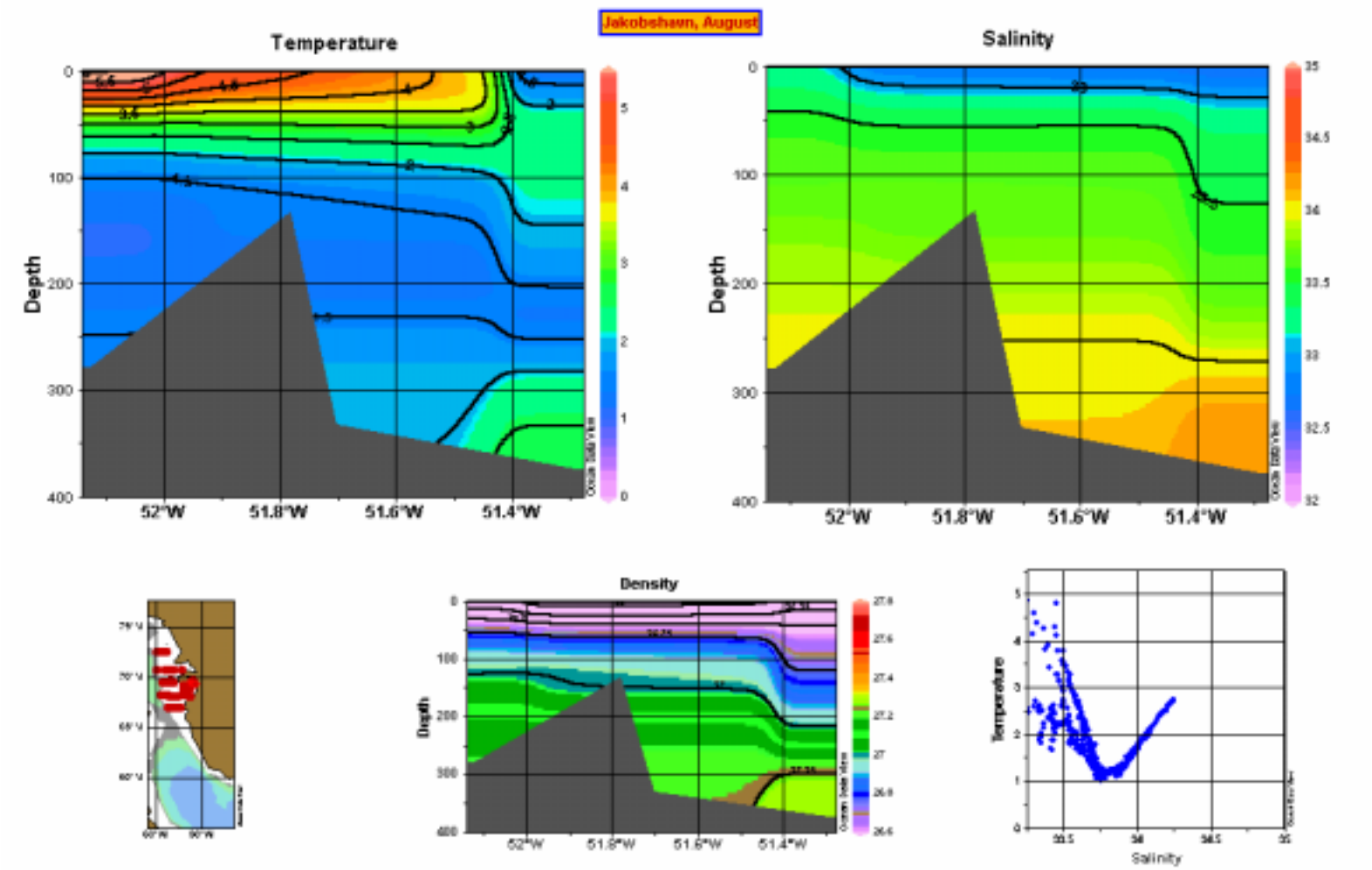



Fig. 20. Vertical distribution of temperature, salinity and density at the Jakobshavn Section, August 24, 2000

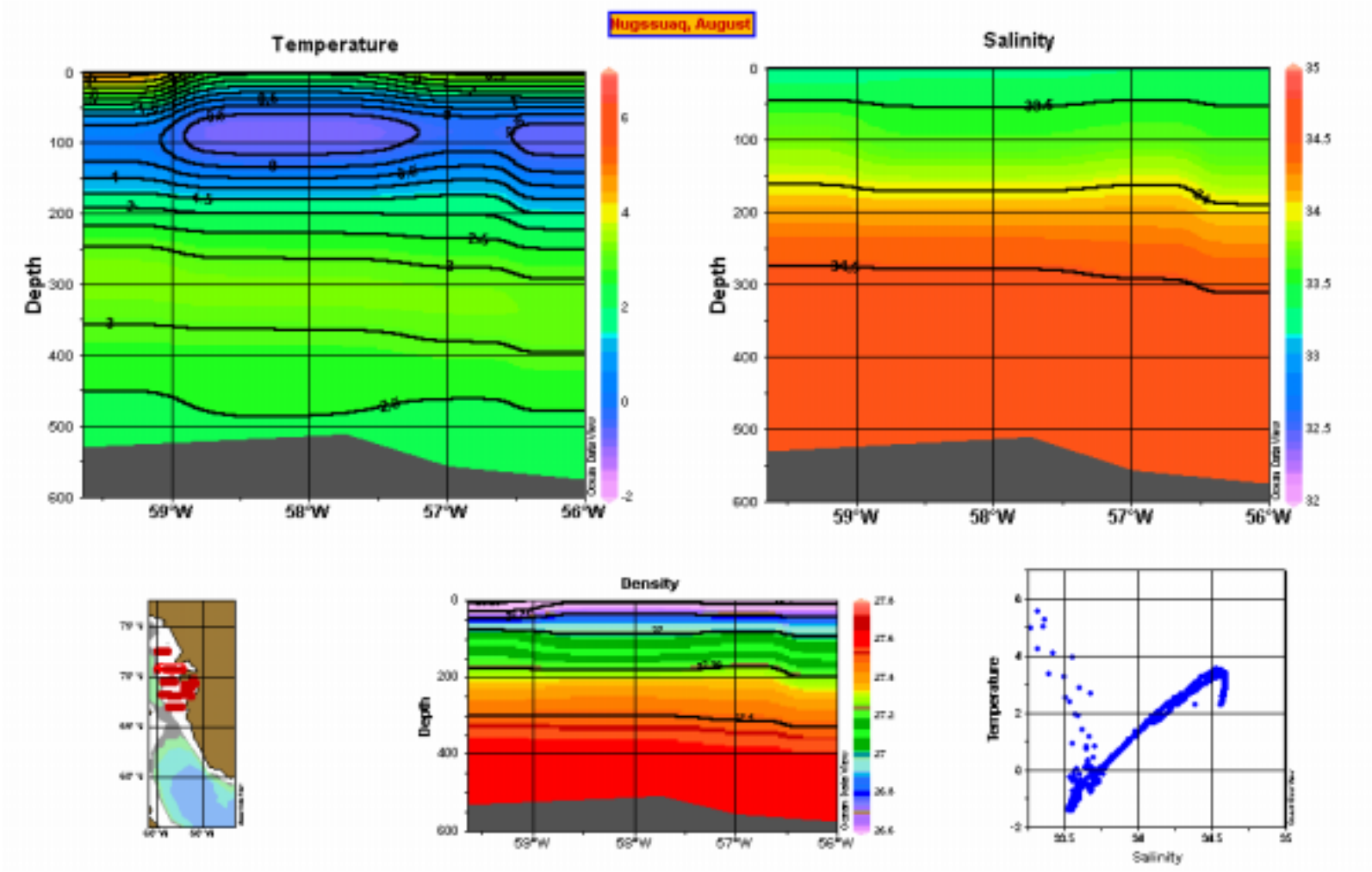



Fig. 21. Vertical distribution of temperature, salinity and density at the Nugssuaq Section, August 20, 2000

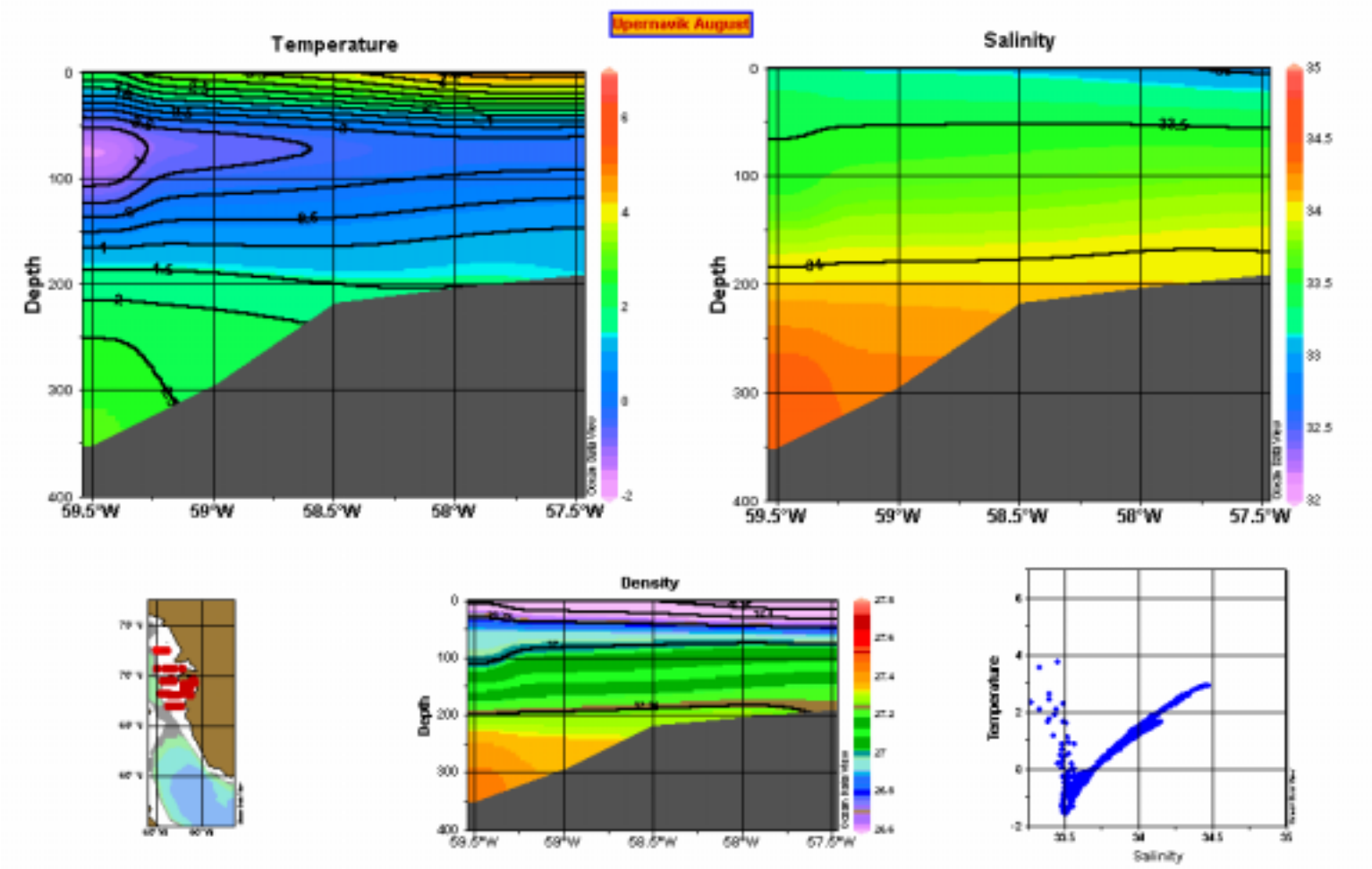



Fig. 22. Vertical distribution of temperature, salinity and density at the Upernavik Section, August 19, 2000