NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N981

NAFO SCR Doc. 85/31

SCIENTIFIC COUNCIL MEETING - JUNE 1985

On the Distribution of Labrador Sea Water

by

M. Stein

Bundesforschungsanstalt für Fischerei
Institut für Seefischerei
Palmaille 9, D-2000 Hamburg 50
Federal Republic Germany

Introduction

Labrador Sea Water (LSW) obtains its characteristics by convective formation in the central Labrador Sea (Lee and Ellett, 1967; Lazier, 1973, Talley and McCartney, 1982; Clarke and Gascard, 1983; Gascard and Clarke, 1983). Low-salinity and high oxygen content are typical of this water mass which is found at mid-depth north of 40°N in the North Atlantic Ocean. The definitions of LSW range from 3°C to 4°C and fresher than $34.94*10^{-3}$ (Wright and Worthington, 1970), to potential density less than σ_θ=27.8 (Lazier, 1973) and 3.4°C, $34.88*10^{-3}$ (Talley and McCartney, 1982). The formation processes on the large, meso- and smaller-scale are analysed by Clarke and Gascard (1983), and Gascard and Clarke (1983). They hypothesized that a 200km scale cyclonic gyre forms in winter in the western Labrador Sea and that this gyre retains the developing deep mixed layers in this area long enough for the transformation to Labrador Sea water to take place. The advection of Labrador Sea water out of the Labrador Sea is decribed in detail by Talley and McCartney (1982), using a vertical minimum in potential vorticity as the primary tracer for this water mass.

On the basis of recently collected CTD/Rosette data along the Seal Island-Cape Farewell Section across the Labrador Sea the thermohaline stratification of this area is discussed. Similar to Talley and McCartney (1982) a "theoretical" tracer is used to identifiy the LSW.

Data and Methods

Between November 6, 1984 0.31 GMT and November 8, 1984 14.36 GMT R/V "Walther Herwig" completed CTD/Rosette stations 106 to 123 within the framework of her oceanographic cruise to East- and West Greenland (fig.1). The hydrographic fields were mapped using the KIEL-Multisonde CTD plus Rosette water sampler. Calibration samples were collected at each station, in the central Labrador Sea additionally samples for oxygen determination (Winkler method) were sampled. The CTD was equipped with a bottom sensor.

According to this sensor the CTD was lowered down to 5m above the bottom. At this depth the bottom water samples were collected. While heaving, the CTD/Rosette device was stopped in 500 dbar intervals for calibration and oxygen probes (fig. 3). The temperature readings were checked against reversing thermometers, salinity was determined by means of a Guildline laboratory salinometer.

Talley and McCartney (1982) use the potential vorticity $\left[(f/\varrho)(\delta\varrho/\delta z)\right]$ to identify the LSW. In the present paper the potential density gradient is used to identify this water mass. Assuming that a convectively renewed water mass is outstanding by its vertical homogeneity relative to the waters layers above and below it, min $(\delta\varrho/\delta z)$ is a means to locate convectively formed layers at individual stations. Comparison with Talley and McCartney's data can be achieved simply. Their vertical section of potential vorticity is in units of 10^{-14} cm^{-1} sec^{-1}, fig. 5 of the present paper displays potential density gradients in units 10^{-10} g cm^{-4}. f/ϱ is of the order of $1.12*10^{-4}$ sec^{-1} $g^{-1}cm^{3}$ (at 50°N; not $1.17*10^{-14}$ as printed in Talley and McCartney's paper). For the Seal Island-Cape Farewell section this term is $1.17*10^{-4}$ (f is the Coriolis parameter).

Results and Discussion

On the western side of the section, between stations 106 and 111 the cold and fresh component of the Labrador Current emerges from the thermohaline field (figs. 2,3).

Being colder than -1.0°C on Hamilton Bank the polar portion of this current reflects the 20% of the Labrador Current origination from Baffin Bay as the Baffin Island or Canadian Current (Lazier, 1982). Centered over the 600-800m isobath on the slope (stations 112, 113) about 80% of the current flow are concentrated representing the warm and haline waters arising from the Irminger Current. Off west Greenland the Irminger component of the west Greenland Current is visible by its strongly expressed thermohaline signals (east of station 120). Between these two currents the vast area of the Labrador Sea inhabits about 500km of the section. At depths of 2000m the pronounced halocline separates the low-salinity LSW with salinities slightly less than $34.84*10^{-3}$ and the saline low oxygen layers of the North Atlantic Deep Water, with salinities larger than $34.94*10^{-3}$, oxygen around 6.6ml l^{-1} (fig.3). The undermost storey of the water column is inhabited by the Denmark Strait overflow water flowing around the basin of the Labrador Sea. The oxygen content of this water is higher on the Greenland side than on the Labrador side. In a recent paper Swift (1984) explains the Northwest Atlantic Bottom water being derived in large part from the Denmark Strait overflow. He defines this water mass θ,S-characteristcs near 1°C and salinities near $34.9*10^{-3}$. According to Mann (1969) the Denmark Strait overflow water moving well down the east coast of Greenland towards Cape Farewell has changed its θ,S-charcteristics due to mixing with water above it. The overflow water in this area is very uniform. Examination of the temperature and salinity sections shows that the θ,S-charcteristics are less than 2.0°C, $34.92*10^{-3}$ and a considerable amount of water has a salinity less than $34.90*10^{-3}$. The observed salinities of this slope trapped boundary current were found to range from $34.887*10^{-3}$ to $34.894*10^{-3}$. The "new" overflow water entering the Labrador Sea at its eastern slope yields oxygen values up to 7.03 ml 1^{-1}, whereas the "old" overflow water after having done its cyclonic path along the Labrador basin suffers from oxygen consumption and leaves the Labrador Sea with oxygen values as low as 6.84 ml 1^{-1}. This is consistent with the oxygen values given by Swift (1984) for the deep layers of the Labrador Sea.

Except the deep layers below 2500m and within the upper 200m the central portion of the Seal Island - Cape Farewell Section consists of nearly homogenous water. Temperatures vary only slightly between 3.56°C and 2.89°C, salinities range from $34.80*10^{-3}$ to $34.84*10^{-3}$ (station 117). Relatively high oxygen contents (6.94 $ml*l^{-1}$ to 7.05 $ml*l^{-1}$) within the domain of the low-salinity LSW water result from more recent contact of the LSW with the sea surface compared with layers governed by the North Atlantic Deep Water (fig.3). As mentioned above the exceptional vertical homogeneity of this huge water layer relative to waters above and below it, plus the high oxygen content indicate convectively renewed water masses. For closer inspection the vertical density gradient was calculated for the density range $27.70 < \sigma_\theta < 27.90$. Fig. 5 displays the results of these calculations. Areas of $\delta\rho/\delta z$ less than $2*10^{-10}$g cm^{-4}, $5*10^{-10}$g cm^{-4} and $10*10^{-10}$g cm^{-4} are marked especially. Whereas the $10*10^{-10}$g cm^{-4} line depicts the domain of the North Atlantic Deep Water plus θ,S - gradient layers, the $5*10^{-10}$g cm^{-4} line encompasses the salinity minimum, oxygen maximum layer. Within the scope of this line two salient areas are marked especially. Between stations 116 and 118, and 119 and 120 the local minimum of the vertical density gradient amounts less than $2*10^{-10}$g cm^{-4}.Comparing these results with the potential vorticity minimum as published by Talley and McCartney (1982) the corresponding numbers are less than $4*10^{-14}$ cm $sec.^{-1}$.

Thus, from the present data the conclusion may be drawn that low-salinity layers with high oxygen content and minimum vertical density gradient represent areas of convectively formed Labrador Sea water.

References

Clarke, R.A., and J.C. Gascard, 1983: The formation of Labrador Sea Water. Part I: Large-scale processes. J. Phys. Oceanogr., 13, 1764-1778.

Gascard, J.C., and R.A. Clarke, 1983: The formation of Labrador Sea Water. Part II: Mesoscale and smaller-scale processes. J. Phys. Oceanogr., 13, 1779-1797.

Lazier, J.R.M., 1973: The renewal of Labrador Sea Water. Deep. Sea Res., 20, 341-353.

Lazier, J.R.M., 1982: Seasonal variability of temperature and salinity in the Labrador Current. J. Mar. REs., 40(Suppl.), 341-356.

Lee, A., and D. Ellett, 1967: On the water masses of the Northwest Atlantic Ocean.
Deep. Sea Res., 14, 183-190.

Mann, C.R., 1969: Temperature and salinity characteristics of Denmark Strait overflow.
Deep. Sea Res., 16 (Suppl.), 125-137.

Swift, J.H:, 1984: The circulation of the Denmark Strait and Iceland-Scotland overflow waters in the North Atlantic.
Deep Sea Res. 31, 1339-1355.

Talley, L.D., and M.S. Mc Cartney, 1982: Distribution and Circulation of Labrador Sea Water.
J. Phys. Oceanogr., 12, 1189-1205.

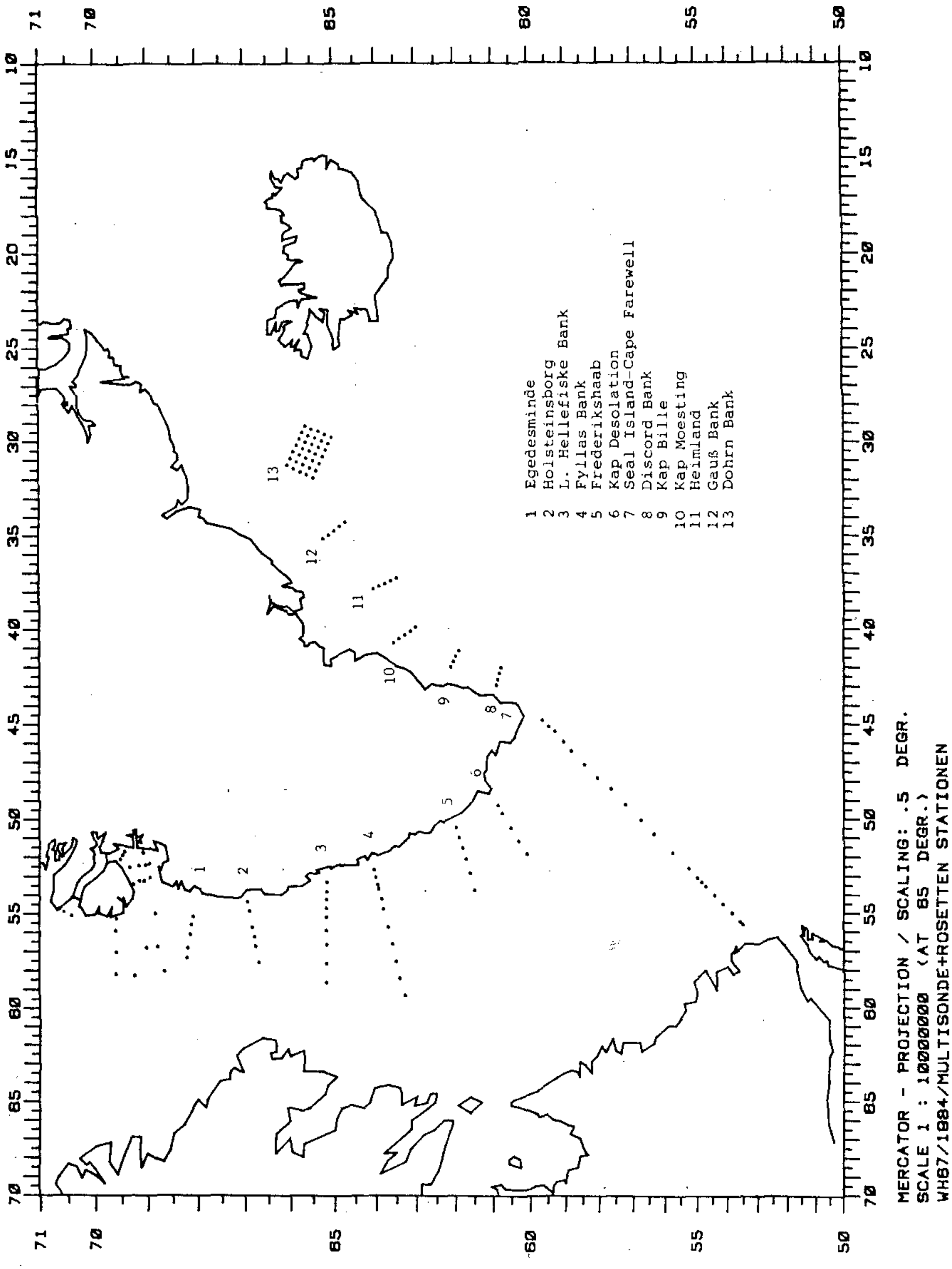

Fig. 1 Station grid and name of sections occupied during cruise 67 of RV "Walther Herwig" to East- and West Greenland

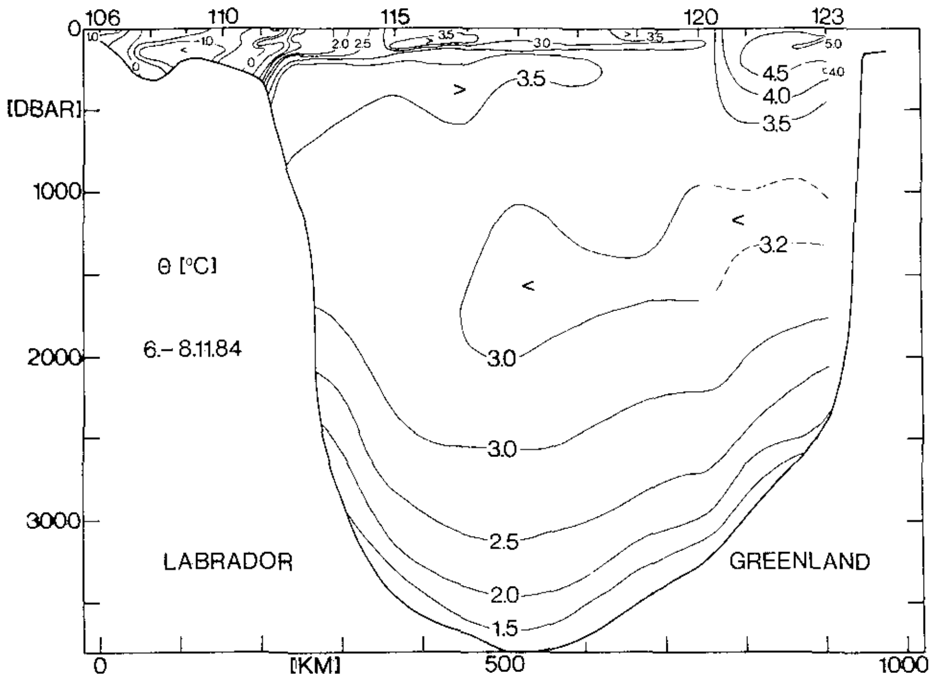

Fig. 2 Potential temperature section

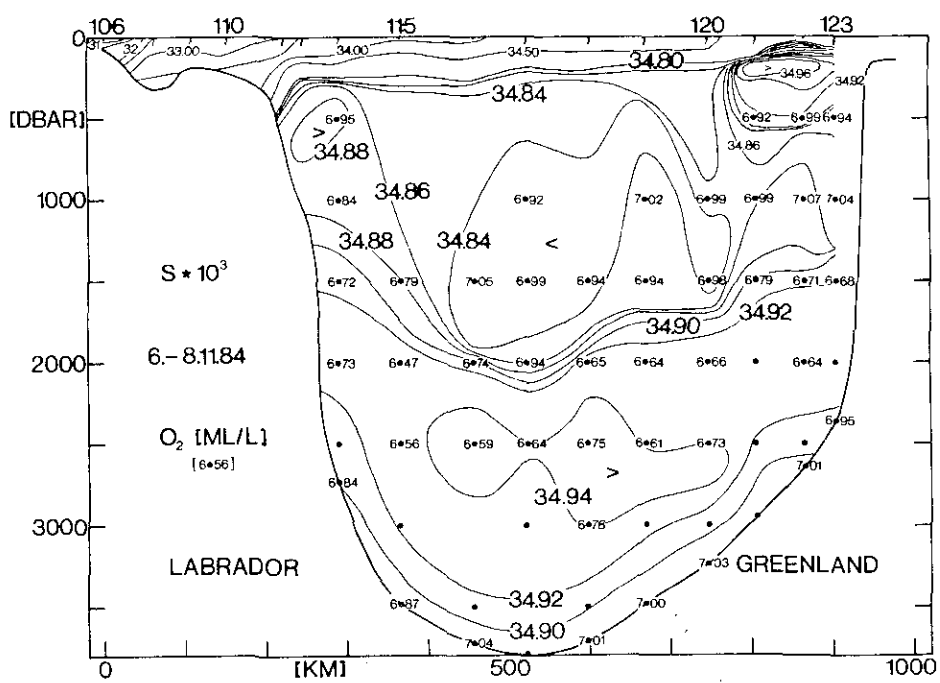

Fig. 3 Salinity and oxygen section

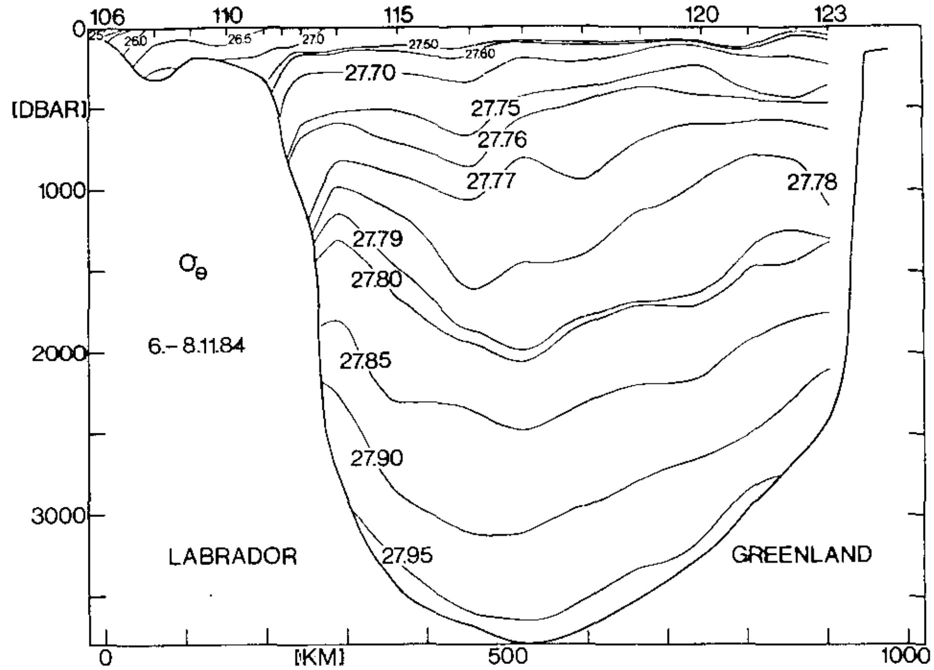

Fig. 4 Potential density section

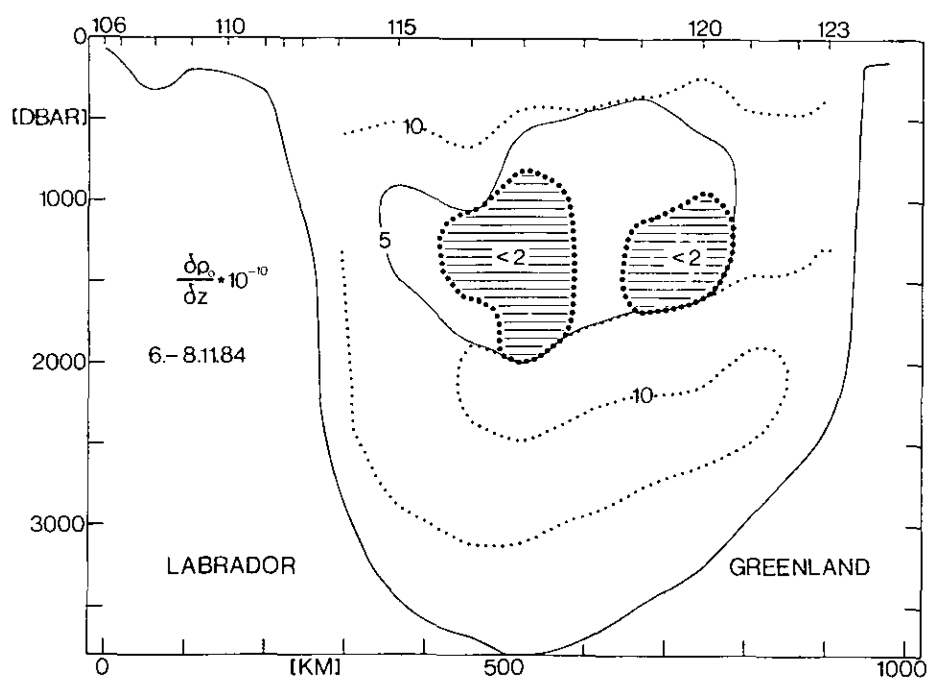

Fig. 5 Vertical gradient of potential density