OCEANOLOGIA, 29, 1990
PL ISSN 0078–3234

Greenland Sea
Acoustic scattering

On the sound scattering at 30 kHz and its relationship to the large-scale circulation pattern in the Greenland Sea

Marek Ostrowski
Institute of Oceanology,
Polish Academy of Sciences,
Sopot

Manuscript[1] received November 7, 1990, in final form May 31, 1990.

Abstract

Simultaneous measurements of temperature and acoustic reverberation at 30 kHz in the Greenland Sea in August 1989 show dependence of acoustic scattering regime on large-scale circulation pattern in this region. Two major cyclonic gyres encountered during the measurements were clearly seen on scattering records.

1. Introduction

Over the past years, it has been well established that regional variations in acoustic scattering are associated with large-scale features of circulation in the ocean and that pronounced changes occur when crossing oceanographic boundaries between water masses. Backscattered energy, as seen in the form of pronounced dark traces on standard echosounder records is produced by layered populations of marine organisms, most of which carry some sort of gas bubbles. Although the majority of organisms composing these, so-called scattering layers do adopt actively their vertical distributions in response to light and to some extent to temperature and pressure, the large-scale variability of the populations is stronger related to hydrodynamic processes affecting the physical structure of water masses (Farquhar, 1977; Conte *et al.*, 1986).

This report presents some of the results of acoustic scattering which were obtained in the Greenland Sea on board the r/v "Oceania" during her third expedition to the Polar Seas, and gives their comparison to

[1]The investigations were carried out under the research programme CPBP 03.10, 1.7, co-ordinated by the Institute of Oceanology of the Polish Academy of Sciences.

the main circulation pattern described in terms of temperature distributions. The aim of this cruise was not to map the variability of acoustic scattering in the region, therefore the measurements suffered two serious limitations: the lack of the direct information on populations of scatterers by means of pelagic trawl sampling, and the discrete character of the data which could be obtained only at selected locations, rather than in the course of a continuous hydroacoustic transects. Nontheless, it is interesting to know how closely such a limited picture of scattering resembles the circulation pattern in the Greenland Sea, especially since the number of available data from this region is still relatively poor.

2. Location and instrumentation

In August 1989 during the r/v "Oceania" cruise AREX-89 hydrographic sections through the Greenland Sea were conducted. Locations of hydrographic stations are shown in Figure 1. The CTD data were collected using a GUILDLINE 8770 probe. Echo levels in the upper 700 meters of the water column were monitored by digital integration of the return signal from an ELAC LAZ 4700 echo sounder with an outboard transducer operating at 30 kHz.

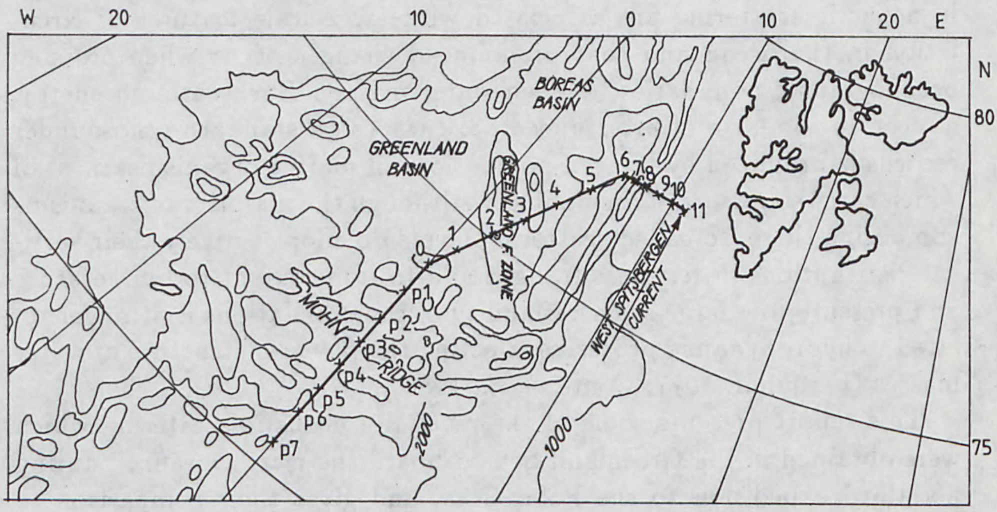

Figure 1: Locations of hydrographic stations from the r/v "Oceania" cruise AREX-89 presented in this paper

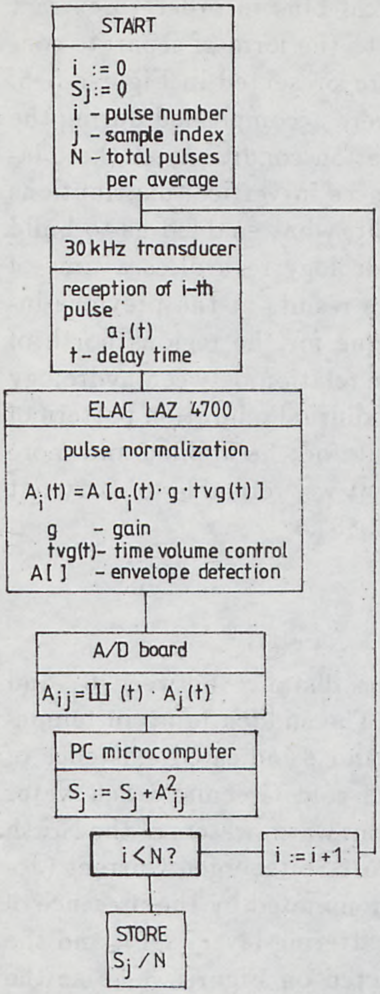

Figure 2: Diagram of the system for acoustic signal processing and recording used during the AREX-89 cruise

The DC envelope of the echo was logged digitally onto a PC/XT microcomputer where the signal was averaged over each 200 transmissions and stored (Fig. 2). The measurements were conducted several times at each station; for further processing only these series were selected, during which the steady signal from permanent layers was not obscured by short period disturbances caused either biologically or by some other equipment in operation. The observational time ranged from one to three hours. In the post-cruise analysis the temperature data were low-pass filtered, and the scattering data averaged into vertical bins in order to extract large-scale variability. The results compiled to the form of separate contour plots for each straight course section are presented in Figures 3–5. All the observations reported in this paper were accomplished during the Arctic day. Under the uniform diurnal radiation conditions at these latitudes we did not expect significant differences in vertical distributions of biological scatterers between day and night, what enabled us to build a simple relation between acoustics and hydrology regardless a time of the day. Such approach was justified by the results of the previous investigations (Farquhar, 1977), and was unique for the regions north of the polar circle. At lower latitudes, where the relation between hydrology and acoustics is obscured by the complicated diurnal migration pattern of marine organisms, the above assumption could not be applied and more detailed investigations are required, from what we were able to carry out during the AREX-89 expedition (Orłowski, 1985).

3. Observations

The first section (Figs. 3a, 3b) spanned the distance between 6^o and 11^oE, across the continental slope at 77^oN. The sudden jump in temperature distribution (T) between Stations 7 and 8 indicated existence of a sharp frontal region. This front separated cold Greenland Sea water masses (called hereafter GSW) in the west, from warm waters of the North Atlantic origin (NAW) transported by the West Spitsbergen Current (Johannessen, 1986). The scattering (Sv) was dominated by the presence of two well distinguished layers: the surface scattering layer (SSL), and the deep scattering layer (DSL). They are depicted on Figures 3–5b as the area of strong intensity enclosed by the –20 dB contour line. The SSL east of the frontal region was entirely enclosed within the upper mixed layer (Fig. 3b). The thickness of the SSL was constant throughout the whole the Atlantic water domain in spite of steady eastward decline of the seasonal thermocline. The DSL between Stations 8 and 10 paralleled approximately decrease of the 2^oC isotherm towards the front edge. The top of this layer observed at 250 m at Station 11, fell nearly to 300 meters in the vicinity of the front. Its thickness diminished as well, from initial 300 meters at Station 11 to some 180 m at Station 8.

On the western side of the front the isotherms became crowded indicating the presence of the GSW core. According to Quadfasel and Meincke

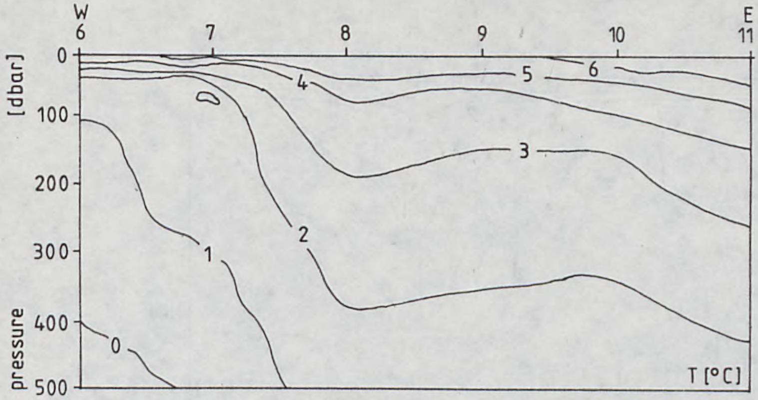

Figure 3a: Temperature section through the Greenland Sea, 8–9 August 1989, 6°–11°E at 77°N

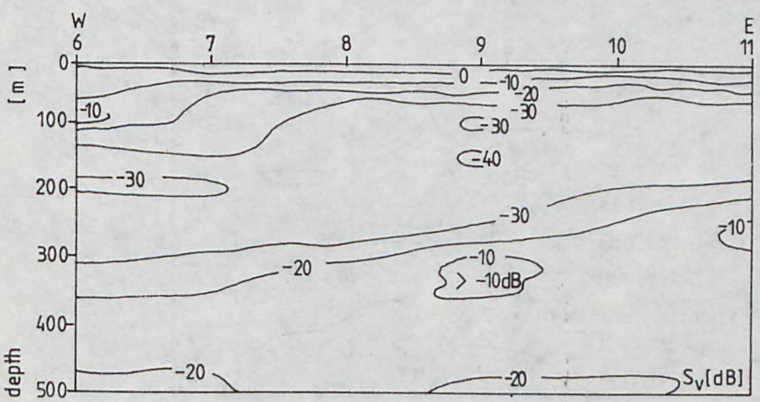

Figure 3b: Scattering strength section through the Greenland Sea, 8–9 August 1989, 6°–11°E at 77°N

(1987), this core corresponded to a cyclonic gyre structure locked to the topography of the Boreas Basin, and separated from the adjacent Greenland Sea gyre by a narrow band of warm water fed by the Atlantic Return Current. In fact, referring to Figure 5a, where the continuation of the temperature distribution following the course change to SW is displayed, such band is clearly seen in the vicinity of Station 4.

Stations 5 to 7 (Figs. 3–4) were found entirely within the cold core of the Boreas Basin. Both layers, the SSL and DSL underwent noticeable changes accros the front. The DSL decreased in thickness to some 100

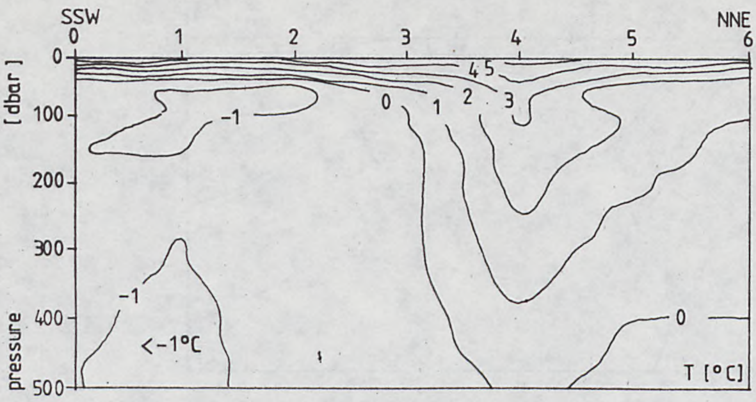

Figure 4a: Temperature section through the Greenland Sea, 10–11 August 1989, 6°E, 77°N – 0°E, 74°N

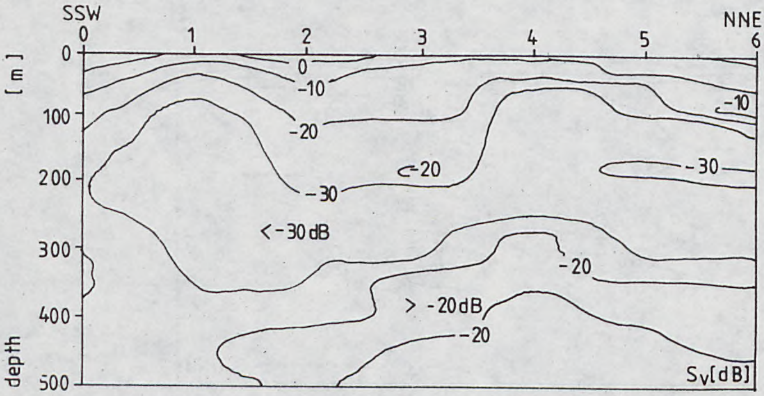

Figure 4b: Scattering strength section through the Greenland Sea, 10–11 August 1989, 6°E, 77°N – 0°E, 74°N

meters, and became centered at the depth of 400 meters. Its intensity decreased, but remained within the same −20 dB limit, characteristic to the NAW, even though the surrounding GSW water mass was colder of nearly 2°C. The SSL became deeper reaching at Station 7 – 150 meters, well below the upper mixed layer for that region.

The warm tongue at Station 4 (Fig. 4a) was manifested in scattering records as a noticable decrease in the vertical extend of the SSL, and in upward displacement of the DSL mean depth. There were apparent similarities between this pattern and that found east to the front, in the

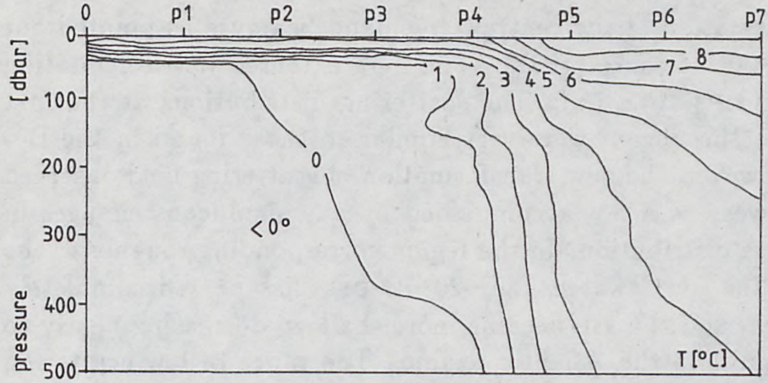

Figure 5a: Temperature section through the Greenland Sea, 11–13 August 1989, 0°E, 74° – 70°N

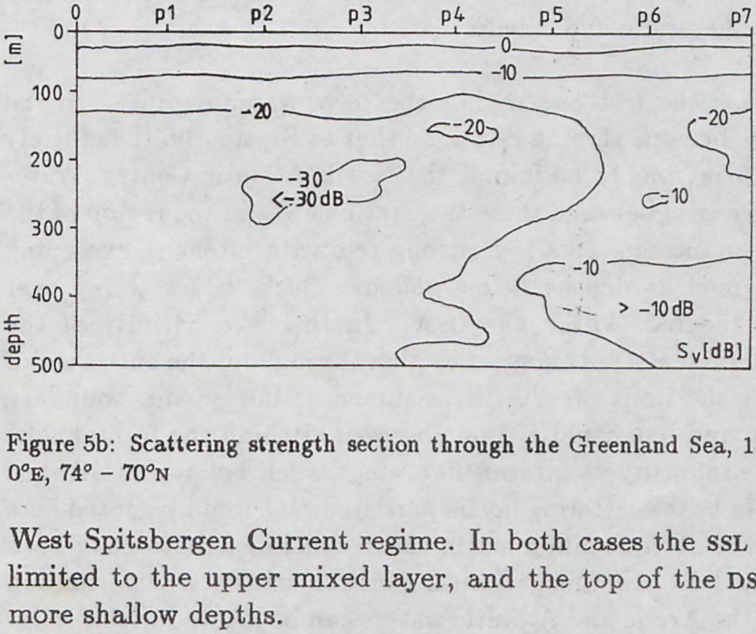

Figure 5b: Scattering strength section through the Greenland Sea, 11–13 August 1989, 0°E, 74° – 70°N

West Spitsbergen Current regime. In both cases the SSL appeared to be limited to the upper mixed layer, and the top of the DSL was reaching more shallow depths.

Moving south-west of Station 4 another abrupt jump in the temperature distribution could be observed (Fig. 4a). In this case the $0\,^oC$ isotherm reached the minimum depth, less than 50 meters, and in the upper 200 meters a core of the $-1\,^oC$ water appeared. The vertical, and horizontal gradients below the thermocline became significantly lower than those observed for the Atlantic water domain. This apparently was the thermal manifestation of the central Greenland Sea gyre as pointed out by Quadfasel and Meincke (1987). The gyre extented between Station 3 (Fig. 4a), and P4 (Fig. 5a). The scattering distributions at the first two stations in this region were very similar to those found in the Boreas Basin. However, the new transformation of scattering field observed farther south-west, was not accompanied by any significant changes in the temperature distribution. In the region corresponding roughly to the occurrence of the -1^{0}C water, the -20 dB DSL dissapeared completely from the record, and the SSL became more shallow, decreasing nearly to the depths typical to the Atlantic regime. The range of low scattering region (LSR) at intermediate depths became here twice as large as in the adjacent waters. Towards the south (Fig. 5b) thickness of the SSL regained to the values from Stations 2 and 3, but neither the LSR nor DSL did reappeared in the way consistent with previous distributions the only patches of increased intensity could be observed at Stations 0 and P4, whereas the gross of the water column below the SSL fell into an intensity range between -30, and -20 decibels.

Station P4 was the last one within the GSW water regime. To the south, isotherms became sloping down, so that at Station P6 the entirely different water mass was to be found: the North Atlantic Central Water (NACW). The distance between these two stations was in the region of the Polar Front (Johannessen, 1986). A strong DSL with intensity exceeding -10 dB was formed at depths below 250 m. Such values were never approached by the DSL within the GSW. In the close vicinity of the front, at Station P6 scattered energy was high throughout the entire water column, so that the limit of -20 dB, assumed earlier as the boundary between the SSL and DSL could not be observed. Behind the frontal zone (Station P7) the intensity at intermediate depths fell below -20 dB, but the high values in both scattering layers persisted. It should be noted here that despite of the obvious difference in the vertical distributions of both quantities: T and Sv, the geographical position of the transformation region between the Arctic and Atlantic waters can be located with similar accuracy in either of the two charts (Figs. 5a, 5b). It is probable that, the picture derived from acoustic data would provide additional data on the front position between stations, if the soundings could be carried out continuously from the ship under way.

4. Conclusions

In August 1989 scattering layers were encountered in the Greenland Sea and in adjacent waters. At high latitudes (74^o – 77^oN), the (cold) Greenland Sea Water (GSW) could, in most cases, be distinguished from the Atlantic water masses by larger vertical extent of the surface scattering layer (SSL), as well as by greater depths and the lower intensity of the deep scattering layers (DSL). At the southern boundary (71^oN) the contrast was even more pronounced: scattered intensity increased by some 10 dB throughout the entire water column, and a new strong DSL was formed in the Atlantic water domain. The major large-scale circulation features in this region: the Greenland, and the Boreas Basin gyres, the strip of warm water between them, the Polar Front, and the West Spitsbergen Current area were clearly marked on scattering records.

References

Conte M. H., Bishop J. K., Backus R. H., 1986, *Nonmigratory, 12-kHz, deep scattering layers of Sargasso Sea origin in warm core rings*, Deep Sea Research, 33.

Johannessen O. M., 1986, *Brief overview of the physical oceanography.* [In:] Hurdle B. G. (Ed.), The Nordic Seas, New York – Berlin.

Farquhar G. B., 1977, *Biological sound scattering in the oceans*, Ocean Sound Scattering Prediction.

Orłowski A., 1985, *Hydroacoustic characteristics of scattering layers in the North-Eastern Atlantic Ocean between latitudes 37^o – 46^oN and longitudes 12^o – 30^oW: r/v "Profesor Siedlecki" cruise, summer 1984*, ICES C.M., B:49, Session Y.

Quadfasel D., Meincke J., 1987, *Note on the thermal structure of the Greenland Sea gyres*, Deep Sea Research, 34.