

# Backscatter Data From the Hydrosweep Multibeam System: First Results

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## Zusammenfassung

Durch einen Umbau der Hydrosweep-Anlage auf FS "Polarstern" durch Atlas Elektronik Bremen wurde der Abstrahlwinkel des Fächers von 90° auf 120° vergrößert. Gleichzeitig mit diesem Umbau wurde die Anlage so erweitert, daß, zusätzlich zu den Tiefeninformationen, auch Side Scan Sonar Daten aufgezeichnet werden und Backscatter-Koeffizienten des Meeresbodens berechnet werden können.

Die Backscatter-Software, die für Hydrosweep verwendet wird, nutzt einen am Scripps Institution of Oceanography entwickelten Algorithmus zur Umrechnung der gemessenen elektrischen Energie in akustische Backscatter-Energie. Diese Umrechnung beinhaltet Korrekturen für die Position und den Abstrahlwinkel des Beams und eine Flächenkorrektur. In diesem Artikel werden vorläufige Ergebnisse der Analyse von Backscatter-Daten aus 3 Testgebieten vorgestellt, die mit dem modifizierten Hydrosweep DS während der "Polarstern"-Fahrt ANT XI/4 gesammelt wurden.

## Summary

The Alfred Wegener Institute recently contracted with Atlas Elektronik to upgrade the Hydrosweep multibeam bathymetry system on the polar research vessel POLARSTERN. This upgrade not only increased the swath width of the system from 90° to 120°, but also adds two new capabilities to the system: collection of sidescan sonar data, and the measurement of seafloor backscatter coefficients. The Hydrosweep backscatter software uses an algorithm developed by the Scripps Institution of Oceanography to convert the measured electrical energy into acoustic backscatter energy. This conversion includes corrections for the position, slope, and area of the scattering surface. In this paper we present backscatter data from three areas surveyed with the modified Hydrosweep DS multibeam system on the R/V POLARSTERN. These data represent the first results from the Hydrosweep backscatter system.

## Contents

1. Introduction
  - 1.1 Hydrosweep Backscattering Strength Measurement
2. Data Analysis
  - 2.1 Ground-truth Information
  - 2.2 Backscatter Data
3. Conclusions
4. References

## 1. Introduction

Sonar sounding of the seafloor is a routine surveying method for various objectives, such as geological surveys to characterize the seabed, examine geotechnical properties, resource evaluation, etc. In order to classify the seabed material, the interaction effect of the bottom relief on the acoustic signal must be known. Stanton and Clay (1986) and Dunsiger et al. (1981) have carried out work to identify the bottom type from its reflection and scattering characteristics. Multibeam sounding systems also have the potential to provide quantitative backscatter information which can be used to classify the seabed. DeMoustier (1986) studied the interaction of sound signals with the seabottom by performing an experiment in different areas of known sediment type using a 16-beam multibeam (SeaBeam) system.

To compute the backscattering strength, angle- and range-dependent factors must be taken into account. The essential aspects to consider include the transmitting transducer beam pattern, the angular reception sensitivity, and the various system gains. The area correction is also important because the seafloor is insonified with pulsed signals and the illuminated area of the seafloor is different from the projected areas of the individual beams. The determination of the bottom slope is also important (deMoustier and Alexandrou, 1991).

Technical details of the

standard Hydrosweep system are given elsewhere, and will not be repeated here (Gutberlet and Schenke, 1989). In addition to the bathymetric data, the modified Hydrosweep system records all of the system information necessary to compute quantitative backscatter. An algorithm developed by the Marine Physical Laboratory of Scripps Institute of Oceanography is then used to convert the measured electrical energies to raw acoustic backscatter energy, taking into account the factors mentioned above.

### 1.1 Hydrosweep Backscattering Strength Measurement

Usually the scattering strength,  $S$ , is related to the scattering coefficient,  $s$ , in the logarithmic scale and may be expressed as

$$S = 10 \log s,$$

where  $s$  is equal to  $P / AI_0$ .  $P$  is the power backscattered by a portion of the sea bottom of area  $A$  per unit solid angle, and  $I_0$  is the intensity of the incident sound wave at the bottom. More precisely, the backscattering strength,  $S(\theta)$  for a particular direction is expressed as

$$S(\theta) = 10 \log_{10} \left( I_0^{-1} \int_A \frac{I_s(\phi) r^4 10^2 \alpha_v r / 10}{b(\theta, \psi) b'(\theta, \psi)} \delta A \right)$$

where  $I_0$  is the incident intensity at a unit distance from the source in the particular direction,  $b(\theta, \psi)$  and  $b'(\theta, \psi)$  are the source and receiver beam patterns respectively, and  $r$  is the distance from the source to the

elemental scattering surface area  $\delta A$ .  $\alpha_v$  is the seawater absorption coefficient for a particular angle  $\theta$ , and  $I_s(\phi)$  is the scattered intensity integrated over the elemental area  $\delta A$  (deMoustier and Alexandrou, 1991).

There are three basic groups of parameters required for scattering strength calculations: the equipment related constants (design constants), the variables related to the equipment operating conditions, and the echo data measured by the system. The Hydrosweep backscatter system records all of these quantities and uses them in the backscatter computations. The primary backscatter parameters recorded by the system are the echo root mean square voltages and the signal durations for each beam. Important system and environmental parameters include the operation mode, source level, pulse length, fixed gain settings, TVG (time-varying gain), traveltime of the sound wave, mean sound velocity, and the sound velocity at the ship's keel.

The signal processing algorithm, which was previously used only for depth measurement, is extended to compute the energy contained in the returning signal. The received electrical envelopes at the bottom echo processor are sampled and converted to root mean square voltages within a -6 dB window around the peak amplitude. The derivation of the seafloor acoustic backscattering strength from the raw rms echo energy values for the individual beams are carried out using an algorithm known as NORGCOR developed at the Marine Physical Laboratory, Scripps Institute of Oceanography. In addition to providing the necessary corrections

to extract the acoustic levels for each beam, NORGCOR performs two major corrections essential for backscatter strength computations. The first is a geometric correction using the system bathymetric data for the computation of bottom slopes across the ship's track. These slope angles are used to correct the effective angles of arrival to obtain angles of incidence on the seafloor. The second important correction performed by NORGCOR is a calculation of the seafloor area insonified by each beam. The area insonified by different beams is less than the projected area for the same beam because it is pulse length dependent. The insonified area calculation is used to compute a correction coefficient by integrating the footprint of the transmitted pulse over the area insonified. More details on the NORGCOR algorithm are given in deMoustier and Alexandrou (1991).

The application of these corrections to the raw energy values yields relative backscattering strength as a function of the angle of incidence. Because there is no calibration of the individual beam measurements, it is difficult to provide the angular backscatter function of the various sediment types, although normalized data can be obtained and has been used for model studies (Alexandrou et al., 1992; Clay and Medwin, 1977; Jackson et al., 1986).

## 2. Data Analysis

In this paper we present backscatter data from three areas for which some ground-truth information is available. By

examining areas where bottom information is available we hope to determine characteristic backscatter strength vs. incidence angle curves for different sediment types.

## 2.1 Ground-Truth Information

The Norway Margin data come from the upper continental slope near the Lofoten Islands at about latitude 69° N. The seafloor in this area lies at about 2000m depth, has a slope of about 6° and contains a small canyon. These data are near sites drilled during Leg 38 of the Deep Sea Drilling Project (Talwani et al., 1976). The upper few meters of sediment recovered from Leg 38 sites 338 to 343 was all similar, generally consisting of terrigenous "Glacial" mud and sandy mud with occasional nannofossil ooze horizons and pebbles up to 3 cm in diameter. The surficial sediment grain size distribution varies somewhat between the sites, but averages about 20% clay, 65% silt, and the remaining 15% sand and pebbles (Emelyanov et al., 1976).

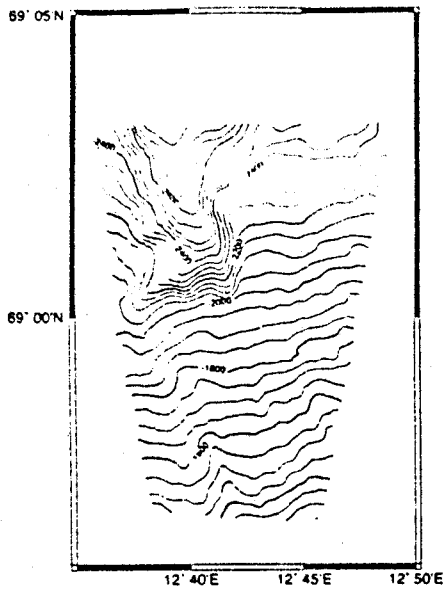
The Bransfield Straits data come from the west-central Bransfield Straits on the Antarctic Peninsula. The seafloor in this area lies at about 900 m depth and is generally smooth, with a slope of less than 0.6°. The backscatter data from the Bransfield Strait lie between two core sites sampled by the U.S. Coast Guard icebreaker GLACIER in 1982. The upper portions of these cores consist of sandy to silty diatomaceous muds with occasional volcanoclastic layers (Singer, 1987). The sediment grain size distribution is about 15% clay, 75 % medium to fine silt, and the

remaining 10% coarse silt to sand. The deeper portions of the Bransfield Strait have very high sedimentation rates caused by high biogenic productivity and current transport of sediment from shallow water.

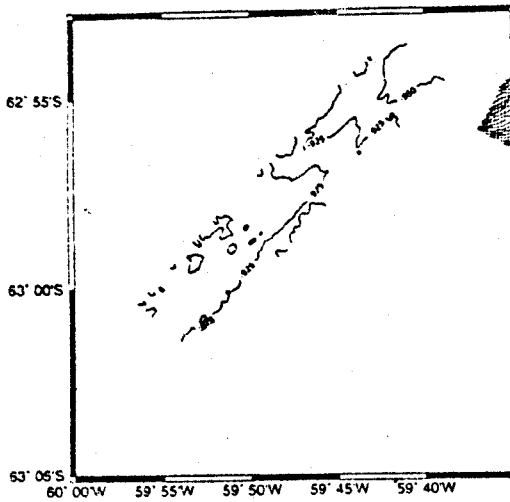
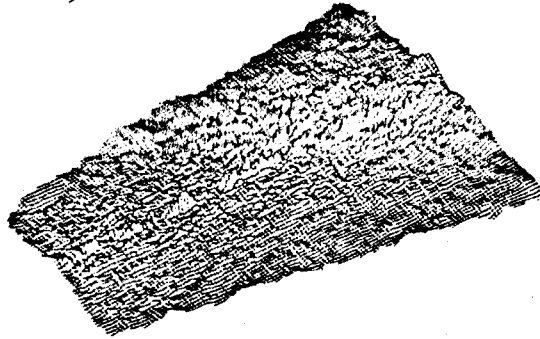
The Drake Passage data come from the southern Drake Passage between South America and the Antarctic Peninsula. The seafloor in this area lies at about 4000 m depth and is rough, with slopes of up to 9°. Ground-truth information in the immediate vicinity of these backscatter data is not readily available. The backscatter data lie on oceanic crust overlain by surface sediments consisting of siliceous ooze and fine-grained glaciomarine sediments. The surficial sediment grain size distribution in this area is unknown.

## 2.2 Backscatter Data

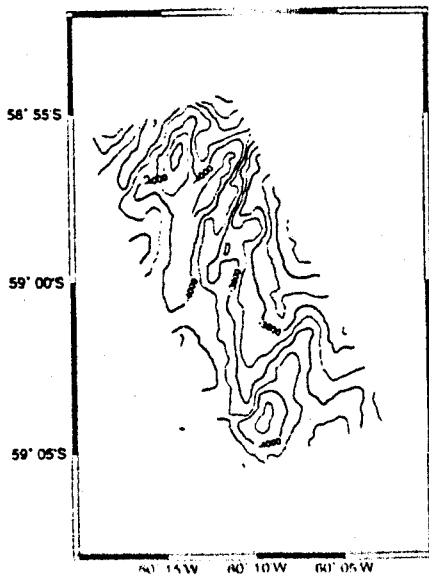
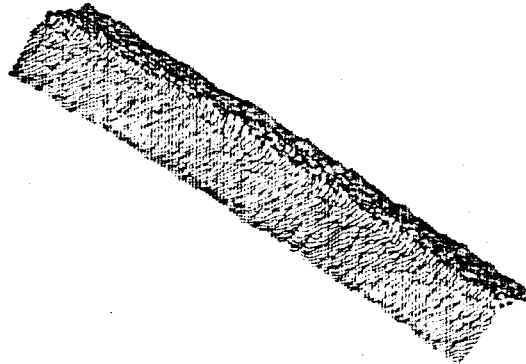
Figure 1 shows the Hydrosweep bathymetry and perspective views of the backscatter data for the three areas discussed above. It can be observed in this figure that the topographic variation of the seafloor has no effect on the backscatter data. This shows that the topographic corrections in the software package are working correctly. In all three areas the backscatter data is of high amplitude with high noise near the center of the shiptrack. This is a typical feature of backscatter data and is due to high coherent scattering. This peak is most pronounced in areas of flat and smooth bottom. We can see that the high central peak in the Bransfield Straits backscatter data correlates with the flat bathymetry shown in the same figure. The central peak is least



a)



b)



c.)

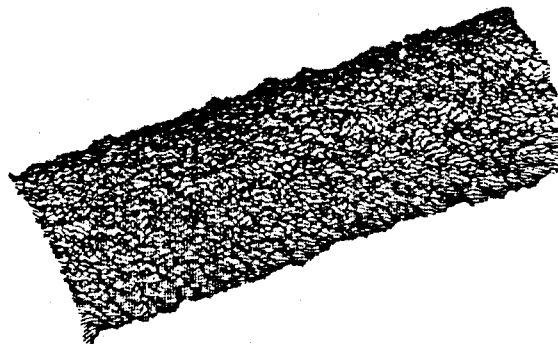


Figure 1. Bathymetry contours and perspective plots of backscatter data for: a) The Norway Margin area, b) the Bransfield Straits area, and c) the Drake Passage area.

pronounced in the Drake Passage data where the seafloor is the roughest.

Figure 2 shows the backscatter strength plotted against the angle of incidence on the seafloor for all three areas. The values of backscatter strength shown along the vertical axis in the figure are not absolute and should only provide a scale to measure relative changes. All three areas show a drop in backscatter strength with increasing incidence angle. In all cases the amount of this drop is about 20 dB. The shape of the backscatter curve for each of the areas is different, however. The Bransfield Straits data show very high backscatter at less than 10° but then the energy falls off gradually at higher incidence angles. The Norway margin data show a similar pattern, but at about 5 dB lower strength at all angles. The data from the Drake Passage decrease gradually in strength out to about 30° and then fall more rapidly out to 45° incidence angle.

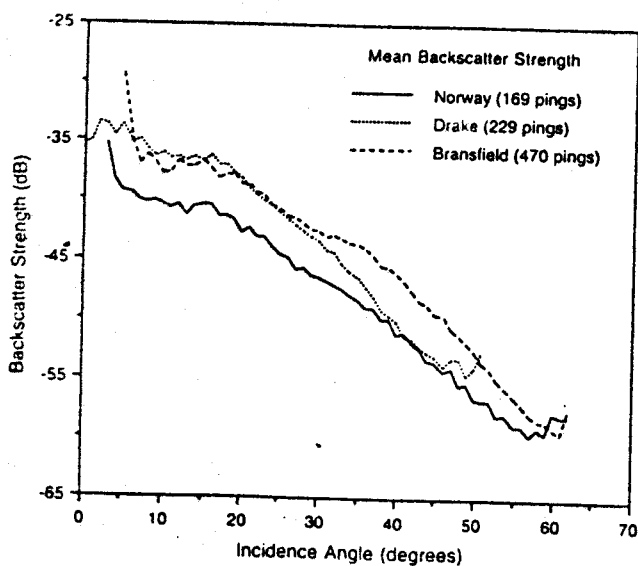


Figure 2. Backscatter strength vs. incidence angle curves for the three areas discussed.

By comparing the shapes of the backscatter curves shown in Figure 2, one could conclude that the material on the seafloor in the Norway Margin and Bransfield Straits areas is similar. The ground-truth data discussed earlier tends to support this conclusion. The materials in both areas are muds, of slightly different composition, but with similar grain size distributions. The 5 dB vertical separation between the two curves may reflect small-scale surface roughness differences. The backscatter curve for the Drake Passage area has a distinctly different shape from the other two areas. Ground-truth data is lacking, but the surface sediment is probably siliceous ooze, a distinctly different material from that found in the other two areas.

### 3. Conclusions

The goal of this project is to develop a method of mapping the distribution of seafloor materials remotely. This paper represents the first step in this process, namely to examine the backscatter response of the system in areas of known bottom composition. The data presented here show some of the differences in backscatter strength observed in different areas, and also some of the similarities that may provide a basis for a material classification scheme. From data such as this we hope to determine characteristic backscatter curves for different materials. These backscatter curves can then be used to characterize backscatter data collected in areas of unknown bottom type and to generate maps of the bottom material.

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