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TRANSMISSION -LOSS CHARACTERISTICS AND GEOACOUSTIC MODEL FOR AN OUTER ALBANIAN CONTINENTAL SHELF PLATFORM IN THE SOUTH-EAST ADRIATIC SEA

M.D. Max, R. Hollett, J. Fawcett and J. Berkson

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SACLANT Undersea Research Centre
Viale San Bartolomeo 400
19138 San Bartolomeo (SP), Italy

tel: +39-187-540.111
fax: +39-187-524.600

e-mail: library@saclantc.nato.int

NORTH ATLANTIC TREATY ORGANIZATION

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David L. Bradley
Director

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Executive Summary: During May-June, 1995, an acoustic experiment was conducted on the outer Albanian continental shelf. In conjunction with the acoustic measurements, an oceanographic and geological-geophysical assessment of the entire Albanian continental shelf was performed. Transmission-loss results of CW pulses at 400 Hz, 600 Hz, 800 Hz, and 1 kHz were successfully modelled.

A standard geoacoustic profile for the outer shelf area has been developed for the Platform Geoacoustic Terrane area in which the roughness, geological and geophysical properties and bottom materials are very similar. The geoacoustic profile provides the basis for proposing other geoacoustic profiles for all areas of the Albanian Shelf.

All map and linked numerical and image data and information is available on a CD-ROM in digital form, using a Geographical Information System (GIS) format and linked data set (DMap).

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Transmission-loss characteristics and geoacoustic model for the outer Albanian continental shelf platform in the SE Adriatic Sea

M.D. Max, R. Hollett, J. Fawcett and J. Berkson

Abstract: Transmission-loss experiments have been carried out on the outer Albanian Shelf. The acoustic measurements were performed together with a combined oceanographic and geological-geophysical survey which identified the different bottom types and their boundaries. Data and modelling are presented, along with an indication of the area of the Albanian Shelf for which the geoacoustic profile and transmission loss results are thought to pertain.

Keywords: Albanian Shelf – transmission loss – Adriatic

Contents

1 Introduction

In May-June, 1995, a two-leg environmental survey and acoustic experiments were carried out in the southern Adriatic Sea, covering the entire sea area from the coast of Italy to the coast of Albania. The first leg of the joint cruise by the NRV *Alliance* collected detailed oceanographic data as part of a longer-term oceanographic survey. The first oceanographic cruise leg (OGEX-1) involved joint hydrographic data collection with the ITS *Magnaghi*, of the Italian Hydrographic Office, and the assistance of the HS *Nautilos*, of the Hellenic Navy Hydrographic Service, for the deployment of surface drifters. A total of 528 km of seismic survey were collected. A series of SW-NE cross-slope traverses with orthogonal tie lines were designed to intersect geological structures at high angles. These were surveyed with a long SE-NW tie line and two close-survey areas to determine detailed morphology. Oceanographic and sea floor data were assessed at sea and compiled in a GIS/DMap [1]* as it became available. Cores were measured onboard for acoustic velocity within hours of recovery. Rapid assessment of the sea bottom allowed charts of bottom type, bottom materials, sediment types and their thicknesses, and sonar roughness and backscatter character to be compiled. All available data were loaded into the linked relational database as soon as it became available so that all environmental parameters were contained within a DMap.

Based on this Albanian environmental data set, an acoustic experiment was conducted on the shelf (Fig. 1), at a site chosen as representative of the largest area having consistent geological, morphological, and geophysical characteristics (Fig. 2). This potential geoacoustic terrane occupies most of the outer edge, and may be characteristic for the narrow shelf edge further south, where the geological and geophysical situation is similar.

Runs were made twice, both outward and inbound from the array and its radio buoy for transmission-loss at four frequencies, 400, 600, 800, and 1000 Hz. On the outbound leg a CW source was towed, the inbound leg was carried out using explosives for broadband transmission and reverberation characterization. In addition, a reflectivity experiment was carried out using explosive shots recorded by three-axies ocean bottom seismometer (OBS). Only the results obtained using the CW source are reported here.

* Max, M.D., Spina, F., Poulain, P., Nardini, P., Turgutcan , F., Risso, R. 1995. The Otranto Gap; Southern Adriatic Sea And Approaches CD-ROM

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General sediment types and disposition

Marine sediments on the Albanian shelf can be divided into inshore and offshore sediment sequences. Offshore the sediments are a thin discontinuous veneer, ranging from 1/2 to 2 m in thickness. The sediment wedges slightly over at the shelf margin where shelf sediments washed off the platform have come to rest on the uppermost slope and thickens toward the base of the slope. However, there are no thick sedimentary prisms lying along the slope and no infilled erosional features.

Inshore, there is a wedge of sediments that have a different character. There is a minor break in sedimentation at the junction between the two sequences, but more often the junction is difficult to distinguish on the reflection seismic records because it is usually flat and almost parallel with the parallel lamination of older and younger sedimentary sequences. The inshore sediments are commonly slumped and do not have erosional features in the seabed while the offshore sediments do not appear to be slumped; the offshore sediments have a higher shear strength.

3
Offshore sediments and sound velocity profiles

Over 85% of the offshore sea bottom acoustically imaged on this survey appears to have thin but smooth sediment cover, with no significant relief. Occasionally, more reflective dark patches on the side-scan records are 100 to 200 m long and less than 20 m wide. These are irregularly developed and show no relief. Rougher seafloor, which is confined to the outer 2.5 miles of the shelf, usually has relief of less than 4 m, with discrete, nearly equidimensional, steep-sided spurs rising from a hummocky, strongly featured bottom. The upper slope also shows a strong roughness.

A relic subareal erosion surface below the thin offshore sediments passing from almost 150 m of water depth into shallow water strongly cross-cuts older horizontally bedded sediments. Above this surface are a number of sedimentary successions, each separated locally by near bed-parallel, unconformities (erosion surfaces). These unconformities have a smoothly down-cutting marine erosive character, that in a few cases pass landward into sub-areal erosion surfaces where incised channels and steep-sided small cliffs predominate. The transition from marine to apparent sub-areal erosion below the Holocene sediments takes place at slightly less than 100 m.

Trawl scars were uncommon on the shelf, reflecting little deep net trawl fishing, but observed trawls were oriented about NE-SW on the shelf itself, and almost parallel to slope along the upper 50 m of the slope.

Large piston cores, from 0.55 cm to 1.05 m long, were taken in the vicinity of the array (Fig. 2, 3). Acoustic velocities in the cored sediments were measured on board the NRV *Alliance* (Table 1) within a short time of recovery. Calculated velocities of both the offshore sediment and the onshore sediment were thus available at sea for modelling the acoustic propagation results, which were also processed in a preliminary form during the cruise. The measured acoustic velocities were within the normal ranges for these sediment. Cores have been described with regard to their appearance and general grain size when cored*, and seafloor sediments are described in a separate report [2].

Small cores from 0.13 to 0.65 cm in length were taken to supplement the large cores (Fig. 3). This was necessary because the stiff bottom damaged the large corer on the second core. The small cores also verified that the very stiff clay forms a thin veneer beneath both of the experiment lines of the site. The geophysical survey shows this veneer over most of the outer shelf. Large cores were taken at other sites using the reserve core nose where there was a softer bottom.

All cores contained gray-green silty clays and then clay sediment below a thin, shelly sand top layer from 0 to 10 cm thick. Gravel and sand in a sandy and silty upper layer contained some shell fragments and some small halfshells, but no living shelly fauna (crustaces/mollusca) were recovered. Very stiff gray-green clay with a relatively

* Max, M.D. Oceanography and Seafloor Characterization of the Otranto Gap. Cruise report OGEX-1/OGAP-1, 12 June, 1995.

high shear strength was found in the bottom of all cores less than a metre below the unconsolidated muds and shelly sand on the seafloor. Cores were commonly disturbed and mixed by the sampling.

A number of cores sampled surface gravel lenses containing many shells and small beach gravel flakes with high rounding, but extremely poor sphericity, typical of beach stone. Pebbles of light gray limestone, dark tan sandstone and siltstone and many smaller fragments of different color were not identified as to rock type. Most of these samples were strongly mixed by the coring process.

Table 1. *Pressure wave velocities measured during the experiment. d, disturbed fine sediment settled in core.*

Depth	Core	
(cm)	OG-1	OG-2
	Velocity Cp m/s	Velocity Cp m/s
10	1638	1502 (d)
20	1650	1654
30	1614	1691
40	1516 (d)	1710
50	1457 (d)	
60	1687	
70	1644	
80	1687	
90	1675	

Thus, at the site in the central plateau region (Figs. 1 and 2), the seafloor consists of about 1 m or less of rigid, non-gaseous clay over a sequence of high shear strength, stiff laminated clays, that in turn overlie a consolidated Plio-Pliocene marine sediment sequence that dried during the last glacial maximum and no longer has marine sediment physical properties or characteristics. While it was exposed to the atmosphere, erosion produced stream channels and a morphology typical of an alluvial plain. At this time, sea level here was lower by about 130 m. The boundary to this area was determined by a geophysical survey (Fig. 2). A flat, smooth seafloor with fine gravel and shelly silt banks locally occupies the surface.

A geoacoustic model of Vp, Vs, p- and s-attenuation, and density of the seafloor and immediate subbottom materials around the site was developed at sea on the basis of the measured and geophysical character of the sub-surface and the sediment velocities with respect to physical properties at other comparable sites. The Cp for the actual surface of the Albanian Outer Shelf Geoacoustic Terrane (Fig. 2) was estimated at about 1525 m/s, with density estimated at about 1.03 g/cm^3. From 10 cm depth in the sediment layer to its base in a metre or less, Cp rises from about 1638 to 1700 m/s and density rises from 1.03 to 1.30. Shear speed in at least the lower half of the sediment layer was estimated at about 500 m/s. The top of the underlying Plio-Pliocene sediments have a generally smooth surface characteristic of a marine peneplane (flat to gently sloping erosional surface) that probably developed during the initial flooding of the shelf, indicating that lithification was not well developed. The increase in Cp from the top of these indurated (dried and compacted, with possible minor cementation) sediments was estimated at from 1570 to 1850 m/s at 200 m depth. The shear speed of these older sediments was estimated to be 400 m/s near the top of the sediment to 600 m/s at about 200 m depth.

4
Experiment configuration

A vertical line array (VLA) and ocean-bottom seismometer/hydrophone sensors (OBS) were established at the array site 'A' (Fig. 3). The array consisted of 64 hydrophones arranged so that there were three subapertures of 32 hydrophones spaced at 0.5, 1.0, and 2.0 m with all array centres at 42 m above the seafloor. CW experiment runs were recorded with a bandwidth of 2 kHz; broadband experiment runs were recorded with fewer hydrophones so that larger bandwidths could be obtained. Verification of data received and processing of the data was begun immediately after each experiment was completed.

Acoustic propagation experiments were conducted along two almost orthogonal lines. Line 1 (Run AB) ran SSE for 17 km from the array over an almost flat bottom at about 90 m depth. Line 2 (Run AC) ran about west-southwest over a flat bottom at 92+ m, which sloped to 102 and 111 m depths at 10 and 11 km respectively. Exact spot calculations of water depth using the reflection seismic records and the water velocity profiles, as well as depths measured on the ship's single-channel depth sounder and the Atlas multibeam SWATH mapper showed an internal variation of less than 0.5 m.

The acoustic source was towed by the R/V *Alliance* along outward going tracks, at constant speed (of about 4 kn), and constant bearing. The source produced a mixture of CW tones at 400, 600, 800, and 1000 Hz. The range was determined from the ship's differential GPS coordinates at 1 s intervals (i.e., at range intervals of about 2 m). The first track was terminated at the limit of reception from the array's radio buoy. The second track was terminated prematurely at a little less than 5 n.mi. WSW from the array, when the radio buoy's batteries were exhausted.

CTDs were taken immediately before and at the end of each run. XBTs were taken in the middle of each CW run and a number of times during the explosive runs to monitor water structure. Two CTDs have been selected as representative (Fig. 4).

5 Propagation data processing and results

The acoustic data were filtered and digitized (at a rate of 6 kHz), in the array, prior to transmission to the ship. The raw hydrophone outputs were stored on VLDS tape, and a selected subset stored in computer files for analysis. The subset consisted of 4 hydrophones selected to span the full physical aperture of the array, at depth intervals of 20 m.

The analysis consisted of sampling the mean-square voltage of the CW tones (in dB re 1 V rms), accounting for the sensitivity of the vertical array system (in dB re 1 V rms for a 1 mPa rms input), and the source level (in mPa rms @ 1 m), appropriate to each CW frequency. The sampling of the mean-square voltage consisted of sampling the power spectrum, and determining the spectral contribution from each tone. Power spectrum sampling was based on contiguous block processing of each hydrophone output, in blocks of 8192 samples (the block length resulting in an averaging interval of 1.365 seconds). The spectral contribution from each tone was determined by summing over adjacent spectral bins around each tone's spectral line. The number of spectral bins included in the sum was sufficient to include a fully leaked signal (i.e., a signal not at bin centre spreads into adjacent bins), without including significant noise (i.e., some 27 bins, corresponding to +10 Hz about each signal). A raw mean-square voltage spectrum (Fig. 7), including effects of a whitening filter below 100 Hz, and anti-aliasing filter above 24 kHz, shows that the signal-to-noise ratios are typically 30 dB or more.

Propagation loss curves were produced at 4 CW frequencies from 400 to 1000 Hz. Figures 5a-d show propagation loss curves for the N-S line 1 (Fig. 3). while figures 6a-d show the results of the E-W line 2 (Fig. 3). The figures show the loss (in dB), as a function of range (in n.mi.), at four source frequencies (400, 600, 800, and 1000 Hz), and four receiver depths (18, 38, 58, and 78 m), for a fixed source depth (70 m for Experiment line 1 and 75 m for Experiment line 2). The water column depth as a function of range for each set is reproduced at the bottom of each figure.

6 Modelling of the Albanian outer shelf data

Because the transmission-loss characteristics of Experiment lines 1 and 2 were similar (except for near the end of line 2 where abnormally high roughness was encountered), we modelled only the longer line, Line 1, using simple geoacoustic parameters. There was a slight bathymetric range dependence with the water varying from about 92 m for the short ranges to 88.5 m at 10 n.mi. This is less than 5 m over 10 n.mi. Thus, although we will use a range independent model, there may be minor effects due to slight bottom depth and roughness variation. An impersistant, thin sediment veneer up to 1 m thick was developed locally on the seafloor along the experiment line. After a number of computer iterations testing different sediment thicknesses, we did not find increased agreement between the model. The data was modelled equally well with and without a sediment layer.

A simple seafloor model was employed. We used C_p = 1800 m/s, C_s = 400 m/s, attenuation ρ = 0.5 dB/λ, attenuation α = 0.5 dB/λ, density r = 1.5 g/cm^3, and a bottom rms roughness of σ_b= 0.5 m. We also set the water/air roughness at σ_w = 0.1 m. We found through numerous iterations that a water depth of 93 m (average determined depth) provided the best fit with the data.

The representative sound speed profiles 2 and 4 (Fig. 4) show typical variation from the CTDs, which are all similar. They are strongly downward refracting. Twenty points were selected to represent the sound speed profile. The numerical code SAFARI [3] was run with this sound speed profile and the geoacoustic parameters. Transmission loss curves were computed for a source depth of 70 m and receiver depths 18, 38, 58, and 78 m. The computations were carried out for the frequencies of 400, 600, 800, and 1000 Hz out to a range of 18 km. Figure 8 shows a representative contour plot of the acoustic propagation. There is an apparent downward refraction of the energy.

In Figs. 9-12, we show the experimental and modelled data on the same plots: dashed curve-sea trial data; solid line-model. The modelled data have been smoothed with a 7-point running window. Overall agreement between levels is very good. The model also closely approximates the individual features of the data. However, there are some instances where the interference structure of the modelled field is slightly out of phase with the experimental data. This is particularly noticeable in the 800 Hz / 18 m case (Fig. 11). This may partially be attributable to range dependencies which are not accounted for in the model. However for 1000 Hz, where one might expect this effect to be even larger, the agreement between data and model is very good. It should be noted that for 1000 Hz -18 m (Fig. 12a), the growth of the model curve at long range is probably the result of insufficient FFT sampling of the SAFARI wavenumber integral (SAFARI-aliasing).

Although only one set of plots is shown here, we carried out sensitivity testing through repeating the computations for different values of the bottom shear speed. Changing the basement shear speed did not significantly affect the results.

References

[1] Max, M.D., Spina F. and Portunato, N., 1995. Digital map and linked data (Dmap) implementation at SACLANTCEN as an aid to sea-going research. SACLANTCEN SM-291, 32pp.

[2] Max, M.D. Seafloor sediment character of the inner and outer Albanian shelf, southeast Adriatic Sea. (in preparation).

[3] Schmidt, H.. 1988. SAFARI Seismo-Acoustic Fast Field Algorithm for Range-Independent Environments User's Guide. SACLANTCEN Report SR-113, 152pp.

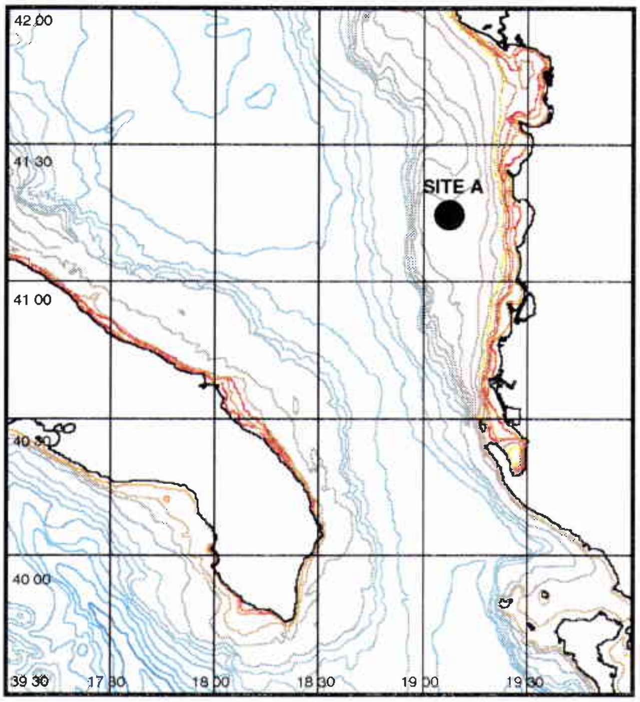

Figure 1. *Map of the southern Adriatic Sea showing the position of the experiment. Radio buoy in centre of black dot at A; see also Fig. 3.*

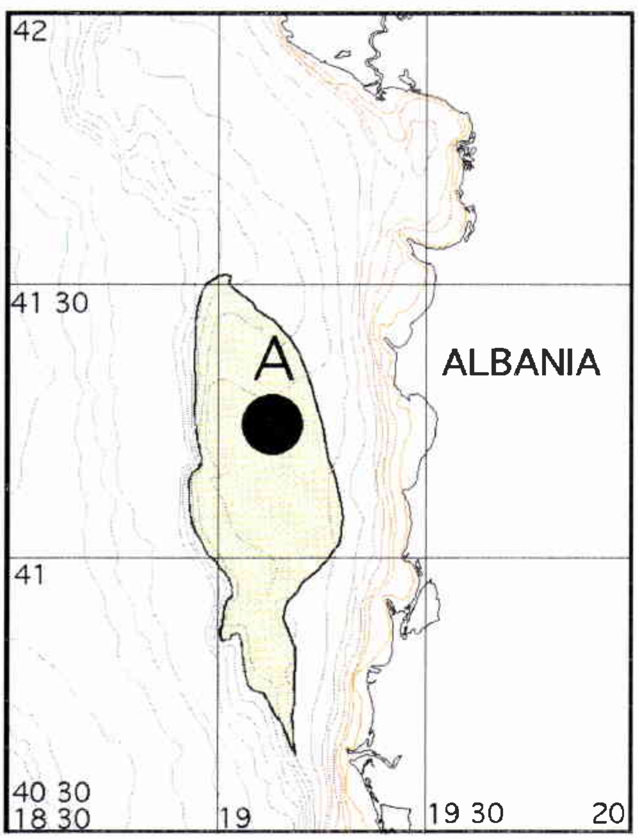

Figure 2. *Detail of the site showing bathymetry and extent of the Albanian Offshore Geoacoustic Terrane for which the transmission-loss and geoacoustical model data applies.*

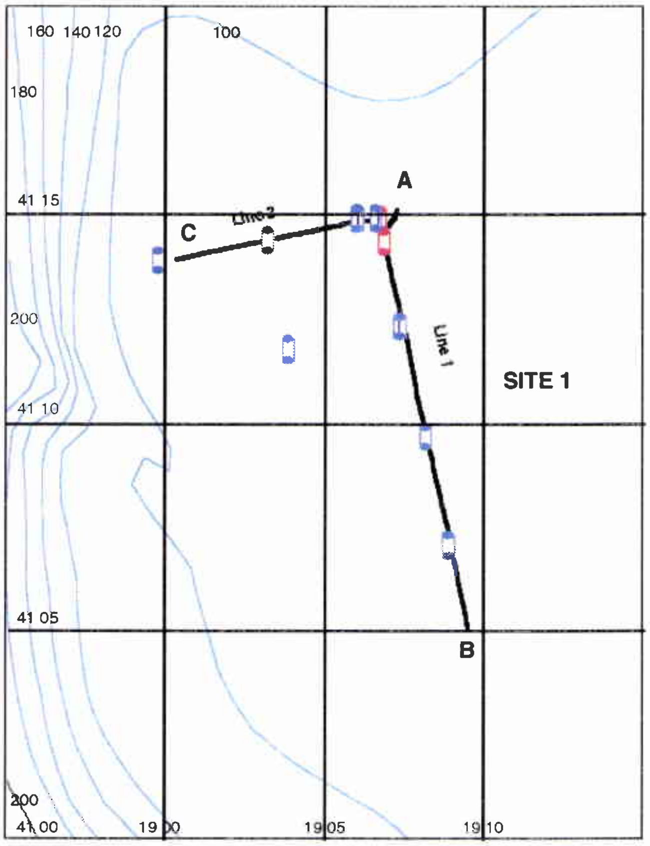

Figure 3. *Location of experiment site tracks in relation to the fixed receivers (vertical array hydrophones). The propagation loss curves in Figs. 5a–5d are from track 1. The curves in Figs. 6a–6d are from track 2. Core positions (icons, red for large cores on which velocities were measured; blue for small cores for sediment type, granulometry, and physical properties only.*

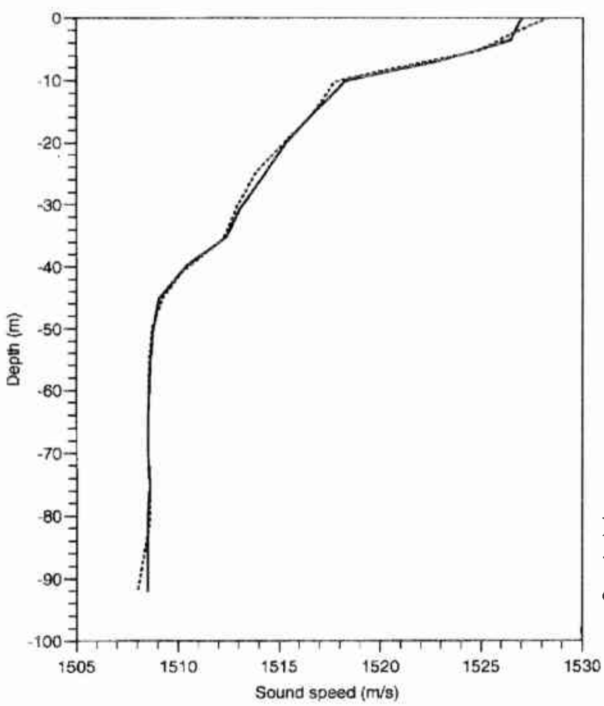

Figure 4. *Sound velocity profiles showing variation for site 1 during the course of the experiment.*

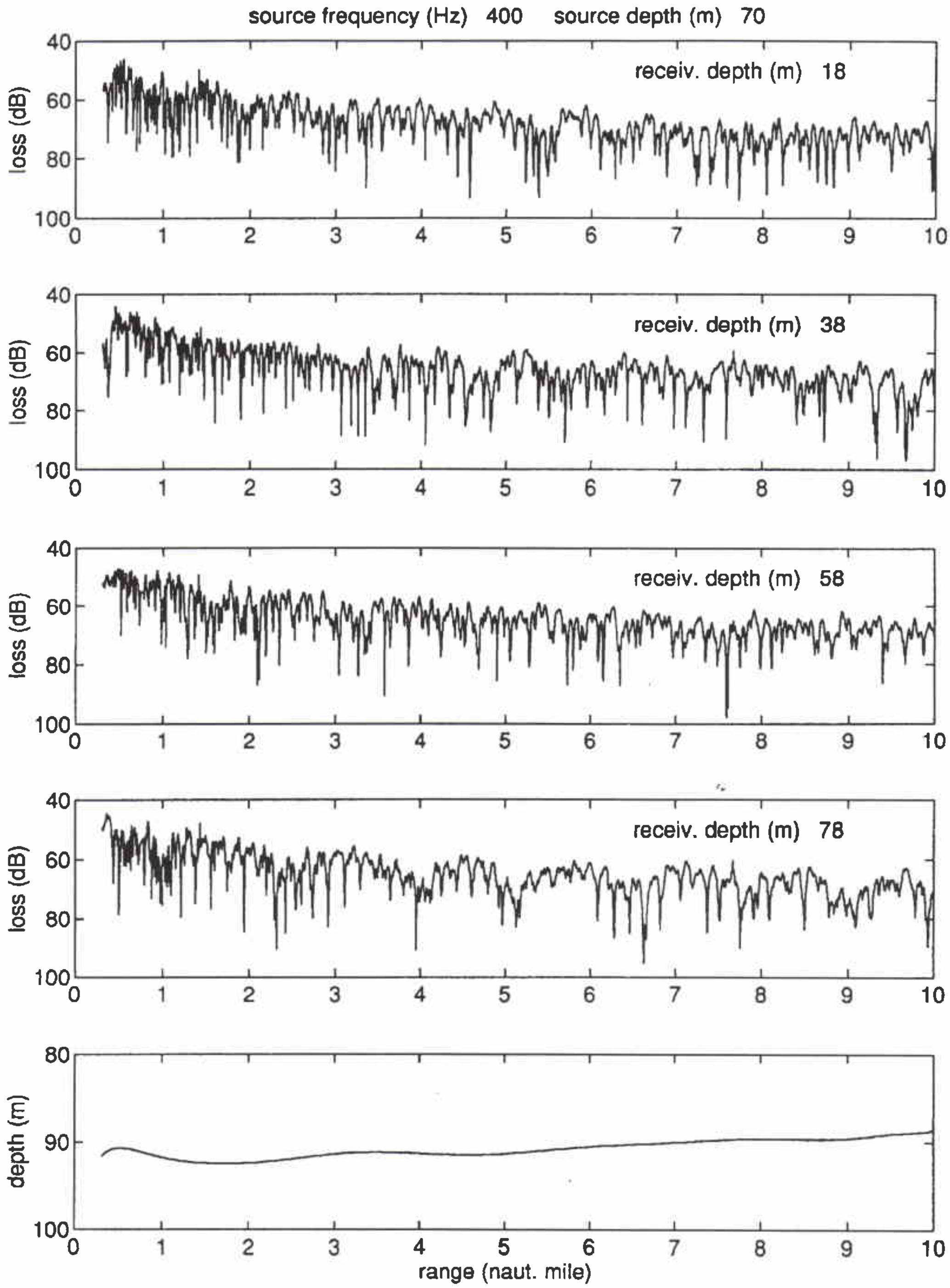

Figure 5a. *Experimental CW transmission-loss results for the N–S line 1 with a source depth of 70 m. Receivers are located at 18, 30, 58, and 78 m. Bathymetry plot for each figure along track. Source frequency 400 Hz.*

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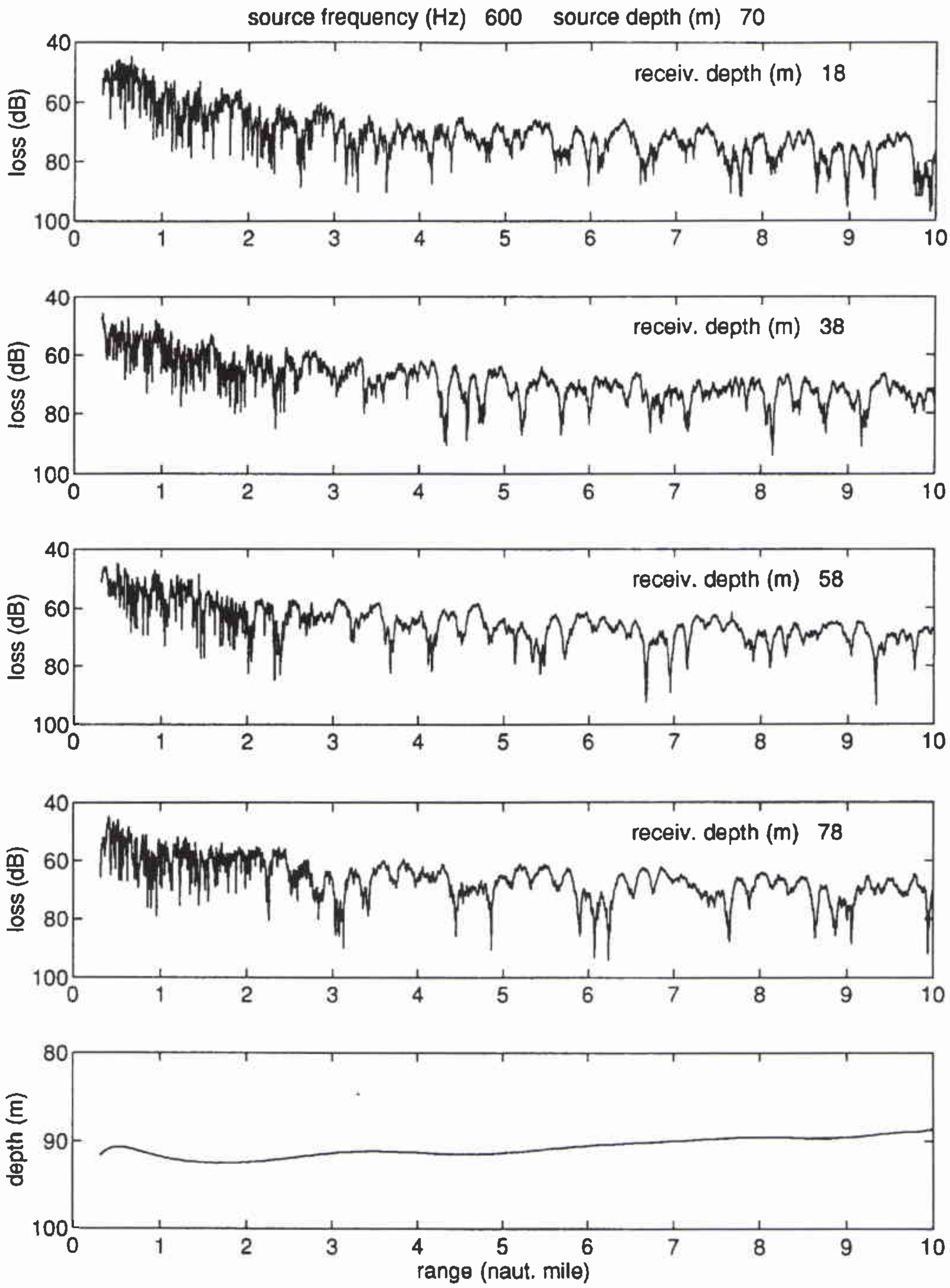


Figure 5b. *Experimental CW transmission-loss results for the N–S line 1 with a source depth of 70 m. Receivers are located at 18, 30, 58, and 78 m. Bathymetry plot for each figure along track. Source frequency 600 Hz.*

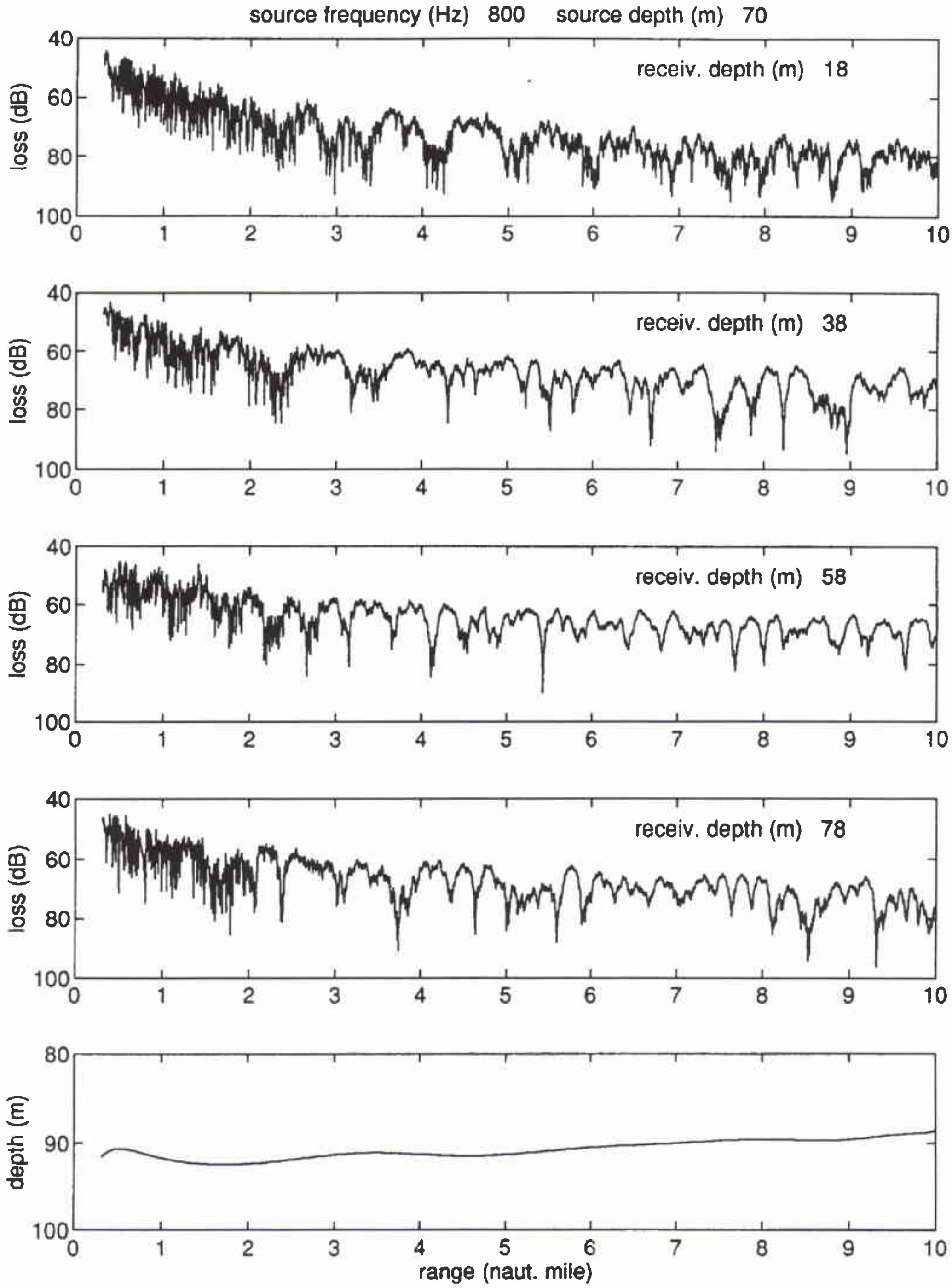


Figure 5c. *Experimental CW transmission-loss results for the N–S line 1 with a source depth of 70 m. Receivers are located at 18, 30, 58, and 78 m. Bathymetry plot for each figure along track. Source frequency 800 Hz.*

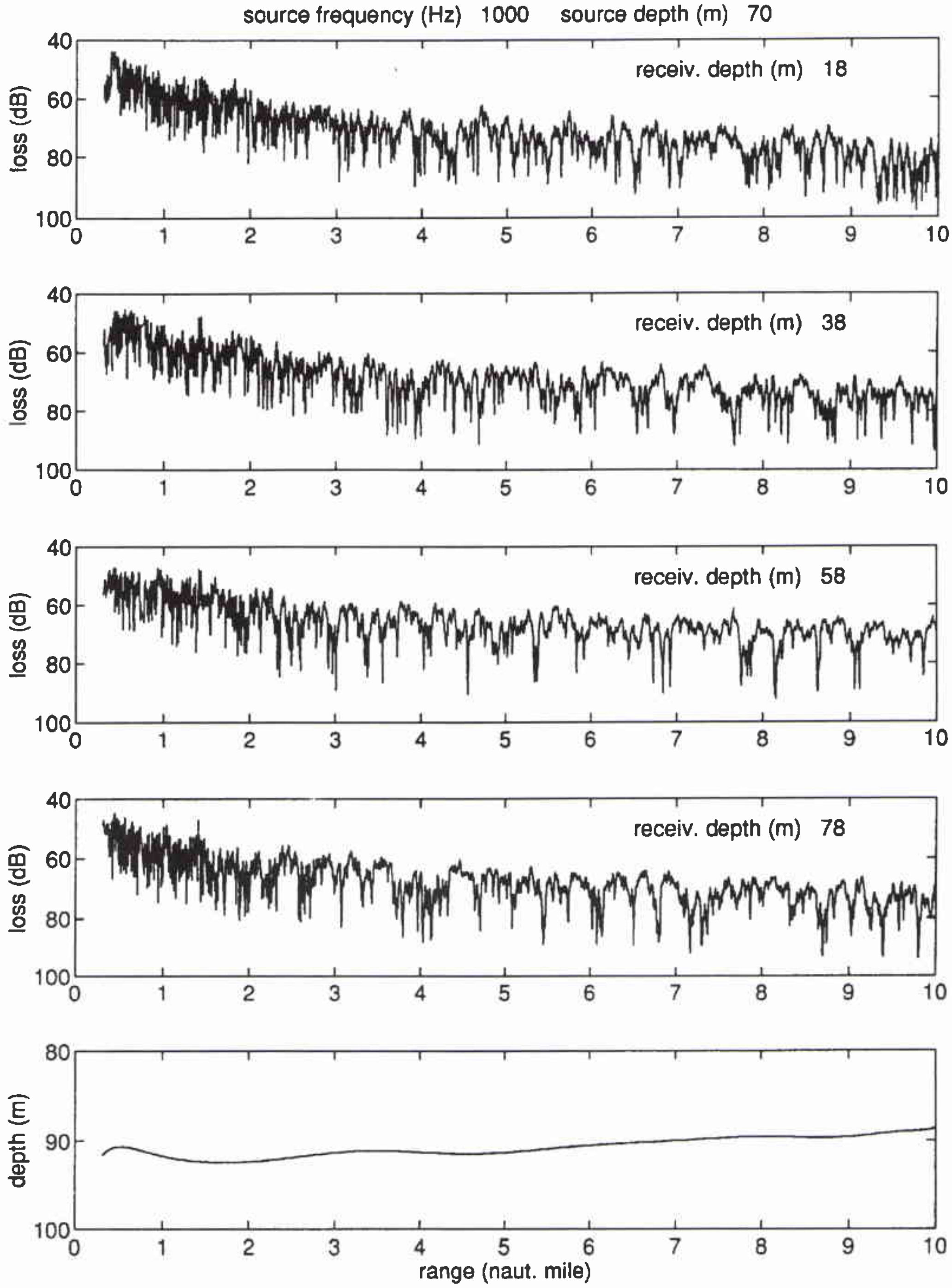


Figure 5d. *Experimental CW transmission-loss results for the N–S line 1 with a source depth of 70 m. Receivers are located at 18, 30, 58, and 78 m. Bathymetry plot for each figure along track. Source frequency 1000 Hz.*

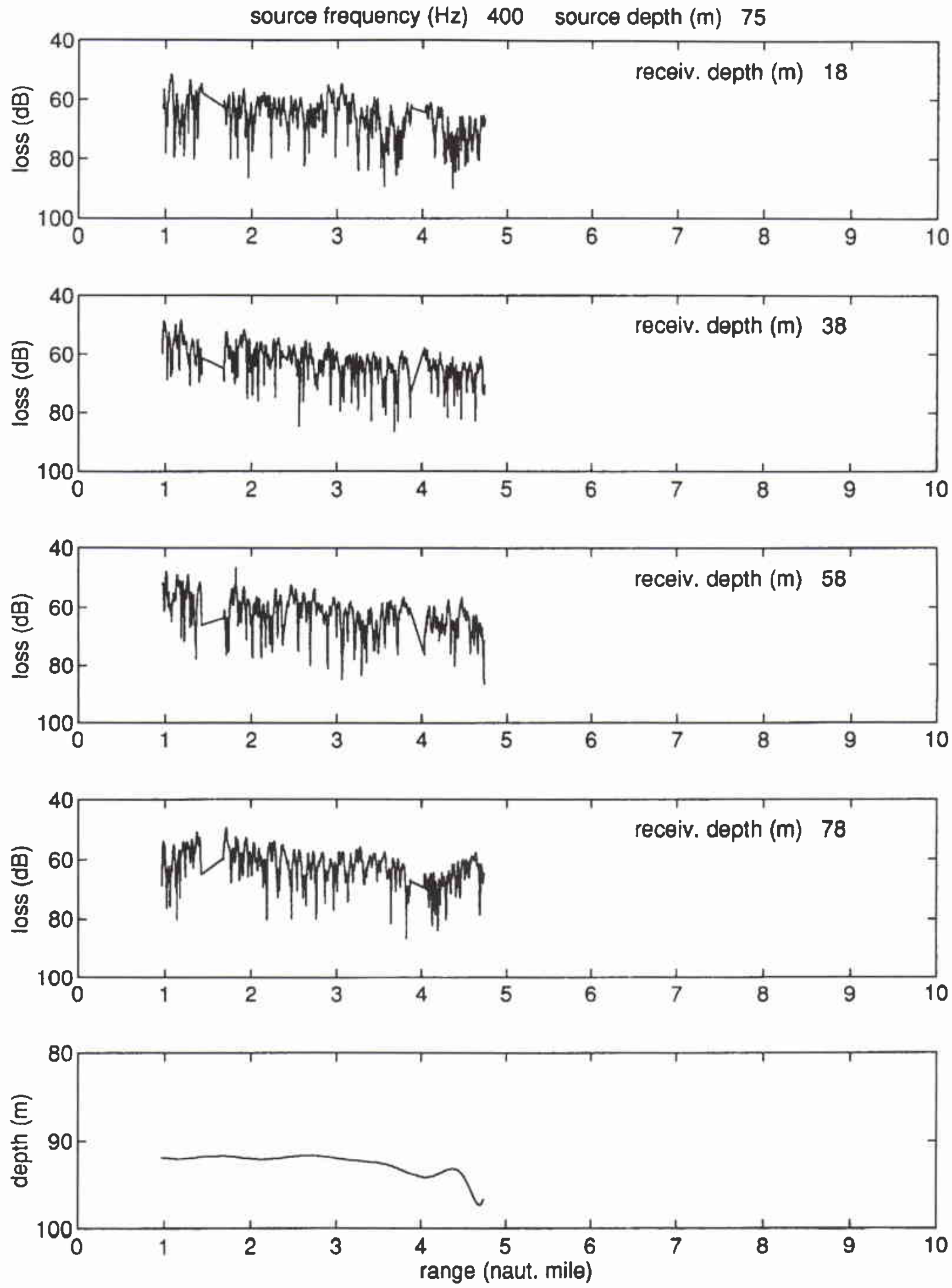


Figure 6a. *Experimental CW transmission-loss results for the E–W line 2 with a source depth of 75 m. Receivers are located at 18, 30, 58, and 78 m. Bathymetry plot for each figure along track. Source frequency 400 Hz.*

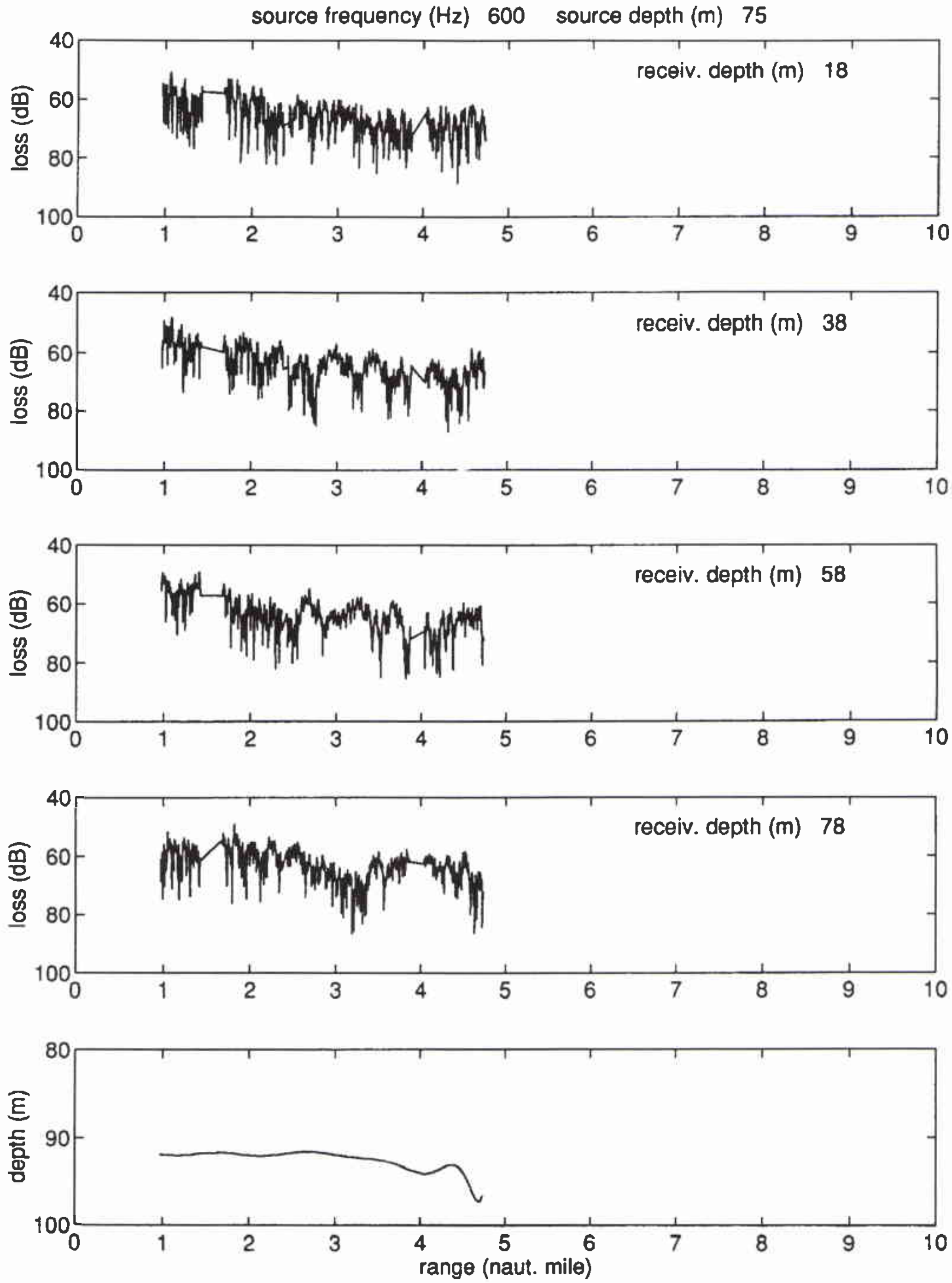


Figure 6b. *Experimental CW transmission-loss results for the E–W line 2 with a source depth of 75 m. Receivers are located at 18, 30, 58, and 78 m. Bathymetry plot for each figure along track. Source frequency 600 Hz.*

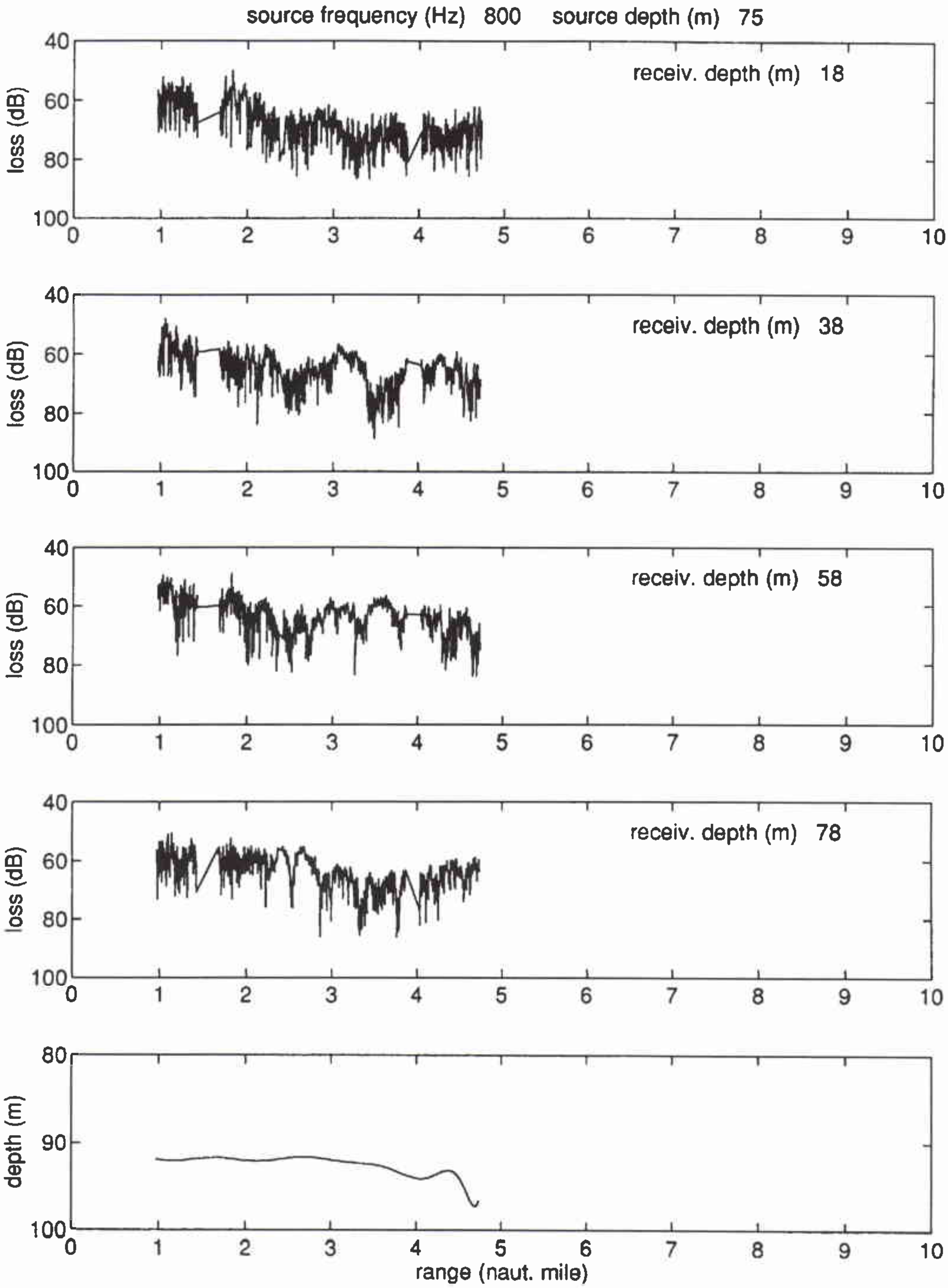


Figure 6c. *Experimental CW transmission-loss results for the E–W line 2 with a source depth of 75 m. Receivers are located at 18, 30, 58, and 78 m. Bathymetry plot for each figure along track. Source frequency 800 Hz.*

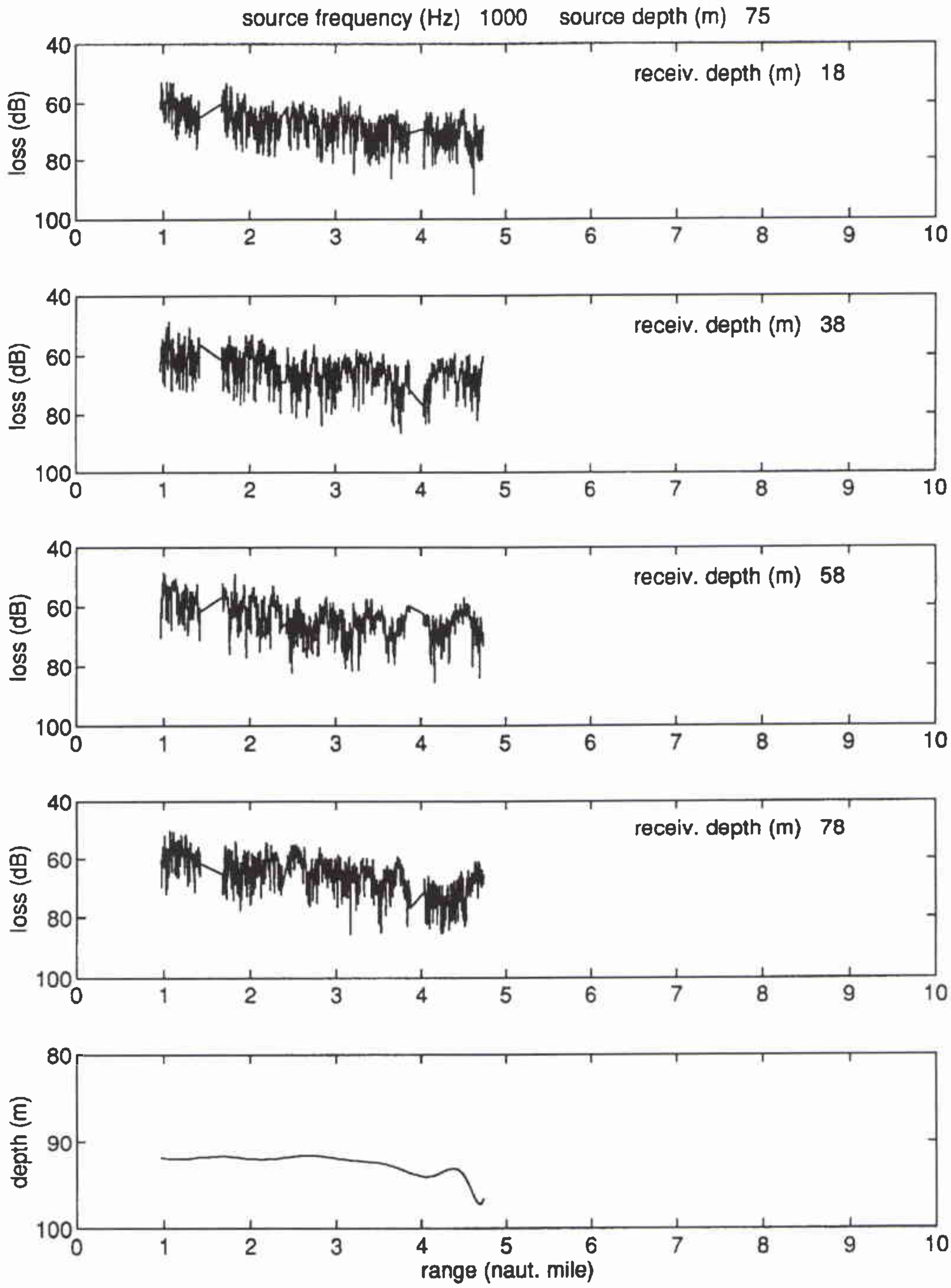


Figure 6d. *Experimental CW transmission-loss results for the E–W line 2 with a source depth of 75 m. Receivers are located at 18, 30, 58, and 78 m. Bathymetry plot for each figure along track. Source frequency 1000 Hz.*

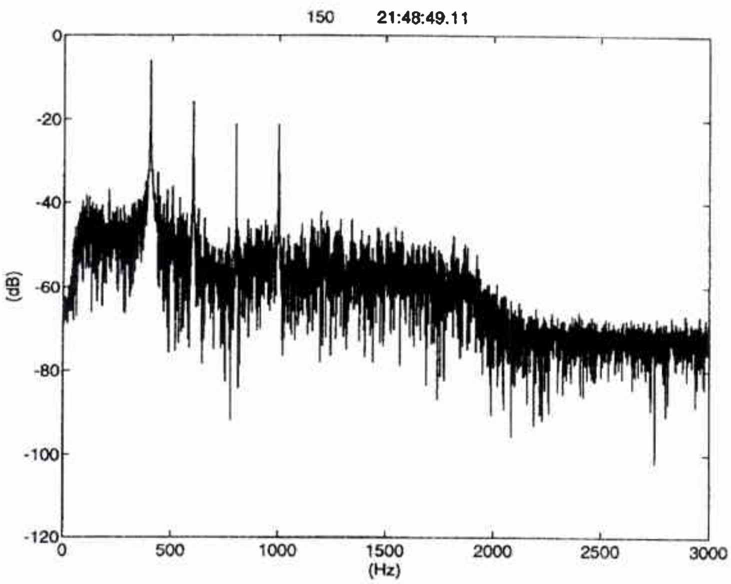


Figure 7. *Example of raw mean-square voltage spectrum (as received from about midway along track 1). The shape of the spectrum below 100 Hz and above 2 kHz is due to the whitening filter and anti-aliasing filter respectively.*

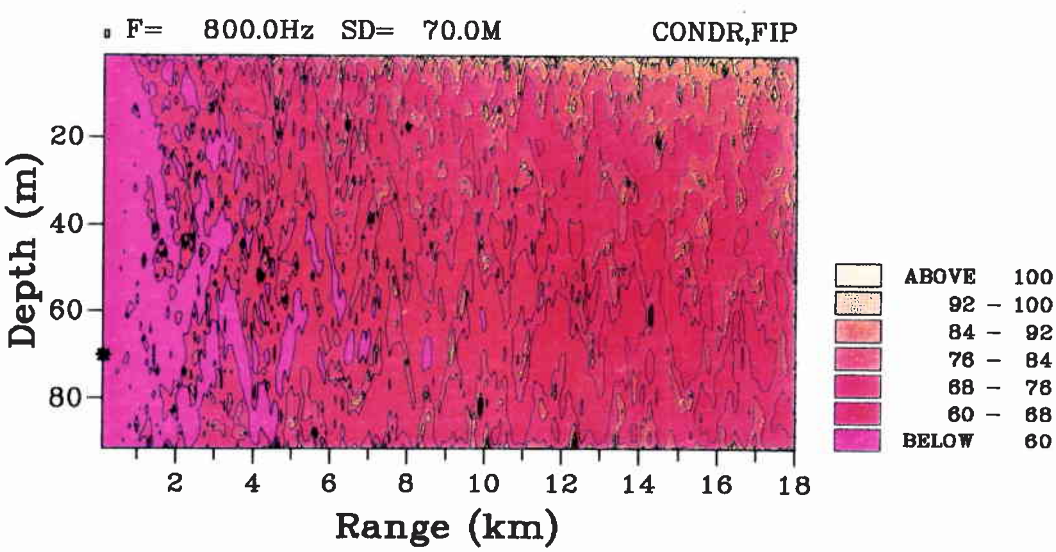


Figure 8. *Representative contour plot of the acoustic propagation.*

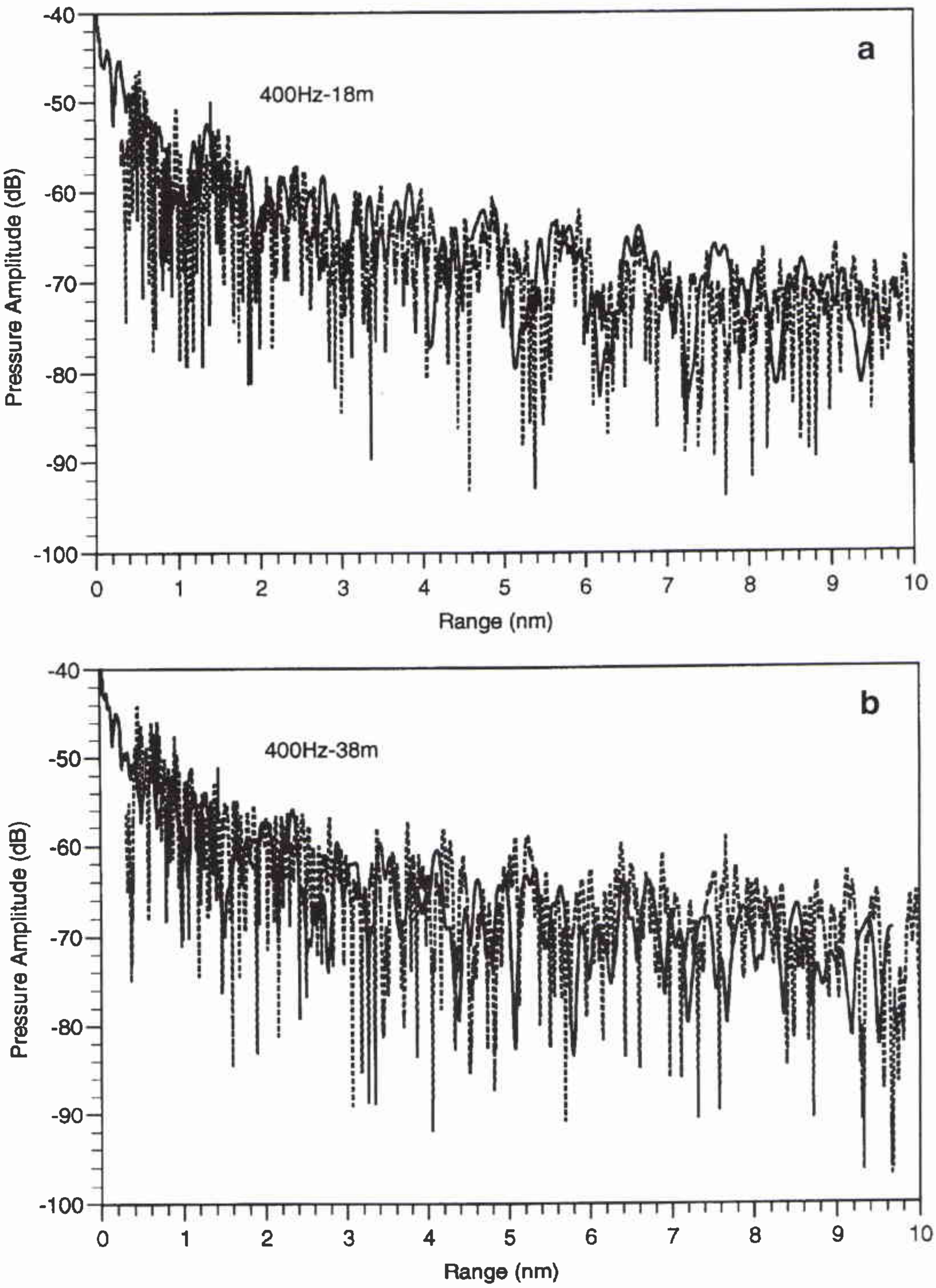
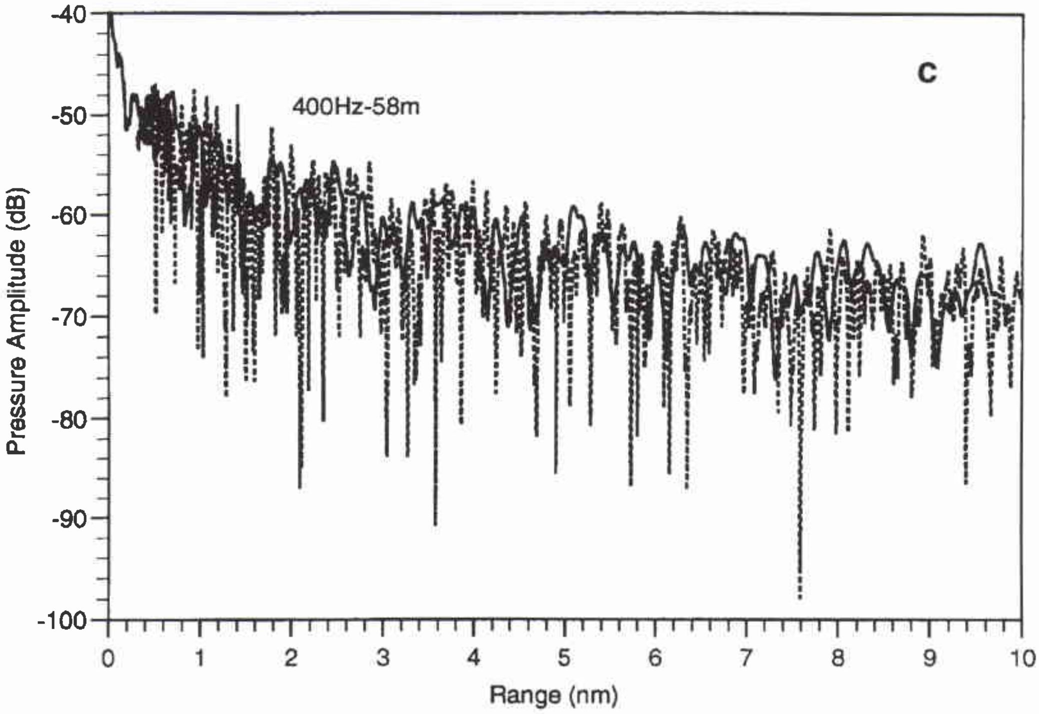


Figure 9a–9b. *Transmission-loss (dashed line) and modelled transmission-loss (solid line): (a) 400 Hz, 18 m: (b) 400 Hz, 38 m. Source depth, 70 m.*



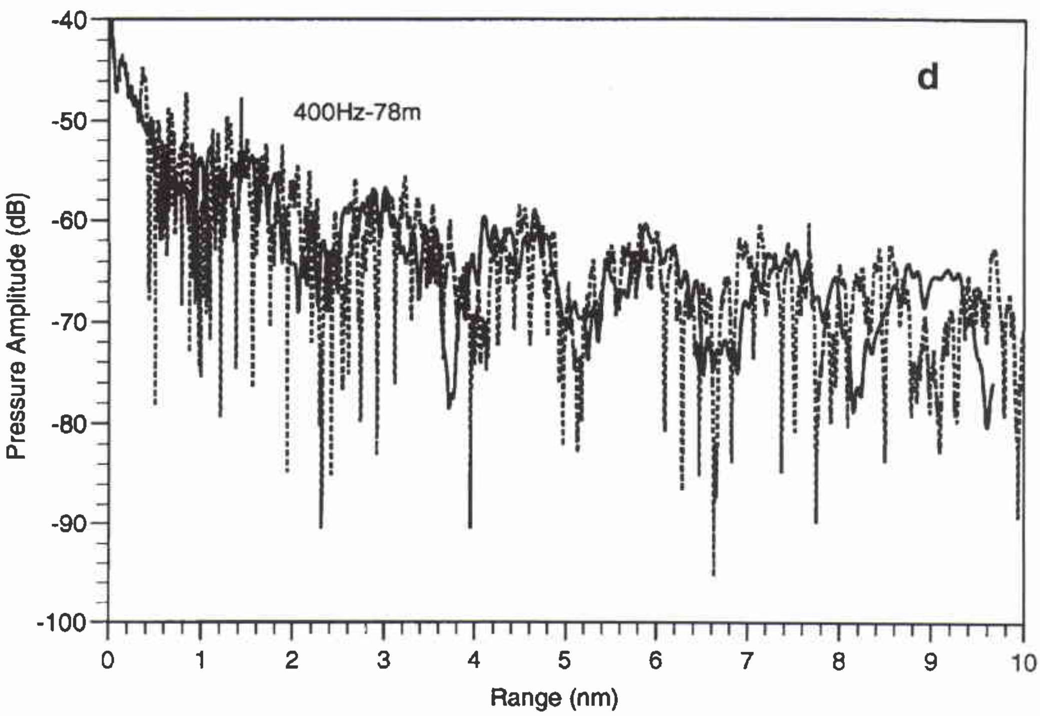
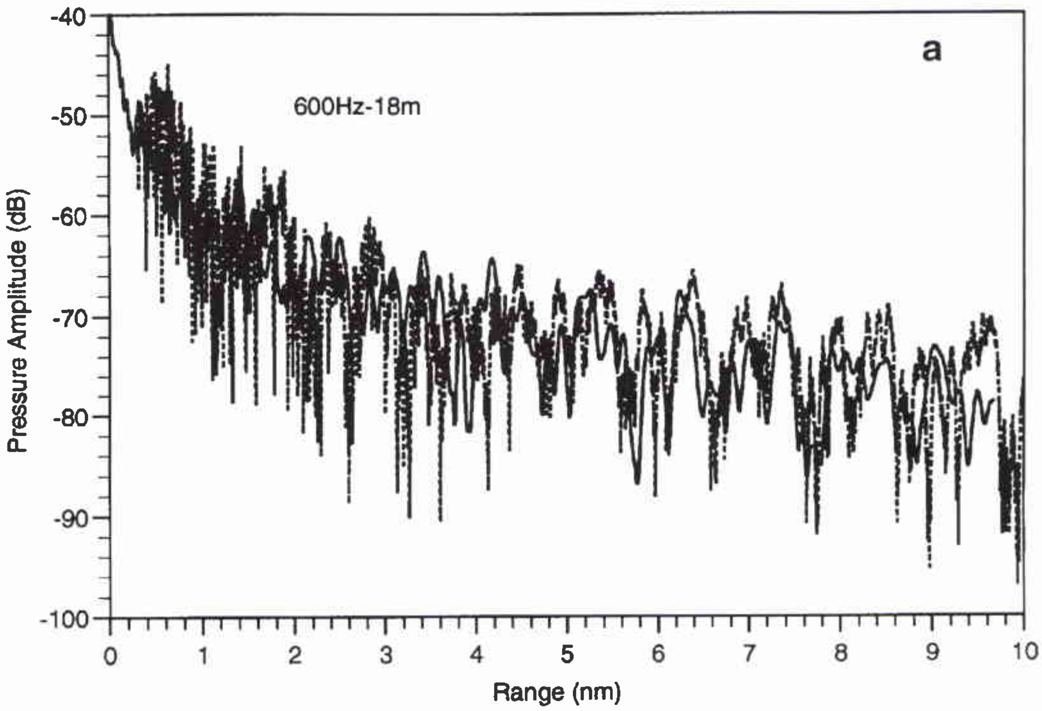


Figure 9c–9d. *Transmission-loss (dashed line) and modelled transmission-loss (solid line): (c) 400 Hz, 58 m: (d) 400 Hz, 78 m. Source depth, 70 m.*



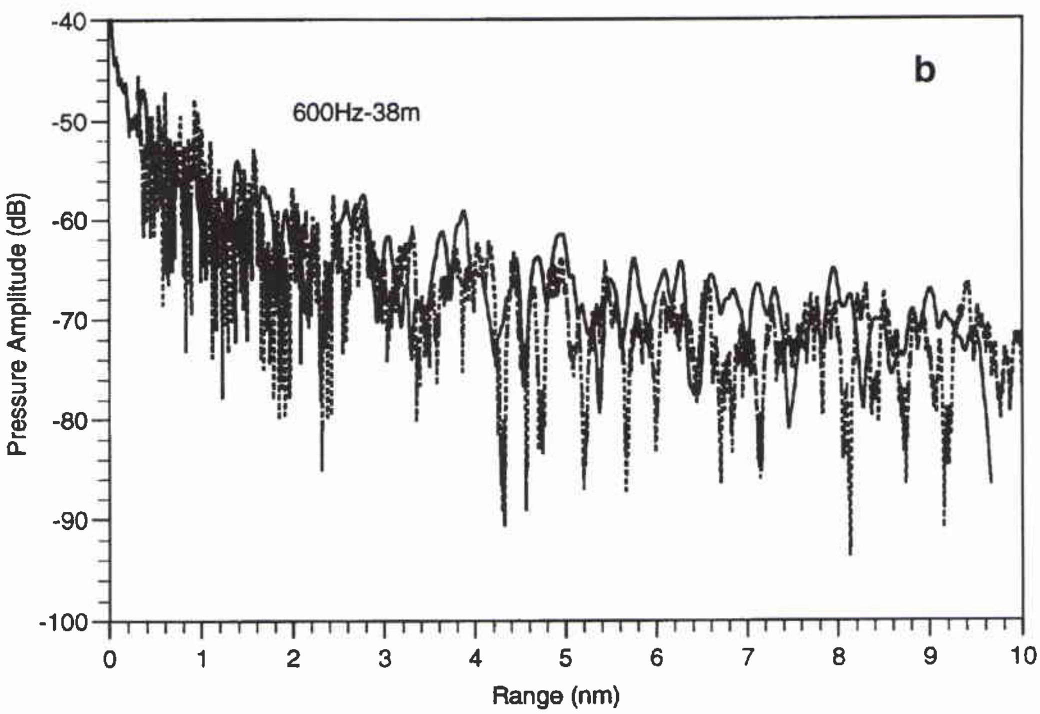
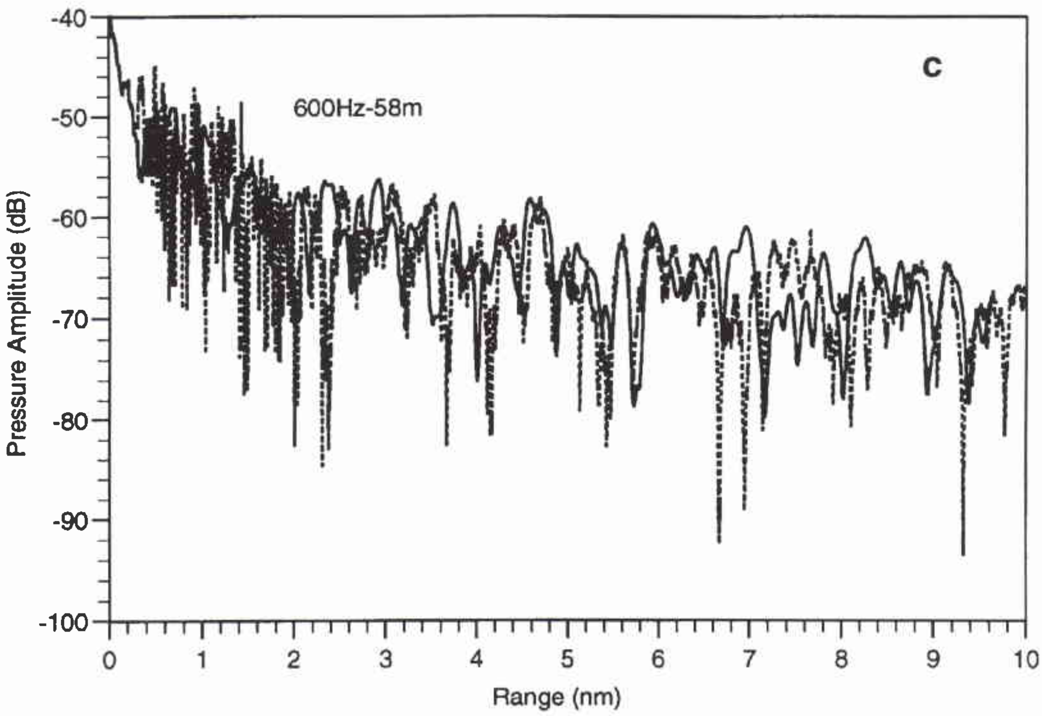


Figure 10a–10b. *Transmission-loss (dashed line) and modelled transmission-loss (solid line): (a) 600 Hz, 18 m: (b) 600 Hz, 38 m. Source depth, 70 m.*



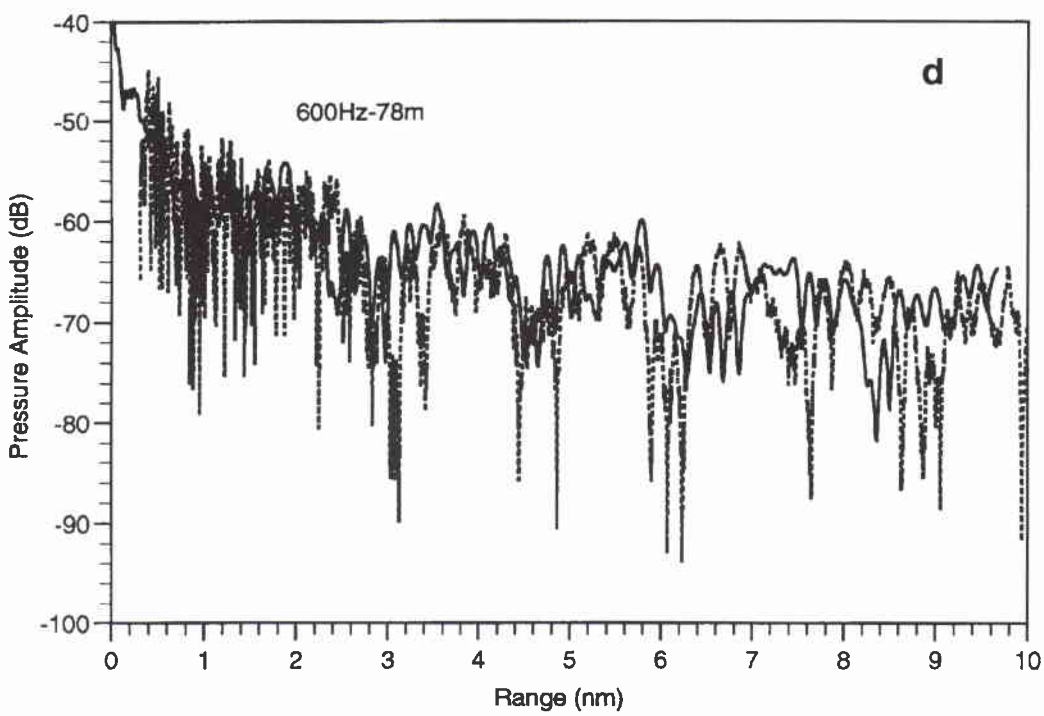


Figure 10c–10d. *Transmission-loss (dashed line) and modelled transmission-loss (solid line): (c) 600 Hz, 58 m: (d) 600 Hz, 78 m. Source depth, 70 m.*

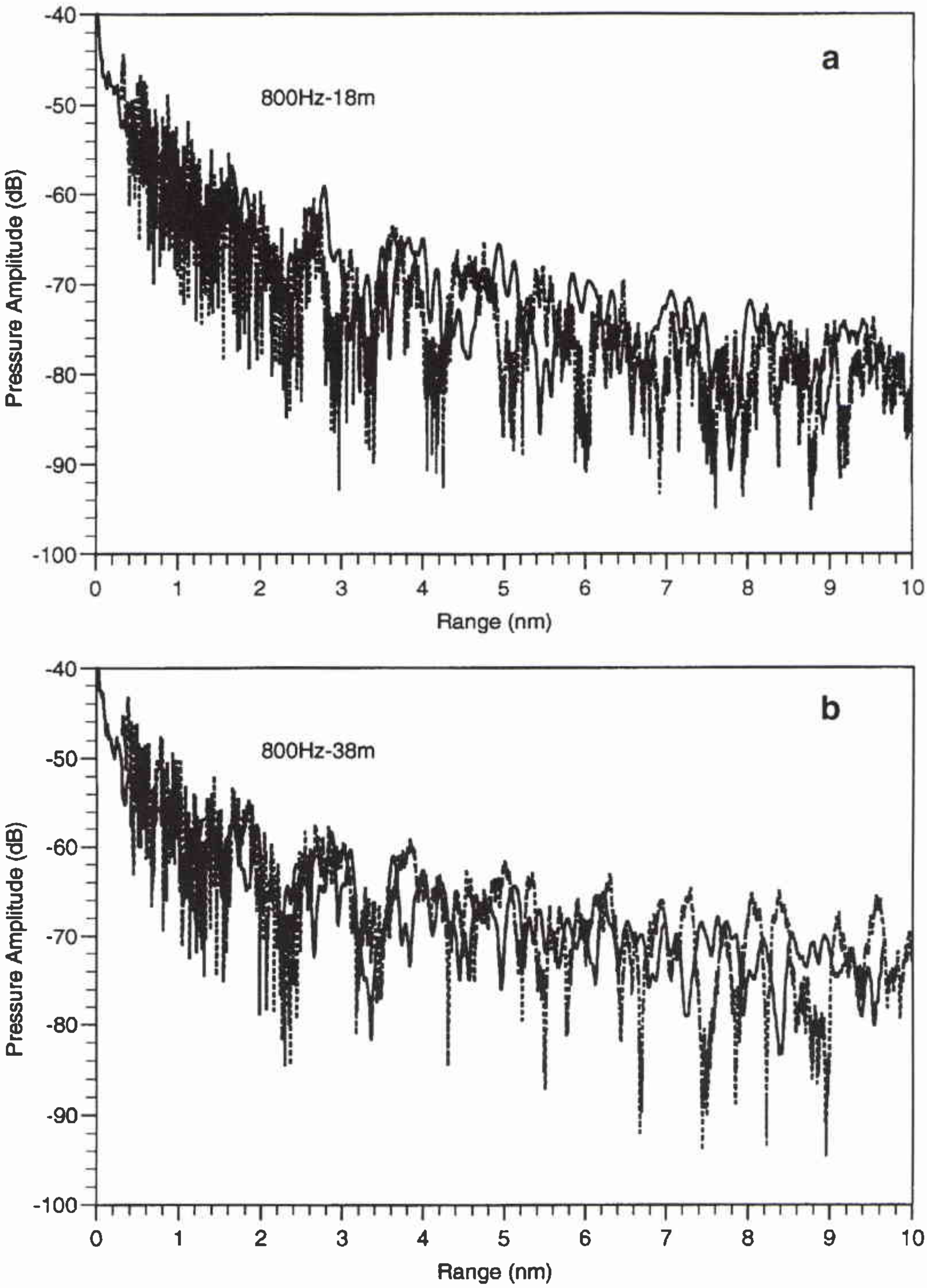


Figure 11a–11b. *Transmission-loss (dashed line) and modelled transmission-loss (solid line): (a) 800 Hz, 18 m: (b) 800 Hz, 38 m. Source depth, 70 m.*

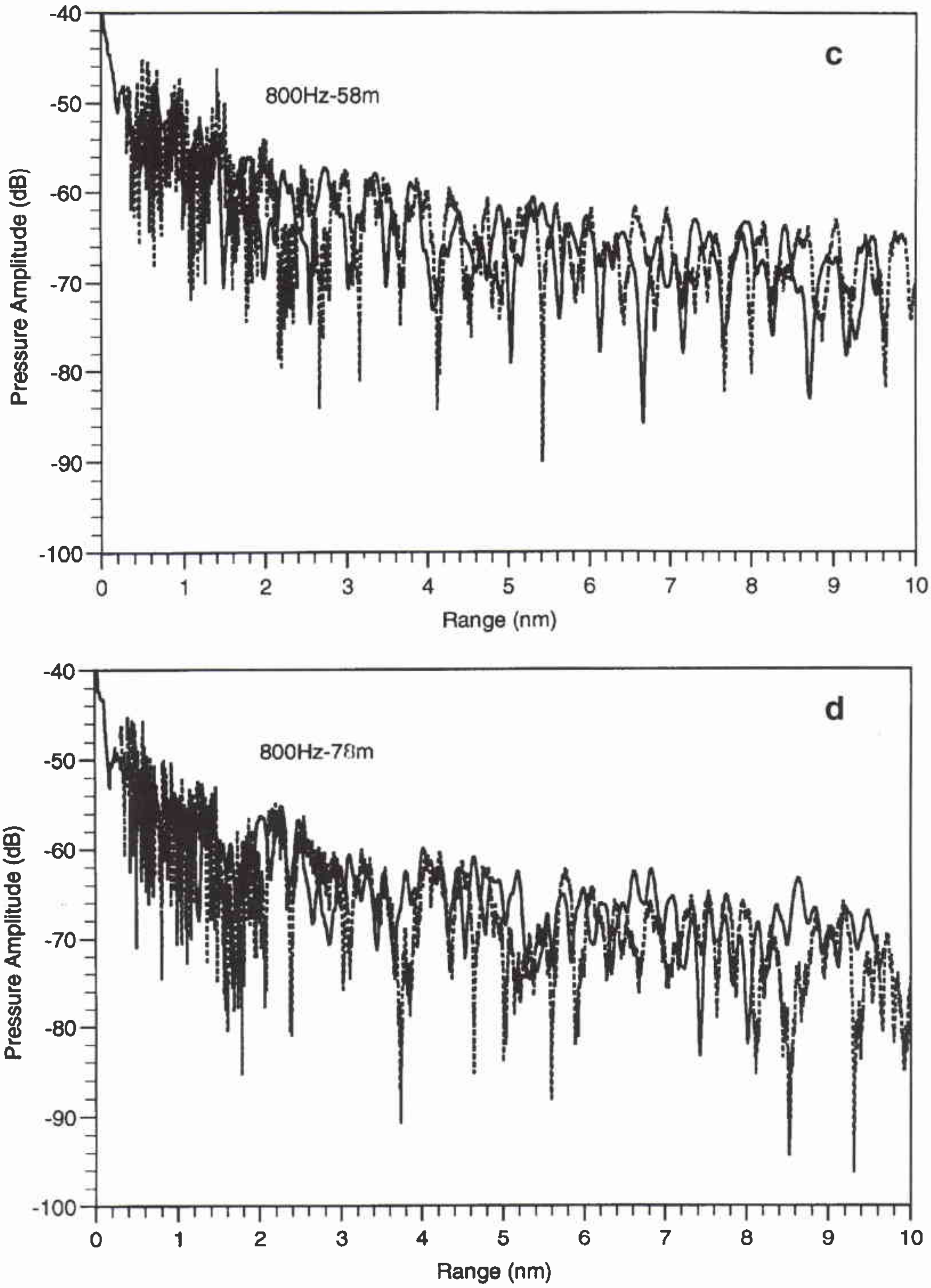


Figure 11c–11d. *Transmission-loss (dashed line) and modelled transmission-loss (solid line): (c) 800 Hz, 58 m: (d) 800 Hz, 78 m. Source depth, 70 m.*

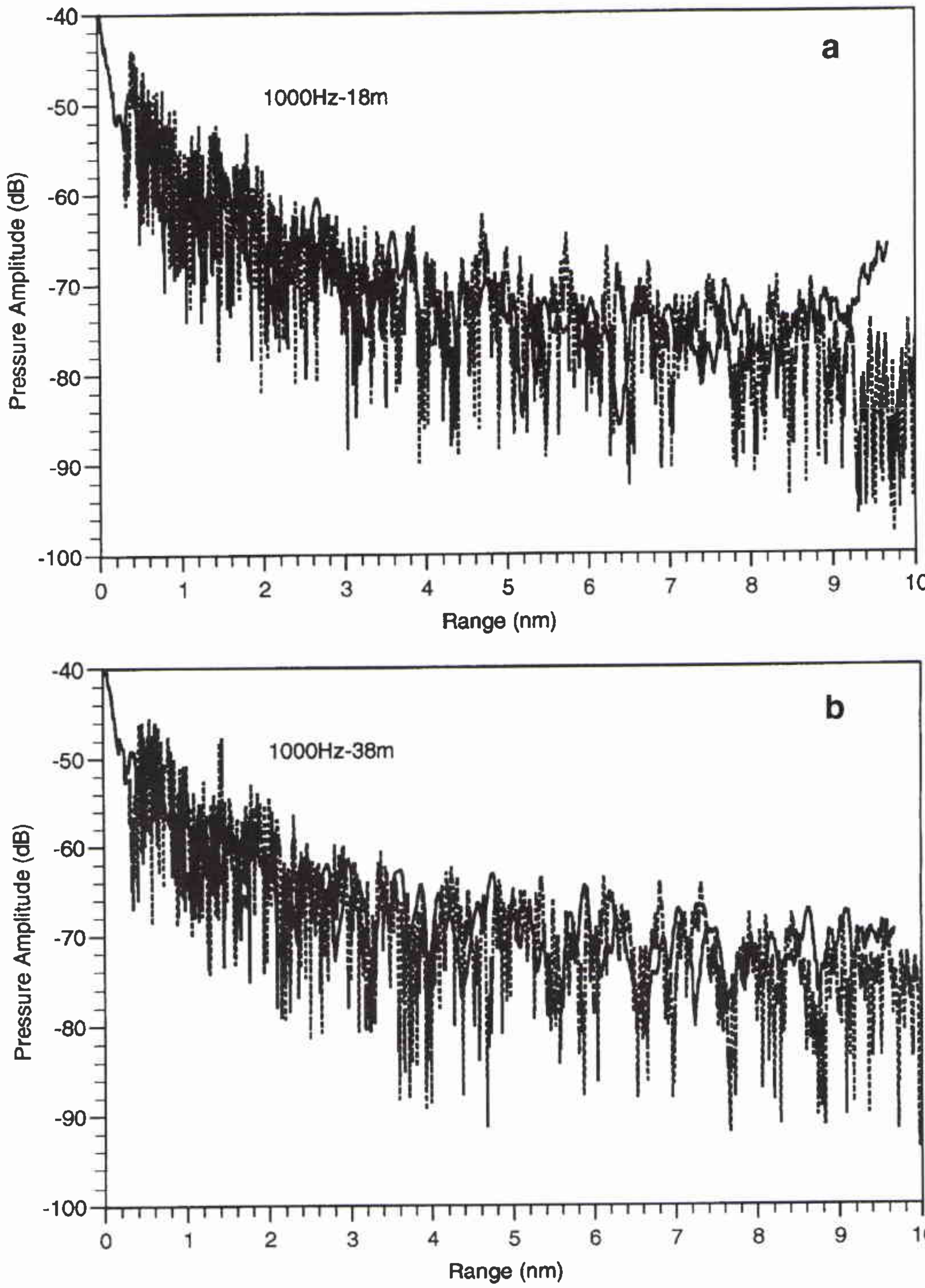


Figure 12a–12b. *Transmission-loss (dashed line) and modelled transmission-loss (solid line): (a) 1000 Hz, 18 m: (b) 1000 Hz, 38 m. Source depth, 70 m.*

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M.D. Max, R. Hollett, J. Fawcett and J. Berkson

Title

Transmission-loss characteristics and geoacoustic model for the outer Albanian continental shelf platform in the SE Adriatic Sea

Abstract

Transmission-loss experiments have been carried out on the outer Albanian Shelf. The acoustic measurements were performed together with a combined oceanographic and geological-geophysical survey which identified the different bottom types and their boundaries. Data and modelling are presented, along with an indication of the area of the Albanian Shelf for which the geoacoustic profile and transmission loss results are thought to pertain.

Keywords

Albanian Shelf – transmission loss – Adriatic

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SACLANT Undersea Research Centre
Viale San Bartolomeo 400, 19138 La Spezia,
Italy

*[From N. America: SACLANTCEN CMR-426
(New York) APO AE 09613]*

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