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NRL Report 7819
(Revised)



# Depth and Seasonal Dependence of Ambient Sea Noise Near the Marginal Ice Zone of the Greenland Sea

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April 1, 1976



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Washington, D.C.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER (14) NRL Report 7819-(Revised) NP | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER (9) |
| 4. TITLE (and Subtitle) (6) DEPTH AND SEASONAL DEPENDENCE OF AMBIENT SEA NOISE NEAR THE MARGINAL ICE ZONE OF THE GREENLAND SEA. | | 5. TYPE OF REPORT & PERIOD COVERED Interim report on a continuing NRL problem. |
| | | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s) (10) James R. McGrath | | 8. CONTRACT OR GRANT NUMBER(s) (16) NRL-S01-47, ZF52-552 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, D.C. 20375 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (17) NRL Problem S01-47 NUC ZF52-552-001 (15) ARPA Order-1781 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Navy Naval Materiel Command Washington, D.C. 20360 | | 12. REPORT DATE (11) 1 Apr[redacted]976 |
| | | 13. NUMBER OF PAGES 31 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) (12) 32p. | | 15. SECURITY CLASS. (of this report) Unclassified |
| | | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Acoustic instrumentation
Ambient noise
Ice floe noise
Marginal ice zone
Sea noise

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)


Omnidirectional data from seasonal and short-term (several days), depth-dependent ambient sea-noise measurements in the 20-to-600-Hz band near the marginal ice zone were recorded in the deepwater basin of the Greenland Sea. Two bottom-anchored, self-supporting buoys, one of which recorded acoustic data for 9 months, were used.

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The first experiment, conducted between Aug~~ust~~ 1972 and July 1973, recorded 1-min samples of sea noise every 4 h from an omnidirectional hydrophone 306 m below the surface. During this time, the ice edge moved over the recording site, providing evidence that the iceline acts as a noise source, raising local levels above both open-ocean and icefield values. Seasonal conditions favor the lowest ambient noise levels during midwinter (Jan~~uary~~) and early summer (June), while the highest levels occur during early spring (March) and early fall (Nov~~ember~~). Evidence indicates that the maximum ambient noise levels near the marginal ice zone are 12 to 16 dB higher than the maximum Arctic Ocean values under contiguous ice cover.

The second experiment, ~~was~~ conducted over a 5-day period, ~~and~~ recorded ambient noise at depths of 241, 1,232, 1,537, and 2,375 m. Results indicate that ambient noise levels near the ice edge within the water column depend on speed and direction of wind.

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CONTENTS

# DEPTH AND SEASONAL DEPENDENCE OF AMBIENT SEA NOISE NEAR THE MARGINAL ICE ZONE OF THE GREENLAND SEA

## INTRODUCTION

### Review

Arctic ambient sea-noise levels are affected primarily by ice cover [1], according to measurements made in the shallow water of the Canadian Archipelago [2-6], in the deep water of the Beaufort Basin [7-8], and in the Gulf of St. Lawrence [9-10]. Spectral lines with levels well above broadband ambient noise levels have been observed [2,11] at frequencies below 10 Hz in shallow water. They are attributed to the excitation of standing waves between the surface and bottom. Amplitude-distribution differences [3] between spring and summer measurements suggest that several different physical mechanisms act on the ice cover to produce noise. Some of these have been resolved [4] into temperature- and wind-dependent effects. Decreasing air temperatures shrink the ice surface, which relieves the resulting surface stresses by cracking. This impulsive disturbance propagates through the ice cover into the water and is responsible for non-Gaussian amplitude distributions. Further measurements [5,6] have confirmed the temperature dependence of ambient noise recorded during the winter and spring, with noise levels raised as much as 30 dB in the 100- to 1000-Hz band. Wind blowing snow across the ice produces sound intensities proportional to the 5.3 power of windspeed [4] (levels increase 16 dB each time the windspeed doubles). As a result, ambient noise levels and statistics associated with extensive icefields differ from open-ocean data. These results relate almost exclusively to measurements under shore-fast, consolidated, and moving icefields.

Few measurements have been made under marginal icefields in the deep ocean basins, however, and none have been made throughout the year. Until recently, the boundary between the marginal ice zone and the open ocean has received little study. Short-term measurements (several hours in duration) [12] during 1971-1972 in the 100- to 1000-Hz band indicate that the boundary acts as a local noise source, raising levels by about 12 dB over open-ocean levels and 20 dB over levels found under the icefield.

### Purpose and Location of NRL Experiment

Three objectives were established for these acoustic measurements in the 20- to 600-Hz band. The first was to determine the effect of depth on ambient noise by recording for several days at several depths in a deep basin, near but outside the marginal ice zone. The second was to measure the long-term variability (over a period of about a year) of sea noise at the same type of site. The site locations are shown in Fig. 1a. The third objective was to relate these acoustic data to season, weather, icefield movements, and manmade sources of noise.

Manuscript submitted January 14, 1976.

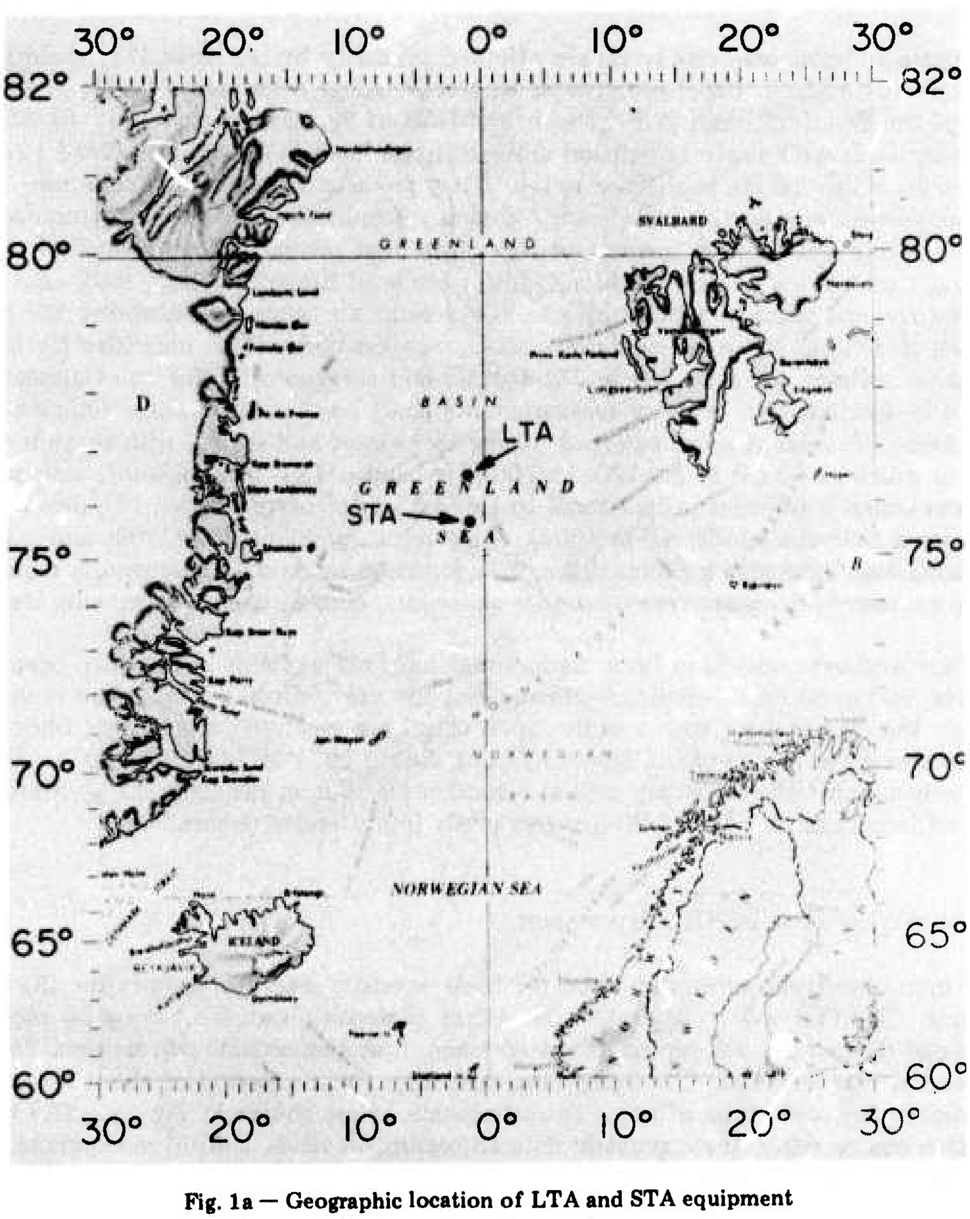


Fig. 1a — Geographic location of LTA and STA equipment

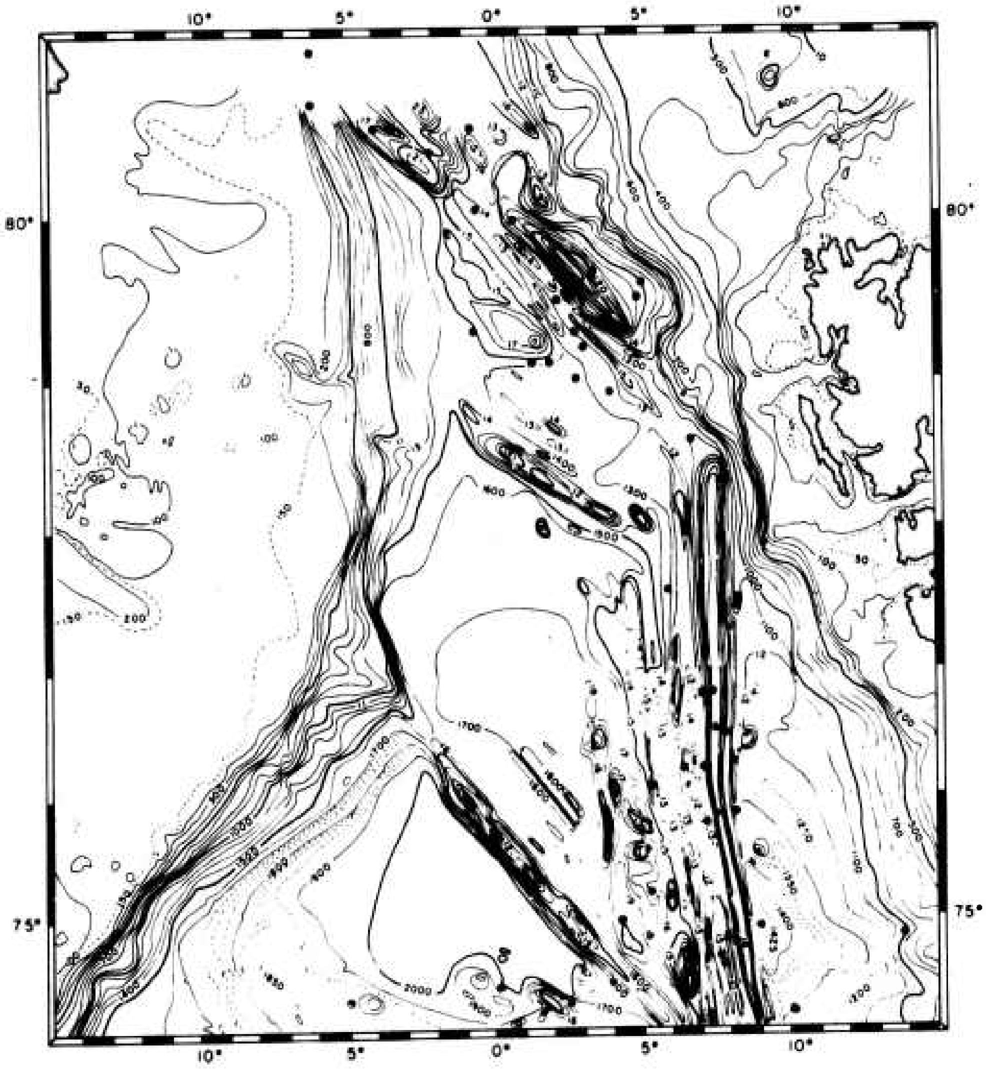

Fig. 1b — Bathymetry of northern Greenland Sea. Small dots indicate epicenter locations.

Two ambient-noise buoys (ANB) were adapted to meet these objectives. Both were deployed from the USNS *Hayes* (T-AGOR 16) in August 1972 and were anchored in the Boreas Abyssal Plain of the northern Greenland Sea. The buoy sites are in about 3000 m of water, 20 n.mi. north of the ridge system delineating the Greenland Fracture Zone. The ridge itself rises 1000 to 1500 m above the ocean floor. Figure 1b shows the bathymetry of the northern Greenland Sea [13, Fig. 2].

The short-term unit was recovered during the same cruise, and the long-term unit was recovered by *Hayes* a year after deployment. Details of the acoustic instrumentation, as well as compilations of data, are given in Appendix A. This report presents and discusses the data on variation of ambient noise with depth and with season near the marginal ice zone.

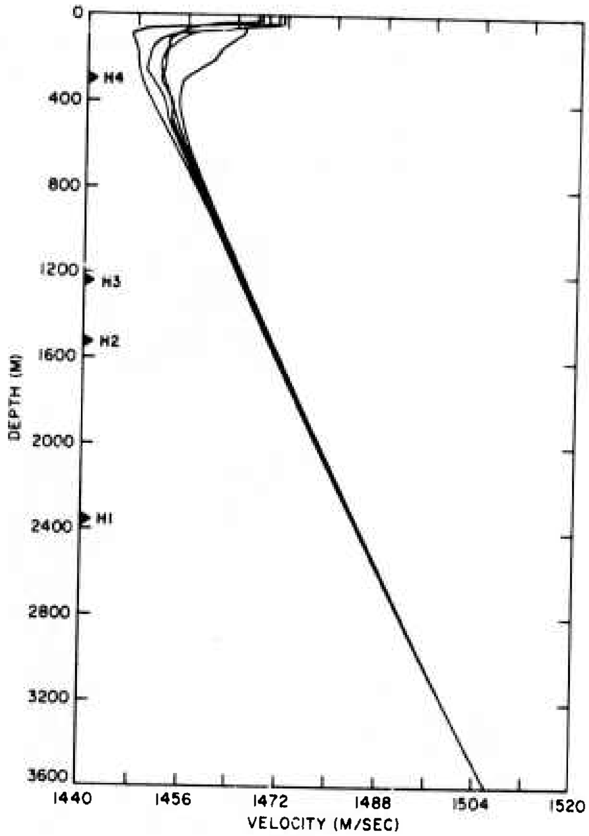


Fig. 2 — Profiles of sound speed vs depth for October

## SHORT-TERM EXPERIMENT AND RESULTS

### General Description and Results

Noise measurements were made between 1600Z, August 27, 1972, and 1200Z, September 1, 1972, at 76°37.1′N, 00°57.5′W (35 km east of the marginal ice boundary) using a short-term ANB (STA) anchored in 3060 m of water. Satellite navigation was used to provide position information; windspeed data were obtained from the *Hayes'* log. A narrow-beam echo sounder provided water depths in uncorrected fathoms. Ice cover at the boundary was diffuse to nearly contiguous, covering 70% of the area in the boundary zone and nearly 90% a few kilometers into the icefield. At the boundary the ice cover consisted of young to year-old ice floes 2-30 m in diameter, with thicknesses up to 2.5 m. The ice boundary extended in places as much as 1 km into the open ocean because of currents and wind. The STA recorded ambient noise between 20 and 600 Hz, for 1 h out of every 4, for each of four hydrophones at depths of 241, 1232, 1537, and 2375 m. Hydrophone depths were chosen to record noise in the sound channel, near and at the critical depth, and well below the critical depth. Archival data shown in Fig. 2 were used to determine the critical depth (about 1600 m for the month of October) within a radius of 50 n.mi. of 76°N, 0°W. After recording 30 1-h samples of data, the STA was released by acoustic techniques and recovered by *Hayes* on September 1.

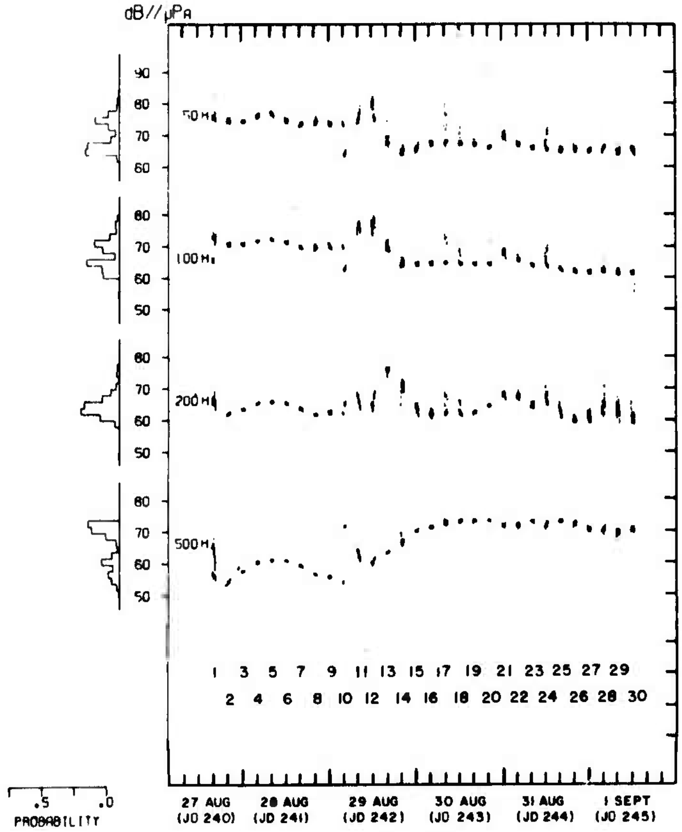


**Fig. 3 — Hydrophone data, 241-m depth**

## Time-Series Data

Figures 3-6 present 30 ambient noise samples for each of the four hydrophones, recorded during the STA deployment period. Each sample is resolved into 60 1-min averages of third-octave levels adjusted to 1-Hz bands centered at 50, 100, 200, and 500 Hz. The sound-pressure spectrum level (SPSL) scale, dB||μPa, is shown to the left of its associated time series. The center frequency is listed above its time series. The date and Julian day (JD) are given at the bottom of each figure. Details of the data-processing technique are discussed in Appendix A. The shallowest hydrophone developed electrical problems at the beginning of the 24th sample; subsequent data are not included in Fig. 3.

Ship passages in the area near the STA site (confirmed by aural monitoring) are evident from the acoustic data scatter in several samples (1, 14-18, 21, 24, and 30). Because the sound-channel axis is shallow (about 150 to 200 m at this latitude), ships are especially noticeable at considerable distances in the 50- to 200-Hz data of the 241-m hydrophone. Ship noise in samples 1, 21, and 30 is attributable to *Hayes*, which was within 10 n.mi. of the site at those times, raising levels even at 500 Hz. Other ship noise was due to a large nearby ship that remained in the vicinity during *Hayes*' operations.

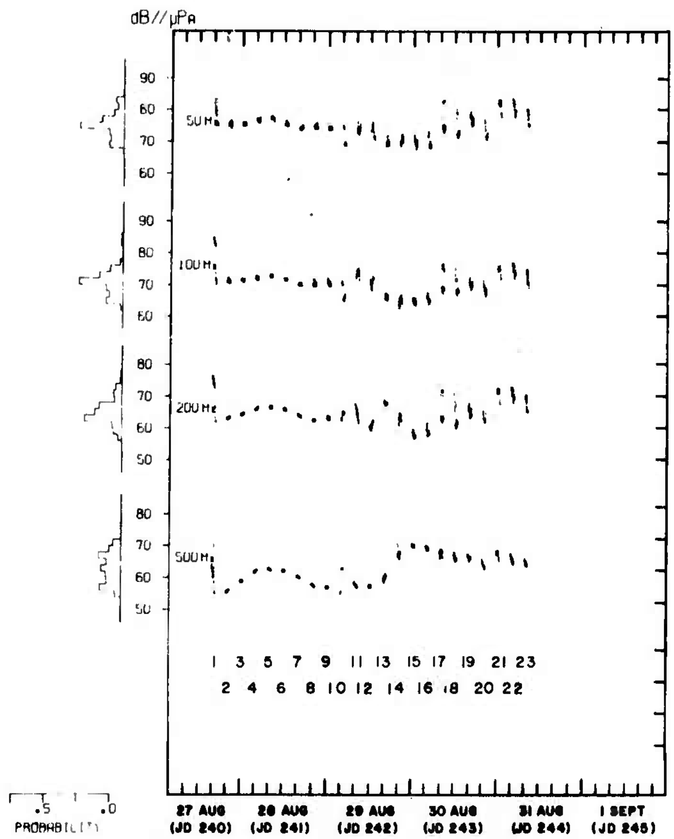

Fig. 4 — Hydrophone data, 1232-m depth

Figure 7a summarizes environmental observations and acoustic data from the deep hydrophone at frequencies of 50, 100, and 500 Hz, while Figure 7b shows navigation observations from the logs of *Hayes* and USNS *Mizar* and chronological information related to acoustic-source operations. During the STA recording periods, the mean windspeed was about 17 knots, corresponding to an average sea state between 3 and 4. *Mizar*'s range from the STA site was never less than 260 n.mi.; it influenced recorded noise levels during acoustic-source operations. The acoustic sources used during the experiment were air-guns, CW projectors, and explosives. *Hayes*' range, however, varied from 10 mm to about 120 mm during the STA recording period. Probably for this reason, the comparison between noise levels—especially at and above 100 Hz—and windspeed lack anticipated agreement with noise level estimates from Wenz's curves.

Air-gun tows were made by *Hayes* for the first 15 min of the recording periods of samples 14-19 and 22. Evidence of other air-gun operations (origin uncertain) has been identified during aural monitoring of the STA recording in samples 3, 6, and 9. Two CW-projector tows were made only by *Mizar*. One projector was towed at a depth of 20 m and operated at 116 Hz, and another was towed at a depth of 50 m and operated at frequencies of 10 to 29 Hz. The spectral characteristics of explosive acoustic sources, in addition to those of other acoustic sources, are shown in Figs. 8a and 8b.

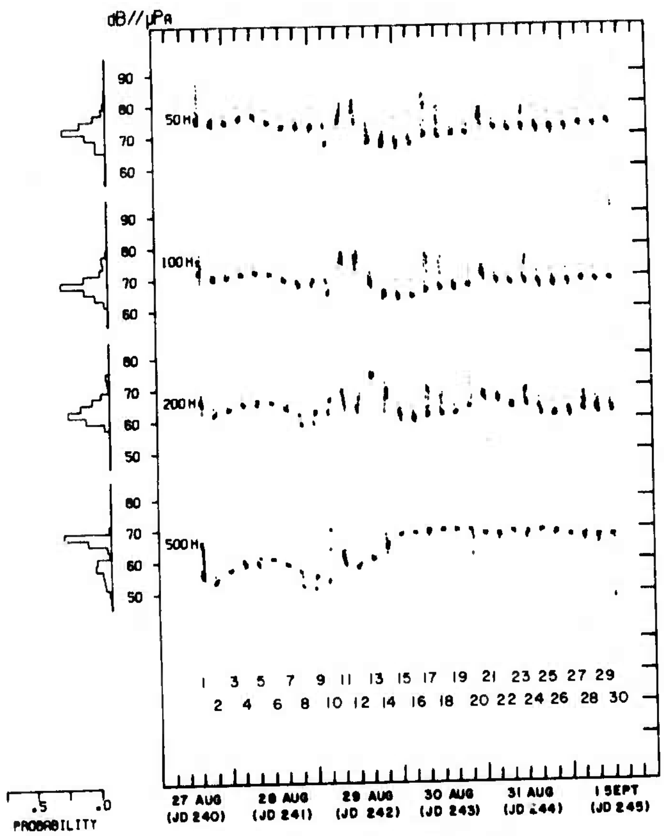


Fig. 5 — Hydrophone data, 1537-m depth

Two weather fronts passed the STA site during the recording period, while the marginal ice boundary was 30 to 35 km away. The first approached from the icefield (northeast of STA) between samples 4 (0400Z on August 28, 1972) and 12 (1200Z on August 29, 1972), raising windspeeds from 10 to as high as 30 knots and increasing wave heights from 3 to about 20 ft. The noise spectrum levels difference for these conditions are consistent with estimates from Wenz's curve.

The second front approached the STA site from the south (open ocean) during samples 15 (0000Z on August 30) through 27 (0000Z on September 1), raising windspeeds from 12 to 28 knots and increasing wave heights from 5 to 14 ft. The noise spectrum level at 500 Hz (deep hydrophone) increased from 70 to about 75 dB||µPa as windspeed increased from about 12 to 28 knots (corresponding to sea states 3 to 6) during samples 15 to 23. Thereafter, the noise spectrum level at 500 Hz decreased from 75 to about 70 dB||µPa as windspeed subsided from 28 to about 7 knots. The noise levels measured during the reported decrease of windspeed do not entirely agree with Wenz's estimates: bathymetric blockage (see Fig. 1b), time lag in windspeed data caused by *Hayes* varying range, wind direction relative to the marginal ice zone boundary and available fetch for surface wave development are jointly responsible. It is concluded that sea noise levels in the open ocean near the marginal ice edge are predictable from Wenz's curves.

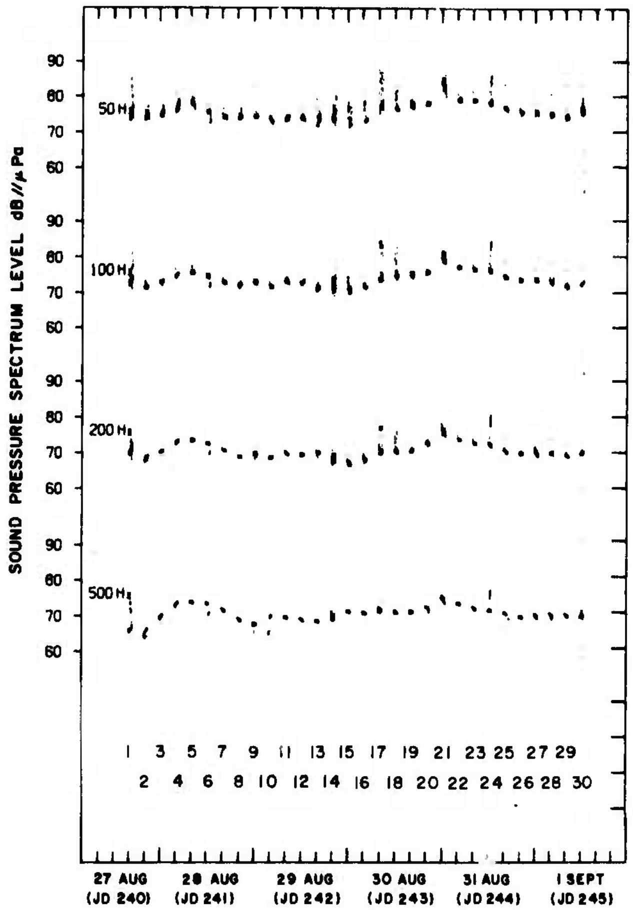


**Fig. 6 — Hydrophone data, 2375-m depth**

The isometric plots in Figs. 8a and 8b show the spectral characteristics of man-made sounds. Such plots were used extensively in analyzing the STA data. Each plot represents a 1-h sample of ambient noise data in the 20- to 600-Hz band from the deep hydrophone. Spectral data were averaged over 1-min intervals. The ordinate is sound-pressure spectrum level (SPSL) in dB||μPa, and the abscissa is frequency in Hz; time is given at the right of each plot. Figure 8a shows about 8 min of air-gun activity in the low-frequency band, 20 to 100 Hz. Figure 8b displays reception of an explosive signal, dropped by *Mizar* about 300 n.mi. away, and of CW projector signals at 29 and 116 Hz.

## Depth-Dependent Data

Figures 9 and 10 present mean SPSL values for four hydrophone depths at the STA site. The processing consists of forming third-octave filtered data reduced to 1-Hz bands centered at 50 and 500 Hz. Each data point is a 10-min average, yielding six profiles per 1-h sample. The 50-Hz profiles are constant with depth at levels of about 75 dB||μPa for the first 30 h of the deployment period. Departures from constant noise-level profiles from 0400Z on August 29 through 0800Z on August 31, are due to known ship

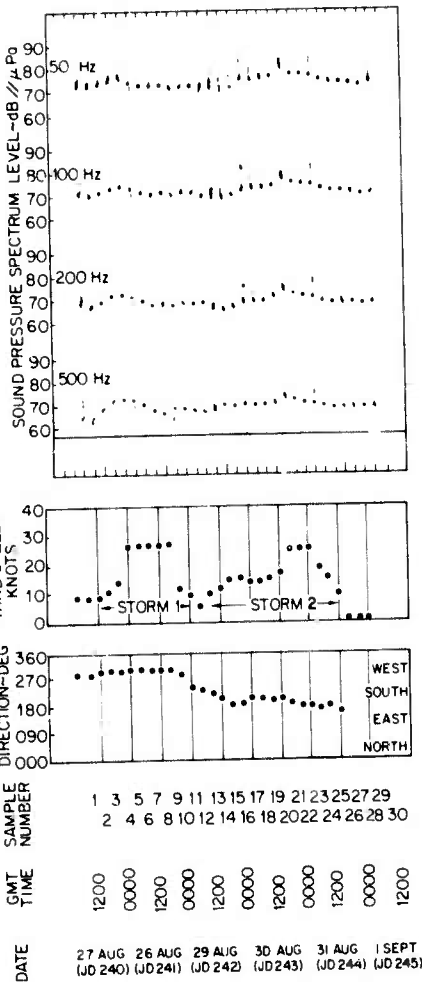


Fig. 7a — Acoustic data and environmental observations

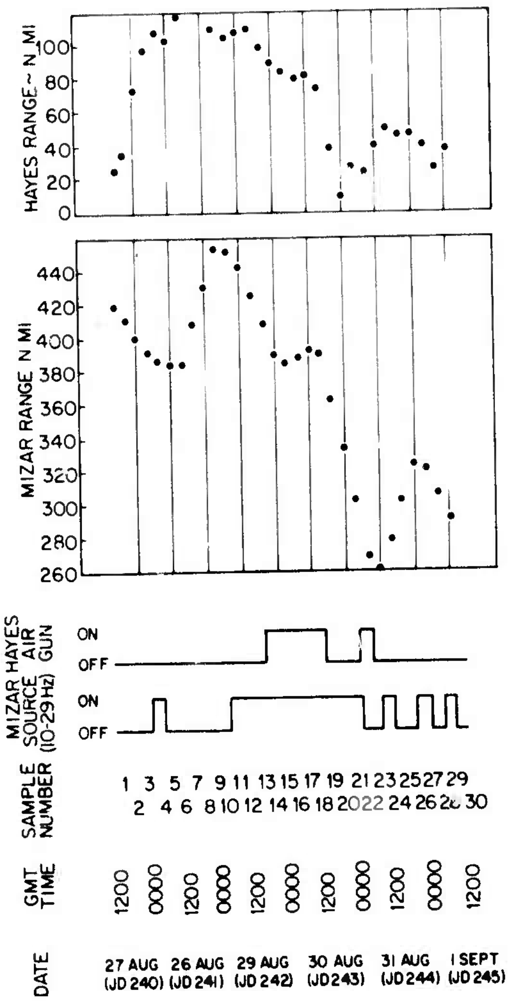


Fig. 7b — Navigation observations and acoustic source information

passages. Shipping surveys were not conducted during the recording period, so that range vs time from the STA site is not known. Ship passages influenced the deeper hydrophones for a longer time. The deepest hydrophone often showed a higher noise level than the shallowest (e.g., 0000Z on August 31 in Fig. 9). It is concluded that 50-Hz profiles are generally constant over the measurement depths and depart from this behavior due to the presence of nearby shipping.

The 500-Hz profiles are initially constant with depth at levels of 58 to 60 dB||μPa down to a depth of 2375 m, where the spectrum level is about 68 to 70 dB||μPa, when the windspeeds were about 8 knots and the wave heights were 5 ft. The source of increased noise levels at 2375 m is not understood but may be related to noise produced in the marginal icefield by the first storm that directly affects samples 4-12. The noise levels then increase with time, but the profile shape remains unchanged until sample 10. Subsequent profiles show "knees," which bend in both directions with passing time; this

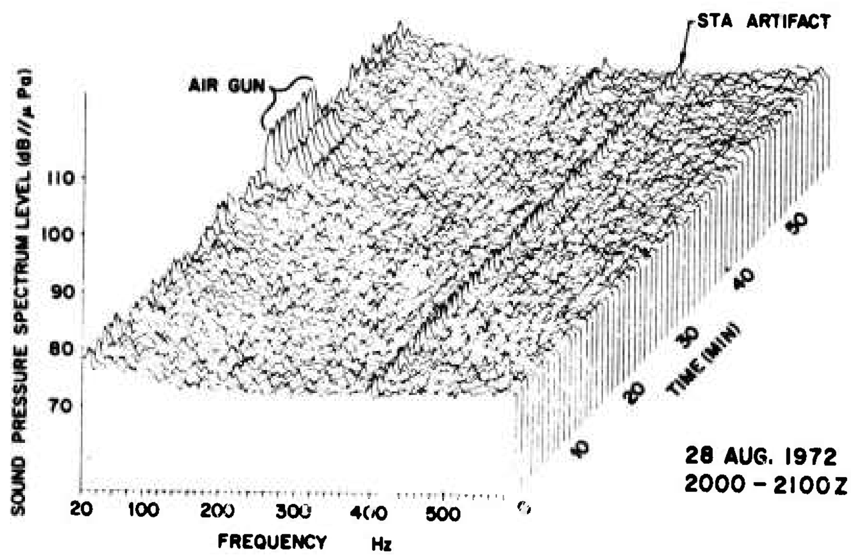


Fig. 8a — Isometric plot during developing seas (sample 8)

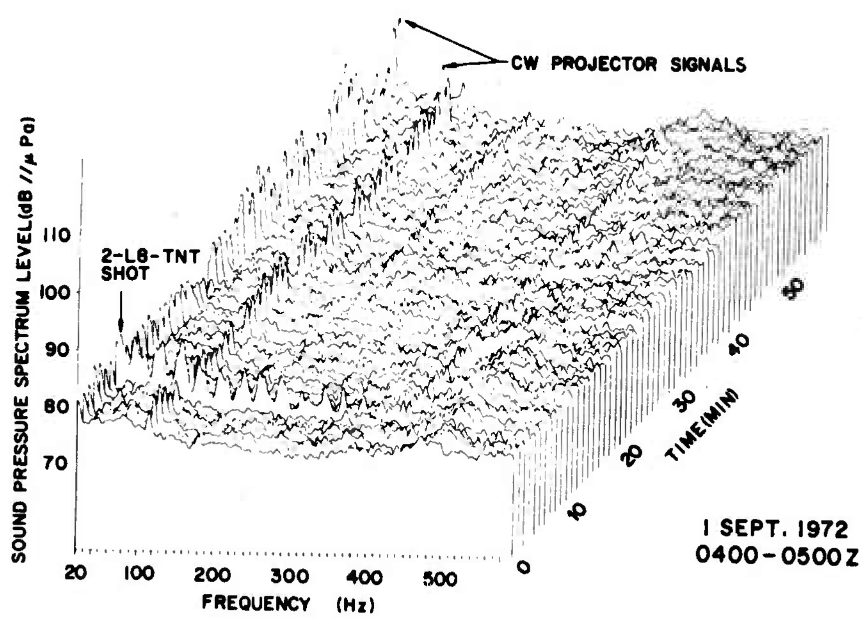


Fig. 8b — Isometric plot during developed seas (sample 28)

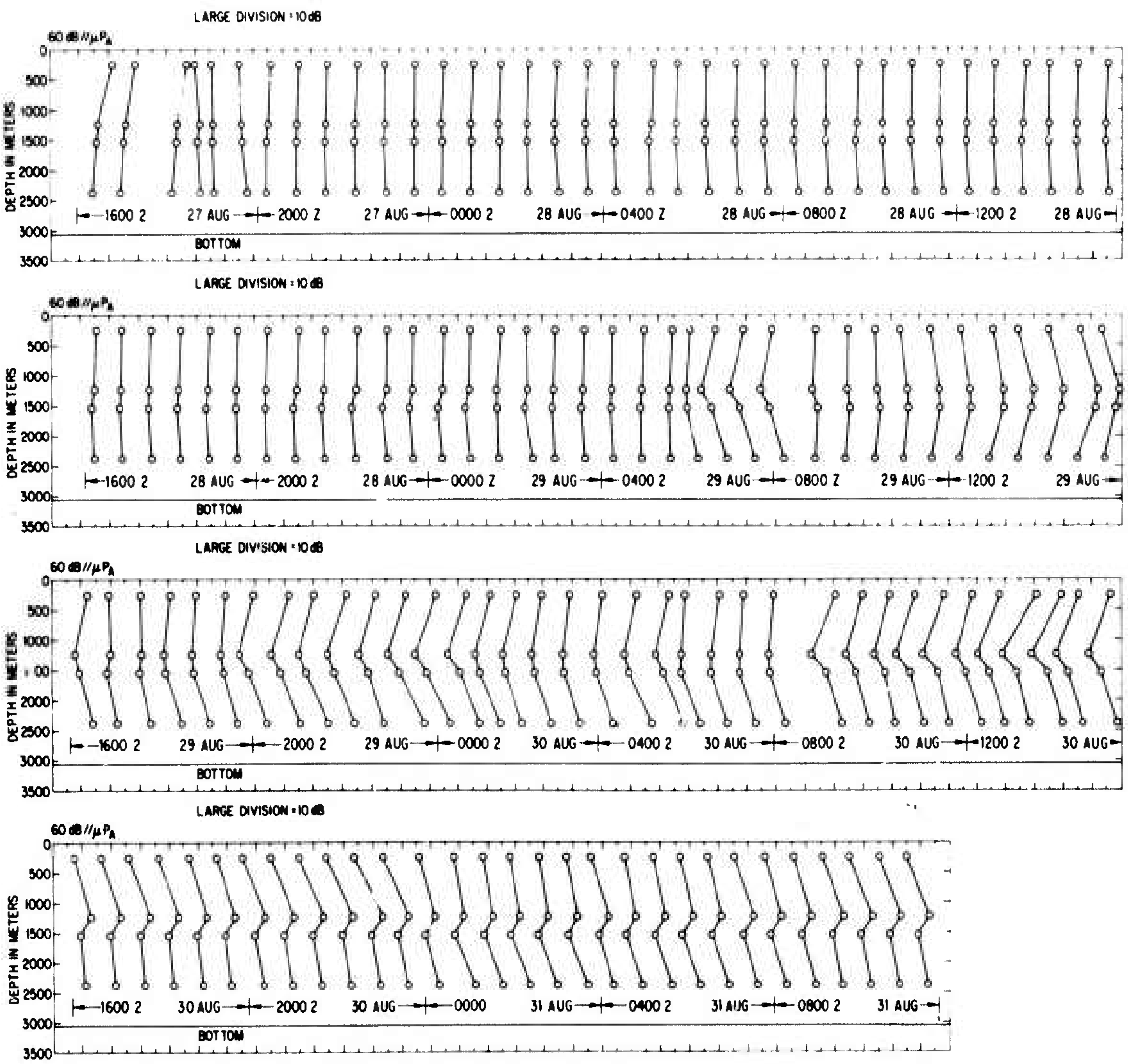


Fig. 9 — Ambient noise depth profiles at 50 Hz

result during samples 13 through 23 appears to be the product of the passage of the second front and nearby ship noise.

## LONG-TERM EXPERIMENT AND RESULTS

### General Description

A long-term ANB (LTA) was deployed from *Hayes* in 3111 m of water on August 26 at 76°30.8′N, 1°2.0′W. One-minute samples of ambient noise were recorded in the 20- to 1200-Hz band every 4 h from deployment through July 1973. A total of 2057 samples was recorded before the LTA was recovered on August 24, 1973. LTA electronic system noise was found to increase, reaching sea-noise levels at about 700 Hz. Thus,

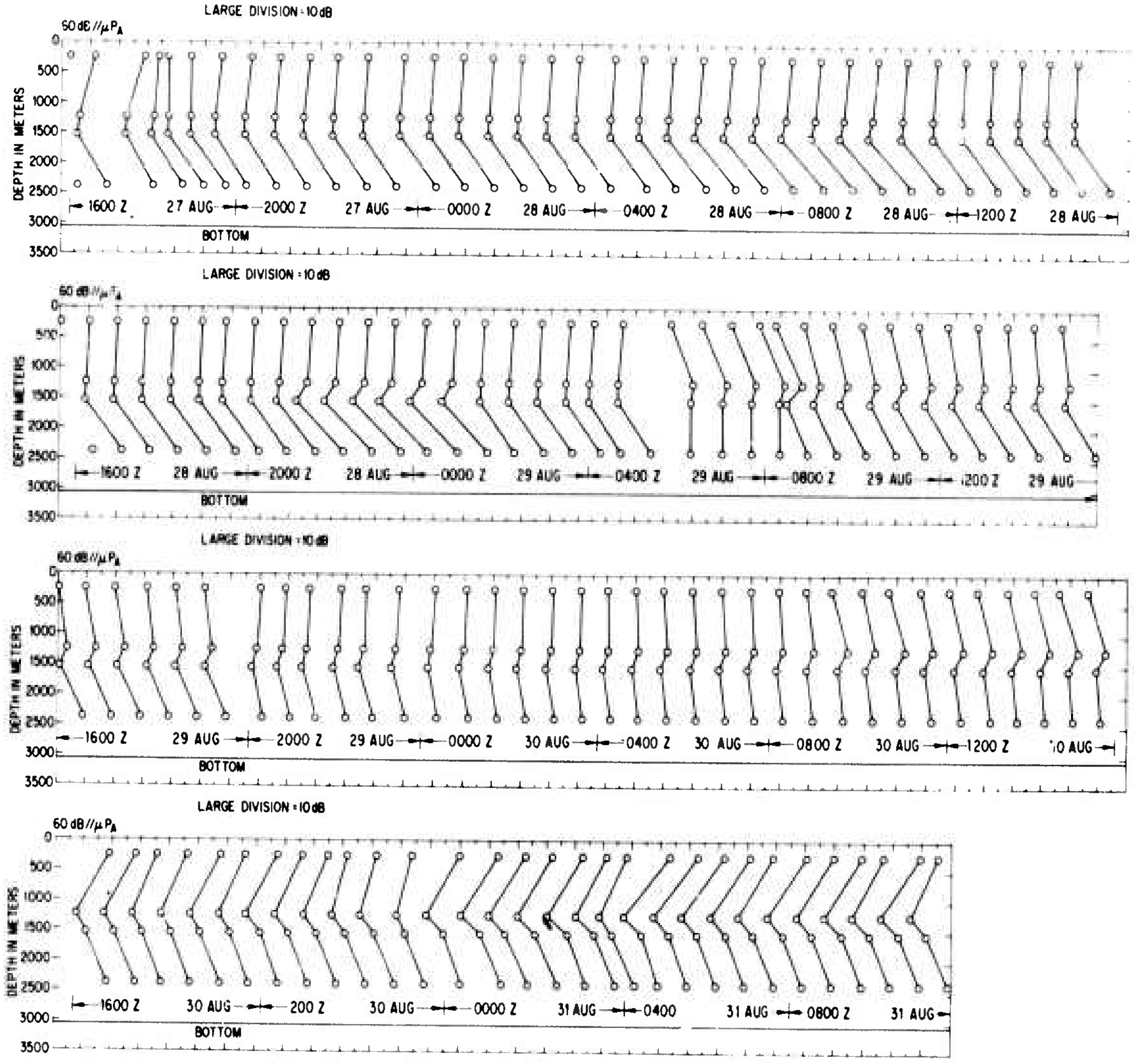


Fig. 10 — Ambient noise depth profiles at 500 Hz

acoustic data are reported for the 20- to 600-Hz band. This section presents and discusses only ambient noise recorded by the shallow (306-m) hydrophone, because the deep (2440-m) hydrophone developed electrical problems 2 days after deployment. Acoustic time-series data are presented in Appendix A.

Table 1 presents a summary of acoustic and environmental data for each month (column 1) and year (column 2) from October 1972 to June 1973. The acoustic data (column 3) consist of monthly mean sound-pressure spectrum levels (SPSL in dB||μPa), standard deviations, and maximum and minimum SPSL levels. The mean SPSL data are obtained from digitally processed third-octave levels averaged over each month and adjusted to 1-Hz bands. According to Wenz [14], the 50- and 400-Hz spectrum levels respond to shipping traffic and weather-induced noise, respectively, while the 100-Hz spectrum levels is often affected by both types of sources. The environmental data consist of iceline distances and mean monthly windspeeds. Iceline location and driftspeed

Table 1 — Monthly Ambient Noise and Environmental Data Summary

| Month | Year | Third-Octave Noise Levels, Center Frequency, 50 Hz, Mean Level (Deviation) maximum/minimum Levels | 100 Hz | 400 Hz | Iceline Distance | Mean Windspeed | Mean Sea State | Number of Acoustic Samples Processed |
|---|---|---|---|---|---|---|---|---|
| — | — | — | — | — | R | W | S | N |
| — | — | (dB\|\|μPa) | (dB\|\|μPa) | (dB\|\|μPa) | (km) | (m/s) | — | — |
| October | 1972 | 89.2 (2.6) 96.6/82.6 | 86.4 (2.7) 93.9/79.7 | 77.4 (3.7) 85.8/66.0 | 118 | 4.17 | | 184 |
| November | 1972 | 88.4 (2.8) 96.5/82.0 | 85.2 (3.0) 94.1/79.4 | 76.0 (4.0) 87.7/68.0 | 114 | 5.56 | 2 | 178 |
| December | 1972 | 87.4 (3.5) 93.8/80.9 | 84.9 (3.5) 93.3/78.4 | 76.3 (4.7) 86.7/65.7 | 125 | 4.27 | 2 | 182 |
| January | 1973 | 86.0 (4.3) 95.8/80.2 | 83.6 (4.1) 93.0/77.7 | 74.2 (5.2) 85.5/66.1 | 93 | 4.03 | 2 | 184 |
| February | 1973 | 87.1 (3.6) 95.2/80.8 | 85.6 (2.9) 93.6/78.5 | 75.4 (4.5) 81.9/67.7 | 60 | 5.99 | 2 | 166 |
| March | 1973 | 88.6 (3.1) 95.1/82.2 | 87.9 (3.6) 96.0/79.5 | 78.4 (4.3) 88.9/69.0 | 10 | 4.10 | 2 | 182 |
| April | 1973 | 86.9 (3.6) 97.1/80.5 | 85.1 (3.1) 95.5/76.6 | 75.7 (4.1) 86.9/66.1 | 30 | 4.12 | 2 | 176 |
| May | 1973 | 86.6 (4.2) 94.8/79.2 | 83.3 (5.0) 92.6/77.0 | 70.4 (8.6) 80.8/62.6 | 10 | 3.44 | 1 | 183 |
| June | 1973 | 86.5 (4.1) 94.2/79.1 | 83.5 (4.3) 90.7/77.0 | 72.3 (7.1) 80.4/62.2 | 70 | 2.86 | 1 | 119 |

data near the recording site were estimated from weekly aircraft observations; windspeeds were estimated twice daily from charts of barometric pressure. The iceline distance R (column 4) from the recording site is given in kilometers for the fifth day of each month, since the fifth day shows best the proximity of the iceline during the spring. The mean monthly windspeed W (column 5) in meters per second and its corresponding sea state S (column 6) are also listed, in addition to the number of 1-min samples N processed in each month (column 7).

The monthly maximum, minimum, and mean noise levels at 50, 100, and 400 Hz appear correlated during the period of October 1972 through June 1973. Noise levels are highest in the fall (October and November) and spring (March and April) and lowest in winter (January and February) and summer (June). The highest mean level values at 400 Hz of 85.8 and 87.7 dB||$\mu$Pa were recorded during the fall and spring, when the iceline was more than 100 and 20 km, respectively, from the recording site. In the spring the mean noise levels, due to proximity of the iceline, are at least 2 to 3 dB higher than the mean monthly values in the fall. The standard deviation of the mean SPSL values at 400 Hz is largest (8.6 dB) during May when the iceline is receding at distances between 10 and 70 km from the recording site. The mean monthly LTA levels approximate the maximum spectral levels of Wenz's limiting curve at 400 Hz. Thus, the mean monthly noise levels show the largest deviations when the iceline is less than 100 km from the recording site. Finally, evidence listed in Table 1 and discussed in the following sections indicates the marginal ice zone boundary is noisiest during the spring.

## Time-Series Data

Figure 11 summarizes acoustic measurements and environmental observations for a 3-month period, February through April 1973, while the ice edge approached and passed over the LTA site. The acoustic data are spectrum levels, 1-min averages of third-octave levels adjusted to 1-Hz bands at center frequencies of 50, 100, and 400 Hz. The environmental observations consist of daily windspeed and weekly ice-edge distance relative to the recording site, and ice driftspeed estimates. Ice-edge distances have been interpolated to provide additional estimates during the month of March, when the iceline passed over the recording site and reversed motion several times.

The general motion of the marginal icefield, no further than 40 to 60 km from the recording site during the year's recording, followed the East Greenland Current in a south-southwest direction. In the spring the ice edge appeared to undergo small lateral excursions in the east-southeast direction, taking the icefield over the recording site before reversing direction. The iceline approached and retreated from the site during March and April at rates of about 1.0 to 11.7 km/day, as shown in Fig. 11. In March, three of four reversals in iceline motion occurred when the windspeed was 5 m/s or less (e.g., March 6, 14, 20, and 26). Thus, iceline reversals appear to be related to the dominant southerly surface currents; the excursions appear to be related to high windspeeds, which often (though not always) preceded iceline reversals.

Sea-noise spectrum levels at 50, 100, and 400 Hz were variable at the LTA site over the entire 9-month reporting period and were especially variable (note the standard deviation listed for each month in Table 1) during the springtime, when the iceline is less than 60 km away. The maximum-minimum noise-level differences are largest, for example,

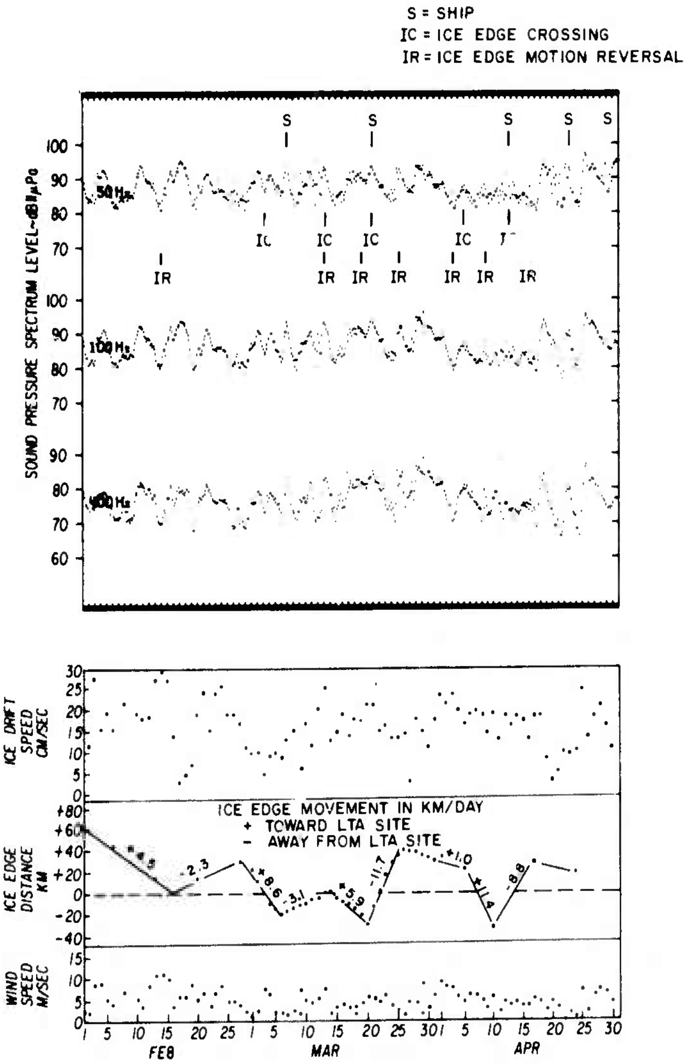


**Fig. 11 — Acoustic data and environmental observations, February-April 1973**

during April, when the iceline is about 30 km away. These differences at 50, 100, and 400 Hz are 16.5, 18.9, and 20.8 dB, respectively. The interpretation of these acoustic data is complicated by the presence of ship noise (identified by aural monitoring and shown in Fig. 11 by the symbol S), by the synoptic character of the environmental observations, by weather-induced noise in the adjacent open ocean, and by noise generated within the marginal icefield during changes in its motion. It appears that the ice edge that passed over the LTA site at least six times and changed or reversed direction near the LTA site at least nine times acts as a localized noise source, raising levels by as much as 10 dB. This conclusion is in general agreement with the measurements of Diachok and Winokur [12], who, using sonobuoys, determined that the ice edge acts as a spatially localized noise source, raising levels at diffuse and compact edges by 4 to 12 dB over open-ocean data, respectively. At the ice edge for sea state 2, Diachok and Winokur report a level of 87 dB||μPa at 100 Hz, compared with the mean LTA value in April of 85 dB||μPa.

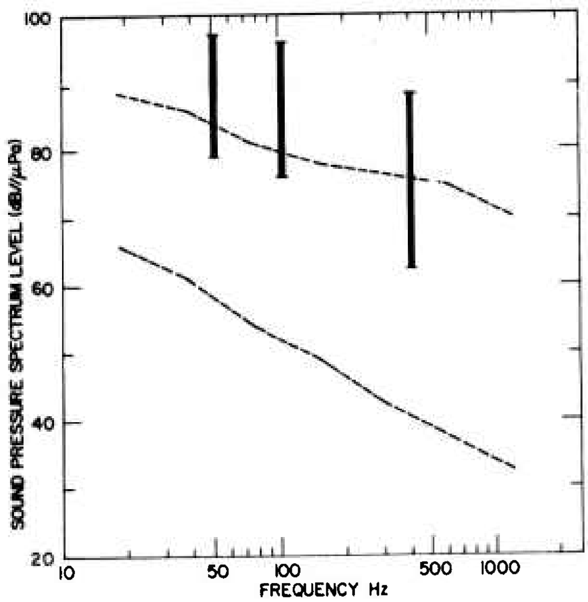


Fig. 12 — Comparison of 50-, 100-, and 400-Hz data to previous measurements

## SPECTRA

Noise levels under the Arctic Ocean ice canopy are quite variable; maximum and minimum spectral levels recorded by Buck [15] over an 11-month period in the Arctic Ocean and adapted by Milne [1, Fig. 7-26] are shown in Fig. 12 by the dashed lines. Variation of maximum and minimum noise levels at 50, 100, and 400 Hz recorded by NRL in the Greenland Sea are shown as vertical bars for comparison. From Fig. 12 it is evident that spectral levels under a consolidated ice cover or under and near the marginal icefield vary considerably over extensive recording periods. The variation in each case increases with increasing frequency. Spectral levels near the marginal ice-zone boundary are higher by as much as 12 to 16 dB in the 50- to 400-Hz band than Arctic Ocean measurements. Consequently, although the Arctic Ocean data show greater variability, the highest noise levels are developed at and near the marginal ice-zone boundary.

The mean levels observed by the LTA hydrophone ($d$ = 306 m) for the months of October 1972 and June 1973 (Table 1) appear to be systematically higher than those observed by the STA hydrophone ($d$ = 241 m), August 27-31, 1972 (Fig. 3). The locations are separated by only 10 km, and closer agreement between these measurements might have been expected. However, as indicated in Table 1 and in the spectra of Fig. 12, noise in the Arctic Ocean, particularly in the marginal ice zone, is highly variable. Thus, this lack of agreement is considered to be an environmental effect.

## SUMMARY

Ambient noise has been recorded at a hydrophone depth of 306 m for 9 months in the deepwater basin of the Greenland Sea near and occasionally under the marginal ice zone, using bottom-anchored buoy systems. The results indicate that high noise levels at the ice edge in the 20- to 600-Hz band are associated with ice-floe collisions caused by winds greater than 10 knots and by reversals in icefield movements. The lowest ambient noise levels were recorded during midwinter (January) and early summer (June), the highest during early spring (March) and early fall (September). Ambient noise levels recorded at the edge of the marginal ice zone at 50 and 400 Hz are higher by as much as 15 to 20 dB than Arctic Ocean data taken for a comparable period in the Beaufort Basin.

Near the marginal ice zone, ambient noise levels between 200 and 600 Hz are predictable from Wenz's curve for open-ocean sites when the wind direction is from the open ocean or at least parallel to the iceline. Wind approaching from the icefield, however, toward nearby recording sites is not so effective in raising noise levels because of the limited fetch. Ambient noise is relatively constant with depth except when individual ships pass, distorting the depth profile time series.

The experience gained in the conduct of this work indicates that impulsive high-level noise requires special-purpose equipment (probably digital) with dynamic range on the order of at least 60 dB over the low-frequency band from 20 to 1000 Hz [16].

Finally, the complexity of the ambient noise field in the marginal ice zone requires highly detailed environmental observations of ice-edge motion and of windspeed for detailed interpretation of the acoustic results.

## ACKNOWLEDGMENTS

This work was supported by the Naval Materiel Command and by the Defense Advanced Research Projects Agency. The author is especially grateful to the officers and men of USNS *Hayes*, without whose willing cooperation this work would not have been possible. The encouragement and comments of Dr. B. B. Adams and Dr. S. W. Marshall were invaluable. Unpublished windspeed and icefield data were made available by Mr. W. I. Whittman and Dr. H. Li, Polar Oceanography Branch, Naval Oceanographic Office.

## REFERENCES

1. A.R. Milne, "Sound Propagation and Ambient Noise Under Sea Ice," Ch. 7 in *Underwater Acoustics*, V.M. Albers, ed., Plenum Press, New York, 1967, pp. 103-138.
2. A.R. Milne, *J. Acoust. Soc. Amer.* 32, 1007 (1960).
3. A.R. Milne and J.H. Ganton, *J. Acoust. Soc. Amer.* 36, 855 (1964).
4. J.H. Ganton and A.R. Milne, *J. Acoust. Soc. Amer.* 38, 406 (1965).
5. A.R. Milne, J.H. Ganton, and D.J. McMillin, *J. Acoust. Soc. Amer.* 41, 525 (1967).
6. A.R. Milne and J.H. Ganton, *Nature* 221, 851 (1969).
7. J.D. MacPherson, *J. Acoust. Soc. Amer.* 34, 1149 (1962).
8. C.R. Greene and B.M. Buck, *J. Acoust. Soc. Amer.* 36, 1218 (1964).
9. F.A. Payne, *J. Acoust. Soc. Amer.* 36, 1943 (1964).

10. F.A. Payne, *J. Acoust. Soc. Amer.* 41, 1374 (1967).

11. A.R. Milne and S.R. Clark, *Bull. Seismol. Soc. Amer.* 54, 1797 (1964).

12. O.I. Diachok and R.S. Winokur, *J. Acoust. Soc. Amer.* 55, 750 (1974).

13. G.L. Johnson and O.B. Eckhoff, *Deep Sea Res.* 13, 1161 (1966).

14. G.M. Wenz, *J. Acoust. Soc. Amer.* 34, 1936 (1962).

15. B.M. Buck, *J. Underwater Acoust.* 21, 17 (1971) (Confidential Paper, Unclassified Title).

16. J.H. Ganton, G.N. Dennison, W.H.M. Burroughs, and A.R. Milne, "Recording Instrument Package (RIP) for Long Term Underwater Measurements in the Arctic," Report 70-4, Def. Res. Est. Pac., Victoria, B.C. Sept. 1970.

## Appendix A
## METHODS OF MEASUREMENT AND COLLECTED DATA

### MEASUREMENT SYSTEM AND DATA PROCESSING

#### ANB Mechanical and Electronic Arrangement

The static mechanical configuration of a typical buoy is shown in Fig. A1. The anchor, an iron cube weighing 500 lb (227.3 kg) in air, is connected by 1/2-in. (12.5-mm) polypropylene line to two American Machine and Foundry (AMF) acoustic-release units. These are mechanically connected in parallel so that either unit, on acoustic command, can drop one end of a rubber-coated chain attached to the anchor line.

The instrumentation sphere, located above the acoustic-release units, is composed of two 2-in.-thick (50 mm) aluminum hemispheres, joined by an equatorial ring, 40 in. (1 m) in diameter. The buoy is held together by a reduced interior pressure of about 8 (55 MPa) psig and by four plastic-covered wire-rope straps (Fig. A2) attached to a ring with four rods that rise to a common point above the buoy. The apex of these rods is the lift point (Fig. A3) for the buoy hull which weighs 1500 lb (682 kg) in air. The buoy hull contains the tape recorder, amplifiers, power supplies, and programmer. Radio and light beacons serve as recovery aids and are attached to the top hemisphere. The electronic arrangement of the LTA acoustics system included a high- and low-gain amplifier providing an effective dynamic range of 50 dB. Two hydrophones (type H-62,* manufactured at NRL, Orlando, with a sensitivity of –178 dB||1V|$\mu$Pa) are attached to polypropylene line supported by glass flotation spheres; the deep hydrophone on the LTA failed due to a seawater short-circuit just after deployment. Electrical signals from the hydrophones are carried to the buoy by individual RG-58 cables, which terminate on the top hemisphere at a junction box containing watertight connectors. Data are recorded on 1/2-mil, 1/4-in.-wide tape. The tape recorder is a four-channel unit with a tape speed of 0.4 ips. These and other details about the buoy characteristics have been generally discussed by Diehl.† Operational differences and details of the STA and LTA buoys are listed in Table A1.

#### Calibration

Calibration tones (50 and 256 Hz for the STA buoy and 17 and 585 Hz for the LTA buoy) and white noise were injected sequentially into the amplifiers and recorded (see Fig. A4) before deployment and after recovery. These calibration signals were used in the subsequent data processing for determining the electronic system response and the

*I.D. Groves, Jr., "A Hydrophone for Measuring Acoustic Ambient Noise in the Ocean at Low Frequencies (USRD Type H62)," NRL Report 7738, Apr. 15, 1974.
†W.C. Diehl, "Initial Construction and Deployments of the Long-Term Ambient-Noise Buoy," NRL Report 7403, May 16, 1972.

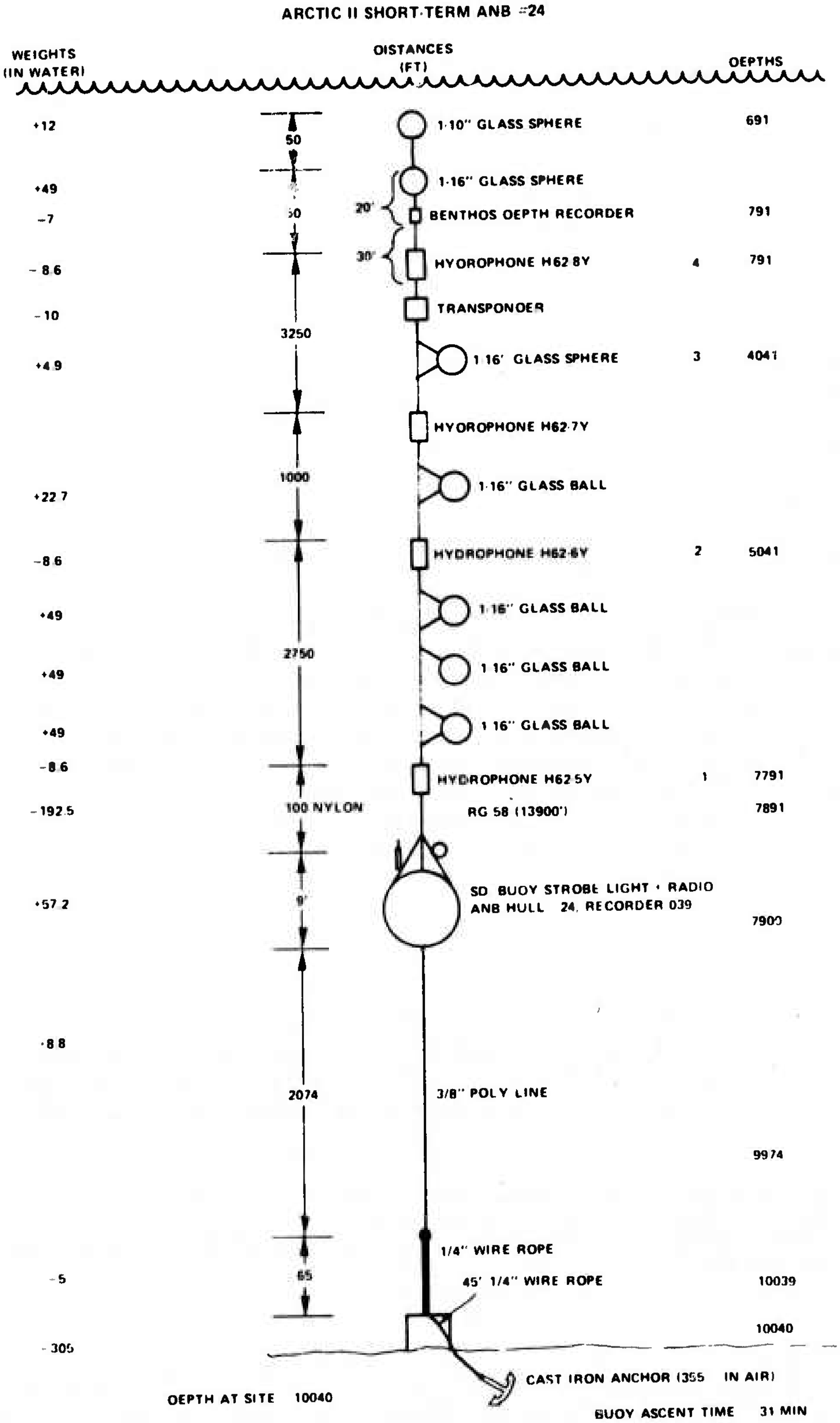


Fig. A1 — Mechanical arrangement of the STA

Fig. A2 — ANB instrumentation sphere

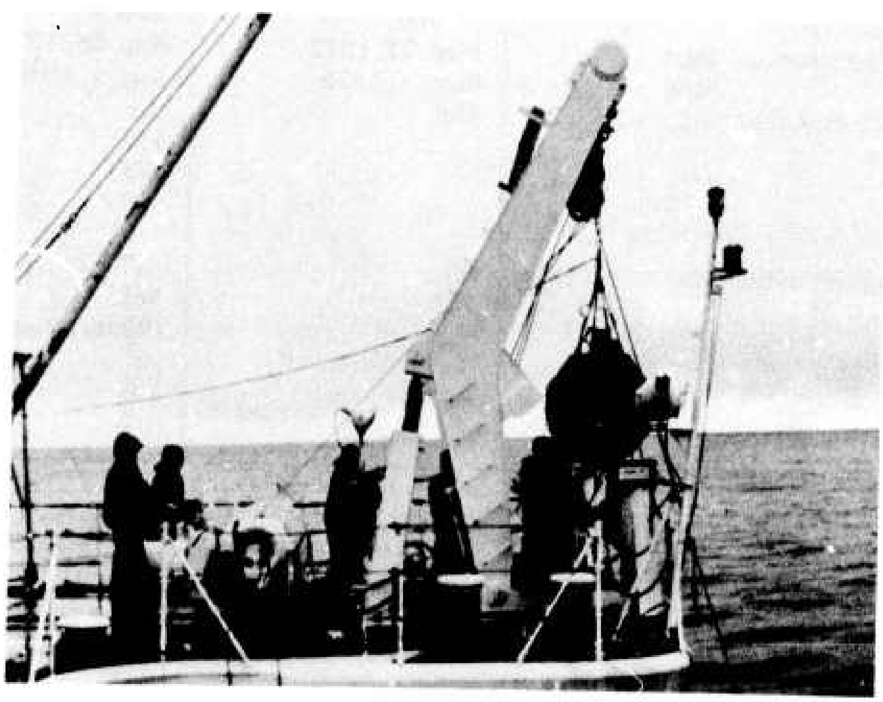

Fig. A3 — LTA buoy during deployment

Table A1 — Details of the STA and LTA Buoys

| Detail | STA | LTA |
|---|---|---|
| Buoy hull number | 24 | 26 |
| Cruise number (deployment) | 72-16-06 | 72-16-06 |
| Deployment date | Aug. 27, 1972 | Aug. 26, 1972 |
| Recovery date | Sept. 1, 1972 | Aug. 24, 1973 |
| Site position | 76°37.1′N 00°57.5′W | 76°30.8′N 01°02.0′W |
| Tape recorder number/speed (ips) | 039/0.4 | 083/0.4 |
| Number of hydrophones | 4 | 2 |
| Hydrophone 1 depth (m) | 2375 | 2440 |
| Hydrophone 2 depth (m) | 1537 | 306 |
| Hydrophone 3 depth (m) | 1232 | — |
| Hydrophone 4 depth (m) | 241 | — |
| Hydrophone 1 tape/serial no. | H62/5Y | H62/3Y |
| Hydrophone 2 tape/serial no. | H62/6Y | H62/4Y |
| Hydrophone 3 tape/serial no. | H62/7Y | — |
| Hydrophone 4 tape/serial no. | H62/8Y | — |
| Days of data (actual/intended) | 5/5 | 350/365 |
| Water depth at site (m) | 3157 | 3111 |
| Bandwidth (Hz) | 20-600 | 20-600 |
| Recording interval: Start | Aug. 27, 1972 | Aug. 26, 1972 |
| Stop | Sept. 1, 1972 | Aug. 1, 1973 |
| Internal calibration frequencies (Hz) | 256 | — |
| | | 585 |
| | | 73 |
| | | 16 |
| | | 9 |
| External calibration frequencies (Hz) | 50 | 17 |
| | 256 | 585 |
| | — | (White noise) |
| Sample duration (min) | 60 | 1.0 |
| Sample interval (h) | 4 | 4 |

Fig. A4 — STA buoy with top hemisphere removed

absolute magnitude of the acoustic noise levels at selected frequencies. All hydrophone units were calibrated at the appropriate temperature and pressure by the Underwater Sound Reference Division (Code 8200), Naval Research Laboratory, Orlando, Florida.*

## Data Processing

The buoy analog tapes from the STA and the LTA sites were rerecorded on 1-mil, 1/2-in.-wide tape, using a special playback-only machine at speed-up ratios of 32:1 and 16:1, respectively, at 7-1/2 ips. A pen-chart record was made of each tape during transcription to identify the actual times of observed acoustic events and to serve as a general indicator of hydrophone and electronic-system performance. An IRIG-B time code with a 1-kHz carrier was transcribed onto each tape for starting the processor at reproducible points. The initial processing was accomplished on a Time/Data (Model 1923-C) spectrum-analyzing system, a computer-directed fast Fourier transform (FFT) processor that permits continuous and program-controlled spectral analysis. Further processing was done on a CDC-3800 computer, where the record structure was completed and analyzed with existing programs. The digital record structures are preceded by a six-word header and consist of an amplitude spectrum averaged for 1 min of 300 and 600 points, 2- and 1-Hz resolution, respectively. The record label includes trip number, year, Julian day, time (hours, minutes, and seconds), hydrophone depth (meters), and status (showing A/D overload, processor overflow, and output error).

*"Calibration of USRD Type H62 Hydrophones Serials 1Y Through 42Y," USRD Calibration Report 3420, July 3, 1972. "Calibration of USRD Type H62 Hydrophones Serials 5Y Through 8Y," USRD Calibration Report 3518, Mar. 29, 1973.

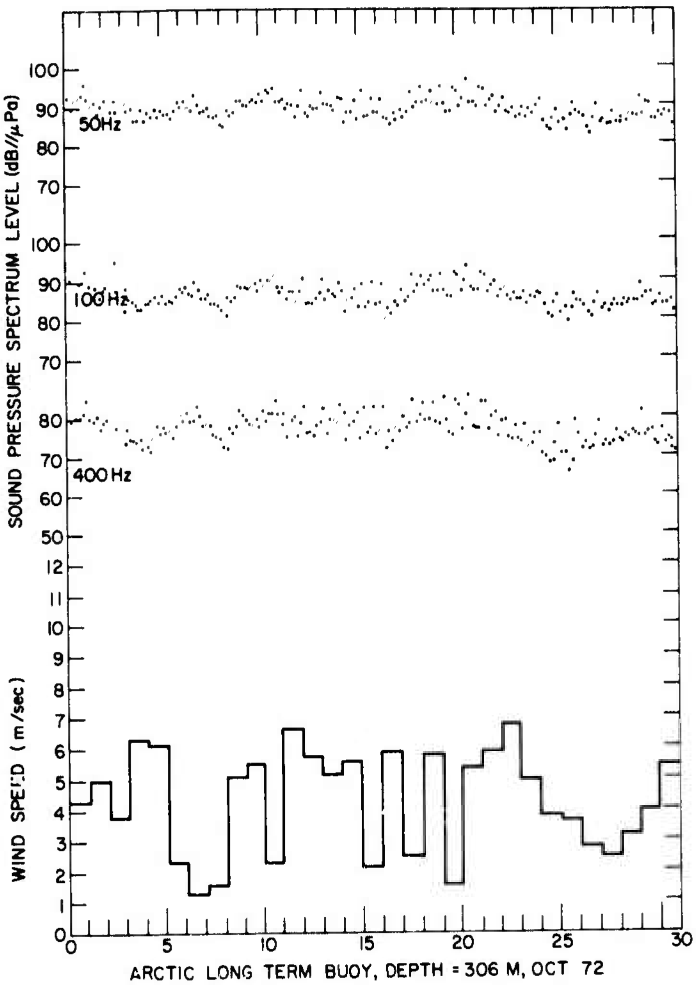


Fig. A5 — Acoustic data, October 1972

## ACOUSTIC DATA

Acoustic data at 50, 100, and 400 Hz are presented as monthly time-series plots in Figs. A5 through A13. All data for the month of September 1973 were at excessively high levels and were excluded. Daily average windspeed data are presented below the acoustic data.

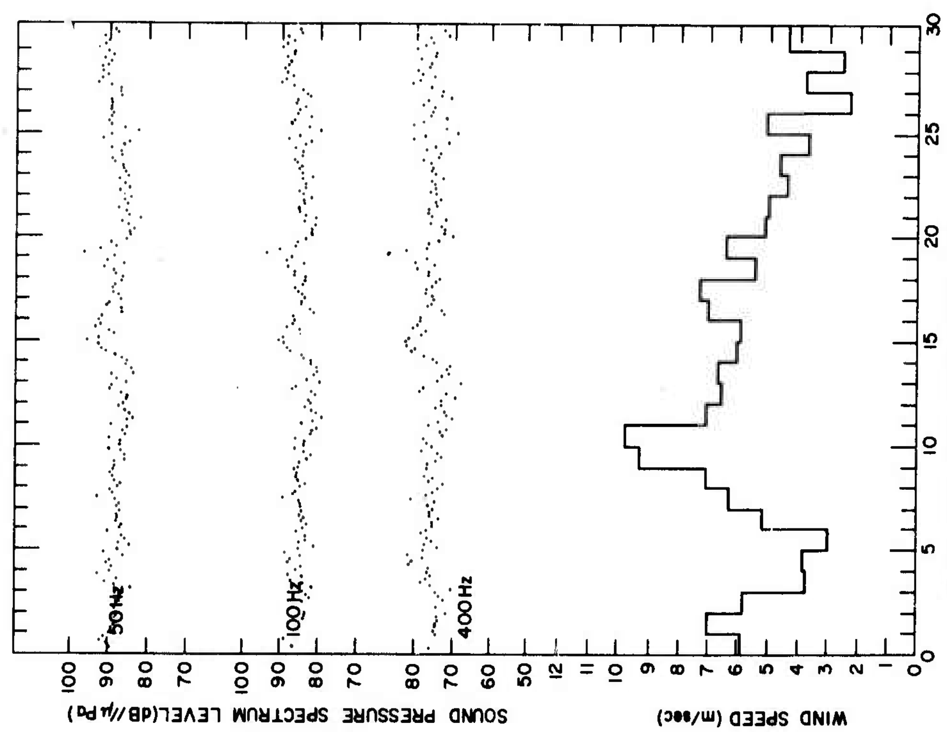


Fig. A6 — Acoustic data, November 1972

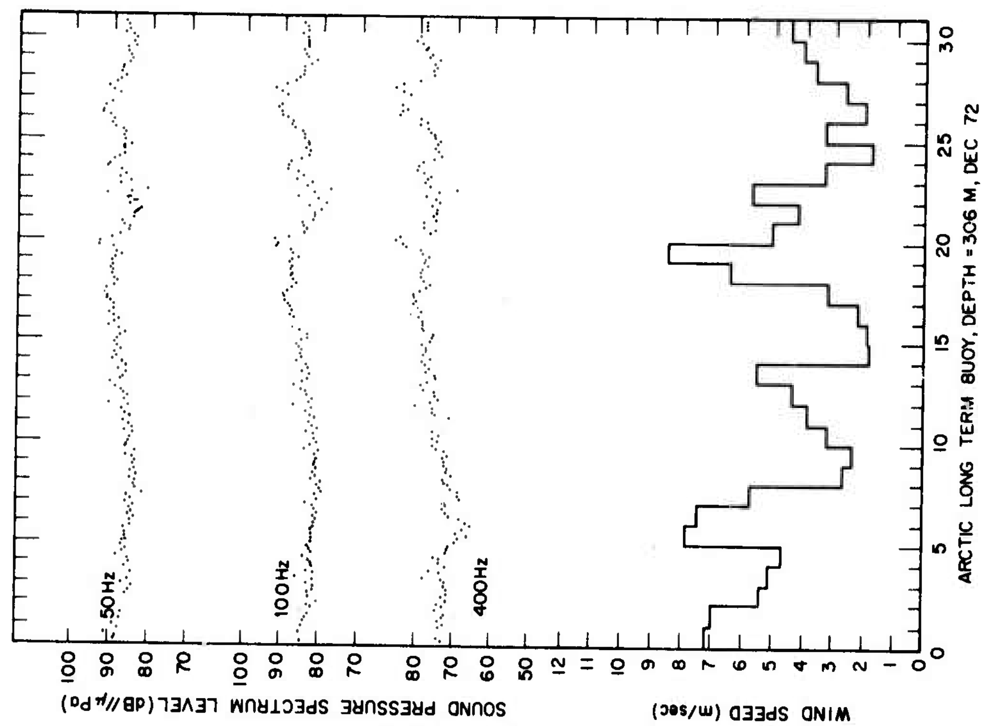


Fig. A7 — Acoustic data, December 1972

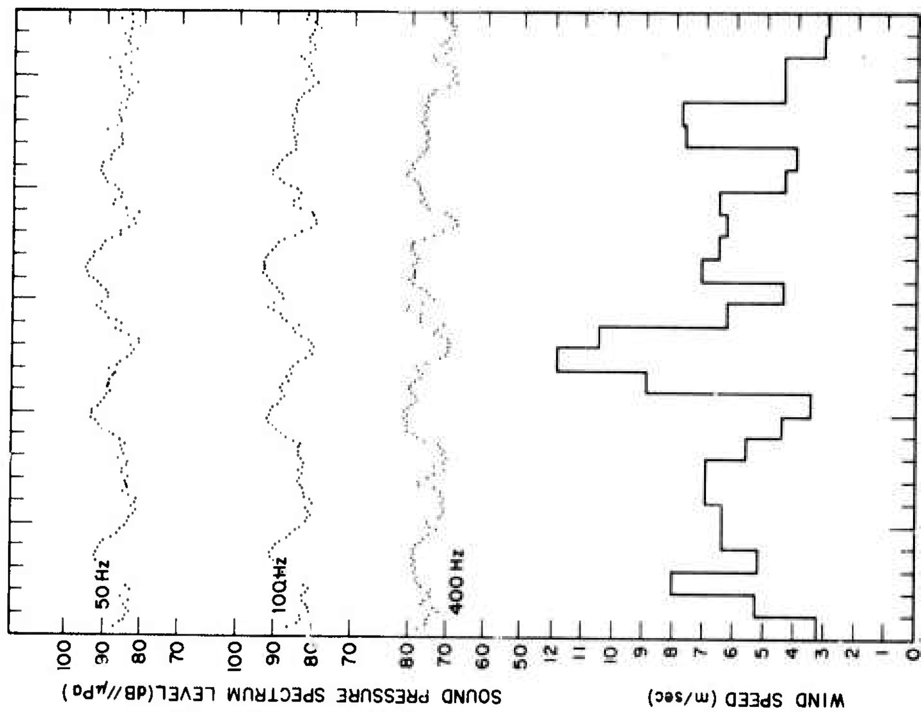


Fig. A9 — Acoustic data, February 1973

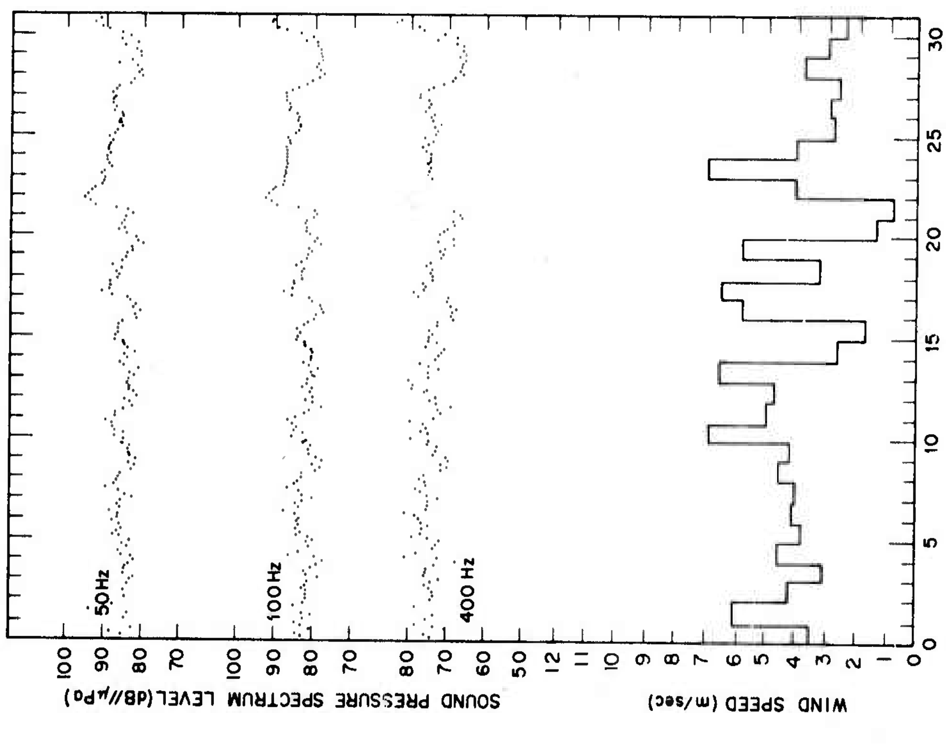


Fig. A8 — Acoustic data, January 1973

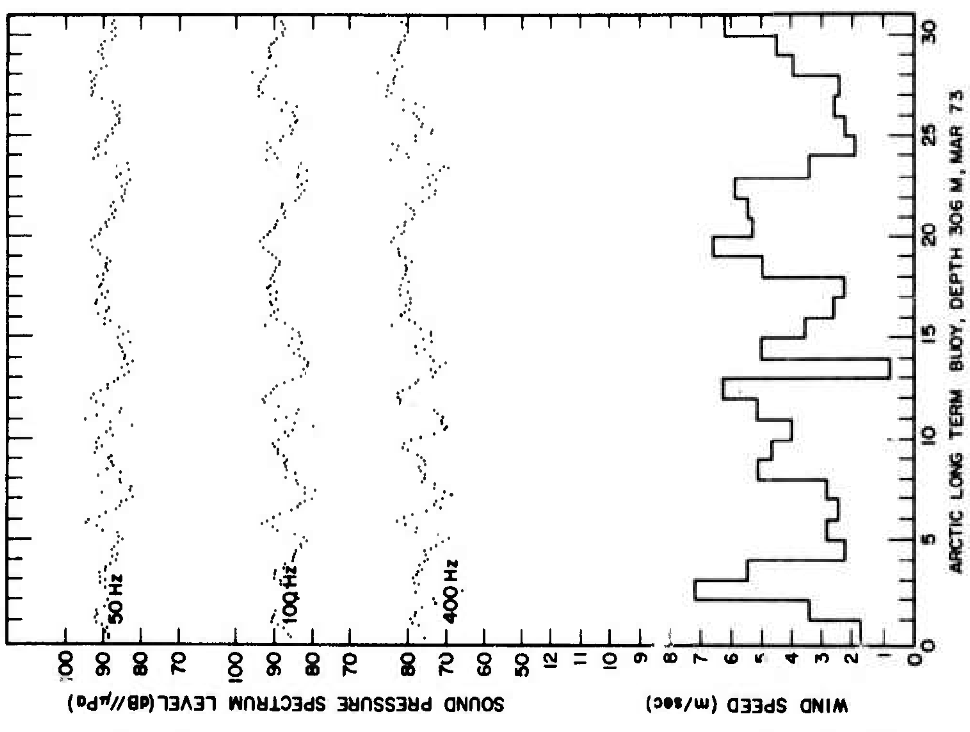


Fig. A10 — Acoustic data, March 1973

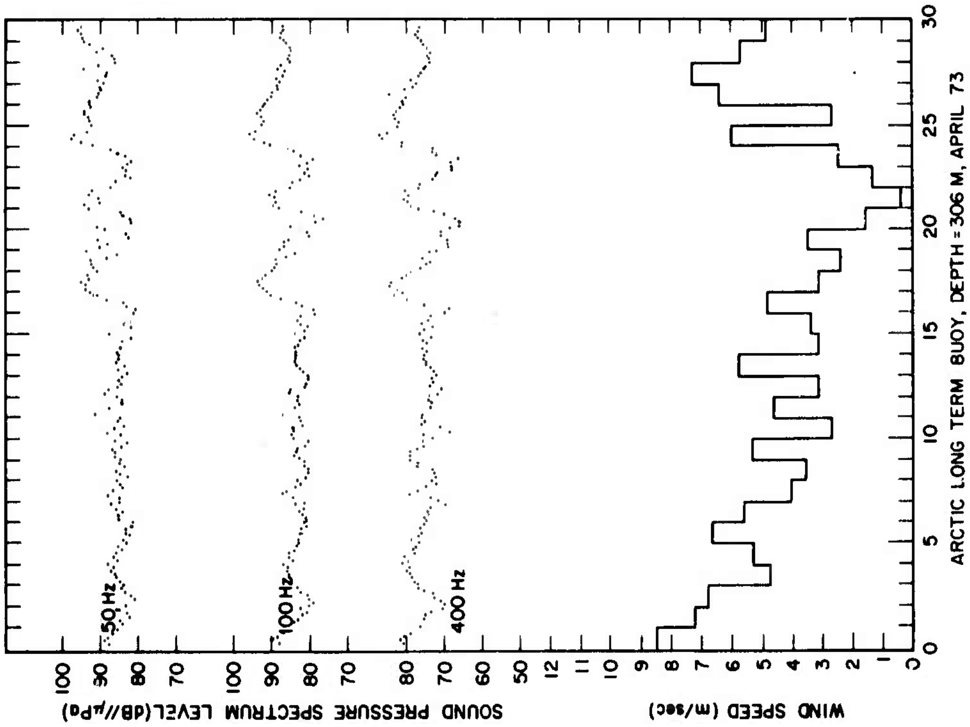


Fig. A11 — Acoustic data, April 1973

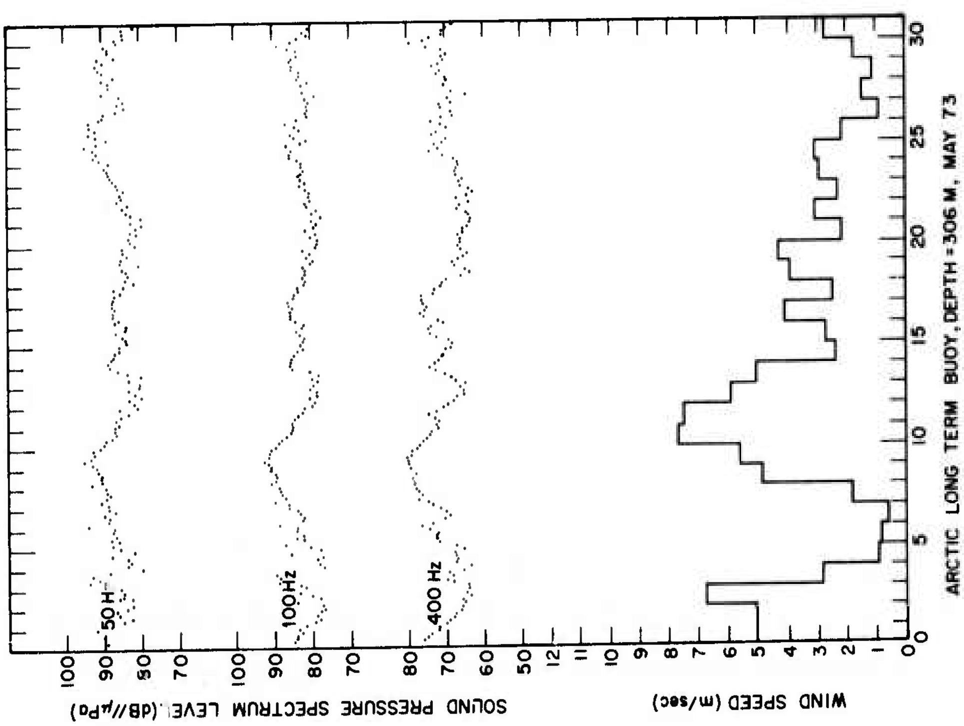


Fig. A12 — Acoustic data, May 1973

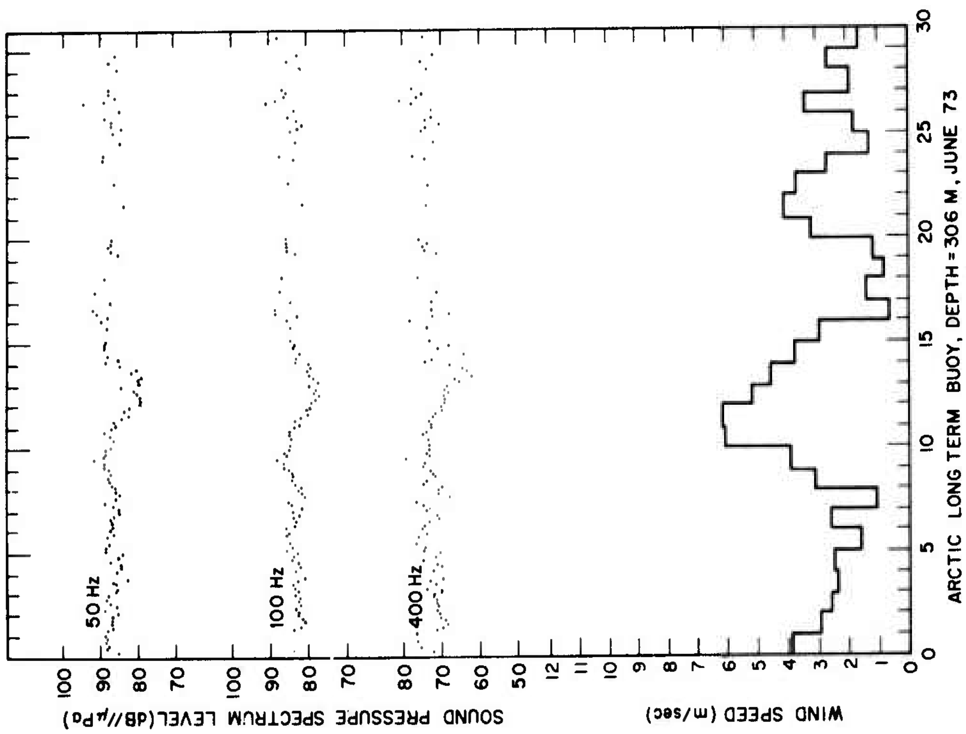


Fig. A13 — Acoustic data, June 1973



*U.S. GOVERNMENT PRINTING OFFICE:1976 211-264/510 1-3