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AN IMPROVED AIRBORNE OCEAN TEMPERATURE ACQUISITION DISPLAY AND ANALYSIS SYSTEM

The Applied Physics Laboratory Submarine Technology Department has developed an improved airborne ocean temperature data acquisition system to provide various platforms with near real-time temperature data spanning several hundred nautical miles. The system has proved its value in many major U.S. Navy field tests. This article describes the development, components, and output products of this improved acquisition system.

INTRODUCTION

In its continuing support of the U.S. Navy at-sea research and development efforts in ocean acoustics, the Submarine Technology Department at APL regularly conducts airborne oceanographic surveys from Navy P-3 Orion antisubmarine warfare aircraft. The resulting physical oceanographic data are essential to the execution of tests conducted in ocean environments that vary over space and time. It has become increasingly important to report the data collected by the P-3 aircraft to the various platforms within a few hours so that test scientists can exploit the features of a real-time ocean environment.

The variability of the ocean in space and time affects both acoustic and nonacoustic field exercises. The primary indicator of variability is temperature $T(z)$, where z is the depth below the sea surface. The goal of preliminary environmental measurements is to determine the physical characteristics of the water column. Until recently, the normal procedure was to acquire environmental data for field exercises, but not to process the data until after the conclusion of the exercises. This meant that the environmental information for major field exercises was based on climatological databases or localized ship observations as the main source for determining test geometries, rather than on the real-time data gathered aboard the P-3 aircraft. The climatological databases contain average representations of ocean conditions by seasons and therefore do not necessarily represent the actual environmental conditions. The ocean environment is composed of many different features such as storms, ocean fronts, ocean eddies, and internal waves, which need to be noted during actual field exercises so appropriate steps can be taken to ensure that test objectives are met.

Aircraft-based surveying can provide detailed temperature profile data over a large area in near real-time. These temperature data are invaluable to the interpretation of experimental results by identifying and characterizing the oceanographic variability that could affect acoustic propagation. The information revealed by actual temperature conditions allows scientists to change and enhance test strategies according to the ocean features found in the operations area. In approximately six hours an area of 200 by 200 nmi can be sampled at 20- to 30-nmi intervals by deploying airborne expendable bathythermographs (AXBT's), thus providing a synoptic look at the mesoscale variability of the test area. The temporal variability in the test area can then be monitored by repeated wide-area synoptic views.

During acoustic exercises, AXBT's are deployed in patterns designed to assess the expected performance of the systems being tested. Environmental surveys are also used in support of real-time estimates of transmission loss along various propagation paths within the test area. Instead of coarsely spaced (30 nmi) flight patterns of AXBT's used for wide-area surveys, more closely spaced (15 nmi) patterns along source–receiver paths are designed to accomplish these goals. For example, Critical Sea Test 7 (CST-7) was an acoustic exercise conducted in the Gulf of Alaska during February 1992. Figures 1 and 2 show how temperature changed as a function of latitude during

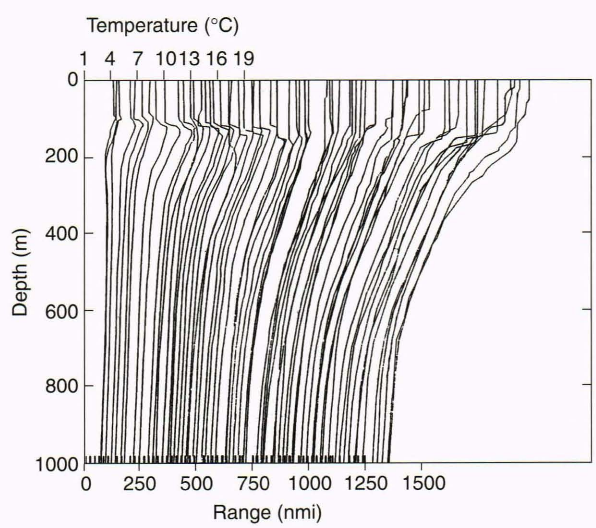

Figure 1. Temperature profiles taken on a survey from the Gulf of Alaska to Hawaii and back in support of Critical Sea Test 7. Profiles are spaced along the *x* (range) axis in proportion to their distance from the Gulf of Alaska starting point.

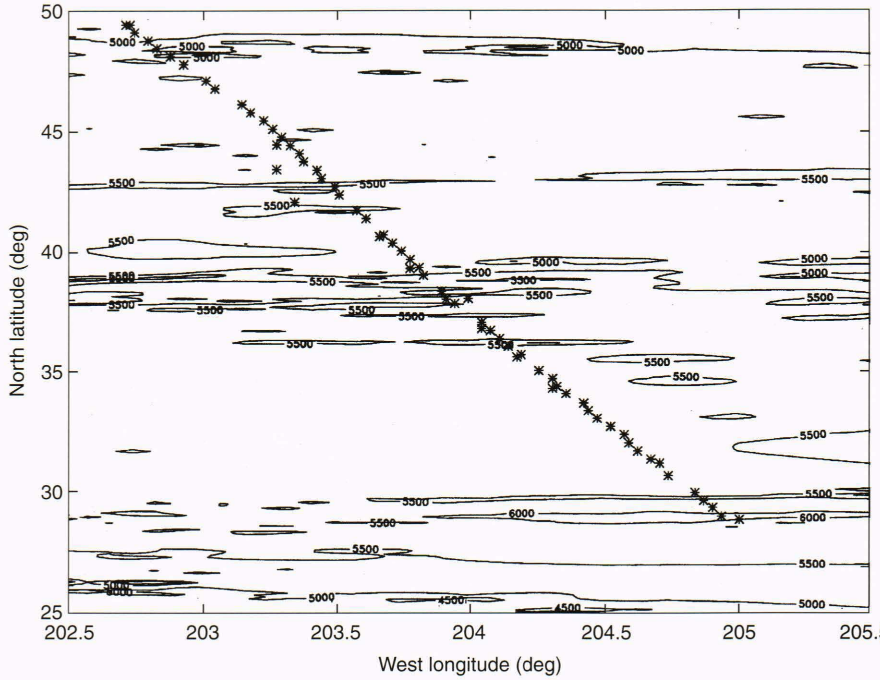

Figure 2. Locations of AXBT profiles taken on a survey from the Gulf of Alaska to Hawaii and back in support of Critical Sea Test 7. Depths are in meters.

Phase 1 testing on an Alaska to Hawaii transit. Such temperature changes affect the sound velocity structure and long-range acoustic propagation. (Succeeding temperature profiles are offset to show features more clearly.)

In addition, aircraft flights provide an opportunity to address tactical bistatic acoustic issues by acquiring the required acoustic data from sonobuoys and sound-speed profiles derived from AXBT environmental measurements. After an exercise, the AXBT data are typically analyzed more rigorously than is usually possible in the field to characterize the sound velocity structure within the test region. The analysis, coupled with the acoustic results, is used in the validation of acoustic performance prediction models being developed for system support.

AIRBORNE OCEAN DATA ACQUISITION SYSTEM

The Laboratory has been providing aircraft-based oceanographic data collection support since 1980. The equipment used initially consisted of a microprocessor-based airborne Ocean Data Acquisition and Analysis Recorder (ODAAR I), which provided environmental data $T(z)$ used solely for post-test analysis.[1] In the past four to five years, personal-computer (PC) technology, coupled with improved rapid communications, has changed the nature of environmental support for these field tests. Data derived from aircraft AXBT surveys are used to measure and analyze the variability of the ocean *in situ*; the temperature data results can be relayed to various platforms participating in field exercises within hours instead of weeks.

ODAAR II

The Laboratory has designed and built an improved Ocean Data Acquisition and Analysis Recorder system (ODAAR II) to collect and analyze *in situ* temperature data during airborne surveys.[2] This system is designed specifically for use on board Navy P-3 Orion antisubmarine warfare aircraft without requiring modifications to the aircraft.

The ODAAR II system consists of a portable computer, a specialized hardware board, and controlling software. An additional unit, a digital audio tape recorder, serves as a backup recording unit. The computer is a PC-based system that allows the use of the full-sized APL-designed analog-to-digital (A/D) data acquisition board. The system is equipped with a 47- to 400-Hz ruggedized power supply to accommodate aircraft power, which is different from standard alternating current.

The ODAAR II system is easy to install, remove, and operate. It encompasses APL-designed and -tested circuitry in addition to Global Positioning System technology. The ODAAR II system has been successfully installed on different versions of P-3 aircraft ranging from the older P3-B to the current P3-C Update III aircraft. The system digitizes analog temperature data received on the aircraft from AXBTs. It can also decimate (reduce the number of data points in a temperature profile while retaining the oceanographic features of that profile) and edit raw data and perform quick-look analysis; this is possible using an incorporated software package called the System for At Sea Environmental Analysis. (C. C. Cooke, J. H. Hanson, M. D. Mandelberg, and R. M. Waterworth, *The Sasea Operations and User's Manual*, JHU/APL, Draft, Jan 1992).

Figure 3 illustrates the ODAAR II system concept. A P-3 aircraft deploys AXBT's that parachute to the sea surface. Each AXBT releases a temperature probe that transmits temperature data to the P-3 aircraft. The temperature probes fall at a known rate through the ocean water column (depth is determined as a function of time

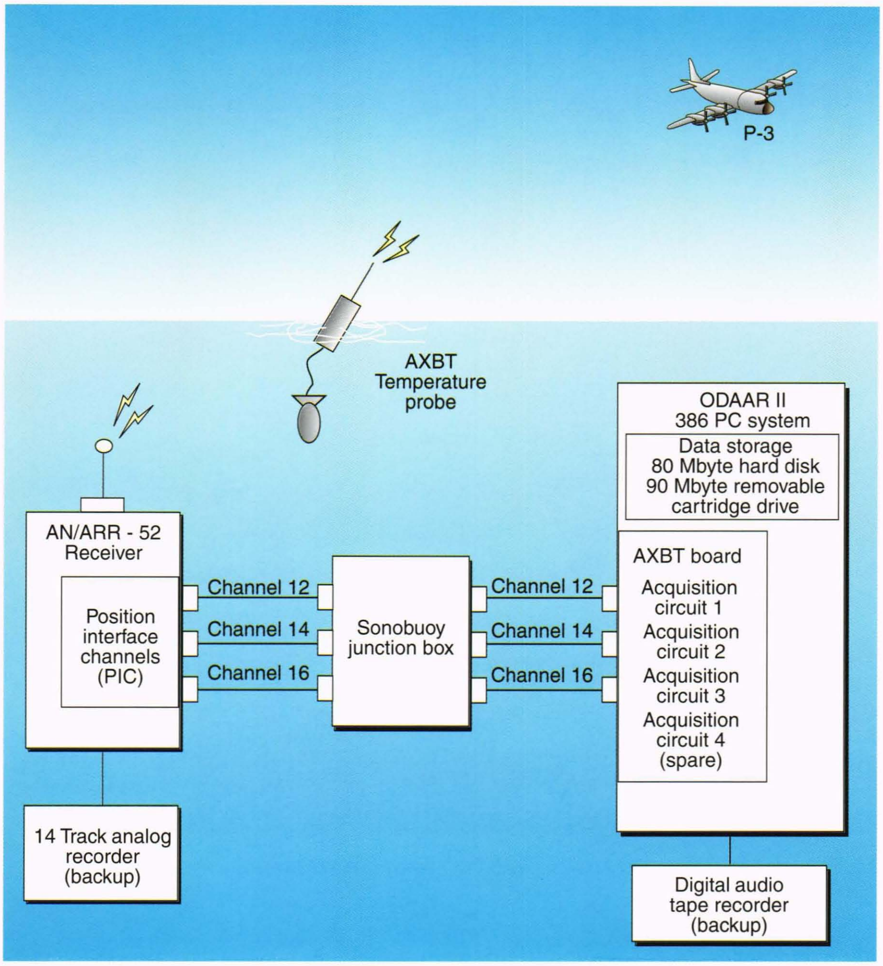

Figure 3. The Ocean Data Acquisition and Analysis Recorder II system concept.

for a given fall rate). The transmitted data are received and demodulated by aircraft sonobuoy receivers.

A deployed AXBT transmits its data signal electronically on a carrier frequency that represents a specific sonobuoy channel. The three carrier frequencies in use are designated as channels 12 (170.5 MHz), 14 (172.0 MHz), and 16 (173.5 MHz). The AXBT data are encoded frequency-modulated signals within the frequency range of 1350 to 2700 Hz (representing a temperature range of −2 to 35°C) according to the Navy standard equation

$$F = 1430 + 36.8T ,$$

where F is the frequency in hertz and T is the temperature in degrees Celsius.

The ODAAR II acquisition system converts the raw analog AXBT signals into engineering units (temperature vs. depth) and then displays a real-time graph of the data on the PC. The temperature data are written to a permanent file for further evaluation and analysis. Although the ODAAR II system has the capability for analysis, its main function is to receive raw analog data and record it digitally.

The APL-designed A/D data acquisition board is unique. The board can simulatenously receive up to four channels of AXBT frequency data. The software can process three channels concurrently for data acquisition; the fourth channel is a spare.

Typically, all data are processed during the flight within hours of the actual data collection. After the P-3 aircraft has landed, the data are typically transmitted to the APL Operations Center. The Operations Center is a central facility where the AXBT data can be further analyzed and incorporated into environmental databases. AXBT profiles are merged with deeper conductivity-temperature-pressure data obtained from surface ships in the operations area or with historical temperature and salinity profiles. Profiles of sound speed are then calculated from the merged deep temperature profiles. Within hours these data are sent out to the participating operational units and are routinely transmitted over Navy communication links to the Naval Oceanographic Office and to the Fleet Numerical Oceanography Command.

ODAAR II SYSTEM FIELD EXPERIENCE

The ODAAR II system has supported the entire suite of APL-run Critical Sea Test exercises (CST-1 through 8), Low Frequency Acoustics (LFA) exercises (LFA-1 through 11), as well as Surtass-3X, Lantex-Medex-92, Grey Slate, Blue Marble, Propatria, and the Magellan I exercises.

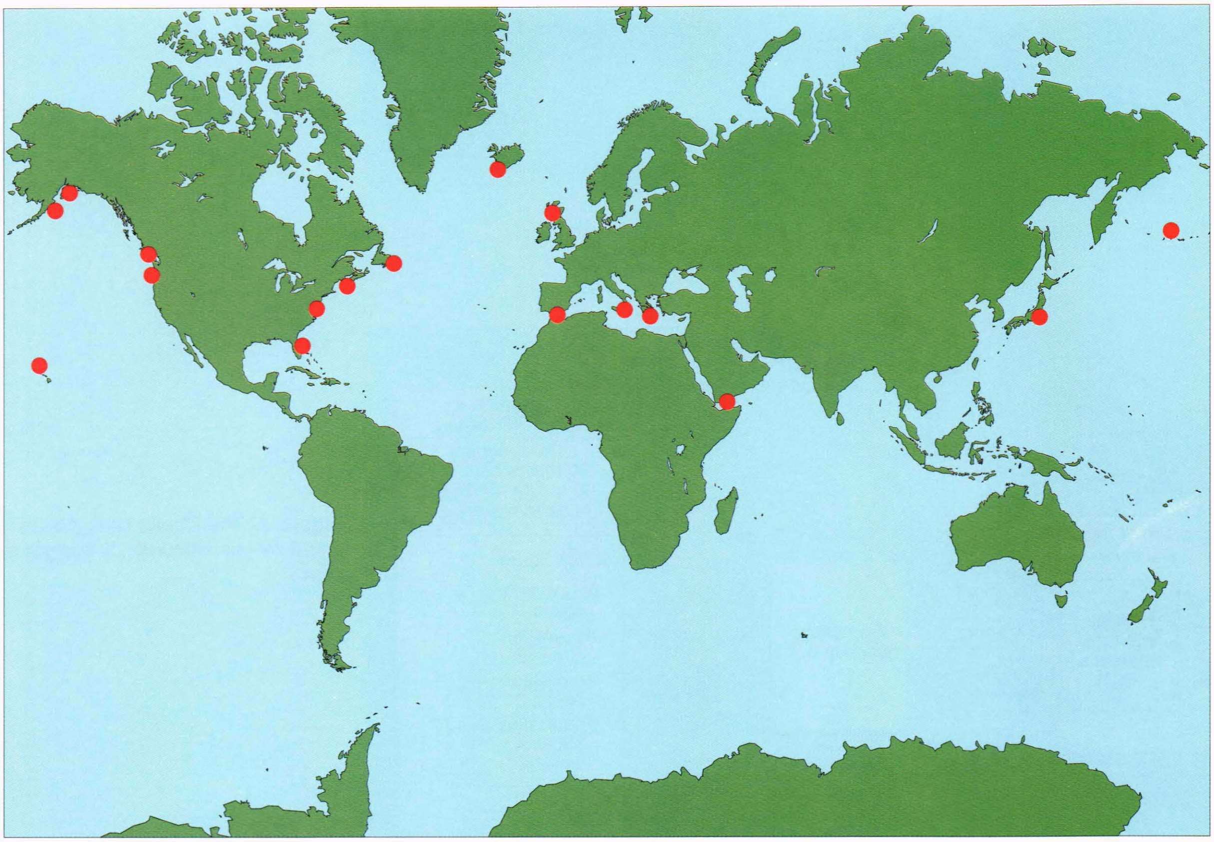

Figure 4. Areas of the world where the Ocean Data Acquisition and Analysis Recorder II has been utilized.

Figure 4 illustrates the areas of the world where the ODAAR II system has been utilized.

One demonstration of the vital importance of quick AXBT data turnaround was during Critical Sea Test 1 in the Norwegian Sea (August 1988). The aircraft wide-area surveys produced an extensive environmental data set over the test operations area and provided evidence of two unexpected ocean eddies inside the area. The ocean eddies produced a complex sound-speed field in the test area. A large warm-core eddy in the center of the operations area produced strong gradients of temperature, salinity, and sound speed over the experimental acoustic propagation paths. A second, smaller eddy was located in the northeastern corner of the test operations area; temperature data collected showed that it was interacting with the larger eddy, thus affecting temperature profiles between the two eddies. These data are displayed as a three-dimensional field in Figure 5. Repeated wide-area surveys were conducted and showed that the mesoscale field remained relatively constant, with only minor changes in the eddy locations and shapes, throughout the entire field test exercise.[3]

With its ability to quickly process and communicate wide-area environmental data, the ODAAR II system has proven its tactical utility in other exercises as well. In the Critical Sea Test 7 exercise (February 1992), conducted in the Gulf of Alaska, the ODAAR II system collected temperature profiles during three P-3 aircraft flights over the test area. At the APL Operations Center, the data from each flight were edited and merged with other ocean profile data collected from surface ships in the area. Within about four hours after the P-3 aircraft landed, the resulting profile fields were sent via modem to the Naval Oceanography Command Detachment at Bangor, Washington, where Navy oceanographers inserted the data into the fleet broadcast. The data were received aboard a Navy vessel participating in the exercise and were used to predict system performance and to assess appropriate tactics in response. Figure 6, generated aboard the vessel, shows predicted range-dependent, one-way acoustic transmission loss. Panel A shows predictions using the standard Navy historical climatology profile database; the other panels show predictions using the profile fields generated from the three ODAAR II system P-3 flights. At ranges of interest in the exercise, calculations using the historical data overestimated one-way transmission loss by about 4 dB. The overestimation, verified by at-sea transmission loss measurements, corresponds to a very significant error of 8 dB for the two-way monostatic active acoustic problem. With improved predictions of system performance based upon the ODAAR II data, the Navy crewmen were able to select appropriate tactics and more successfully execute their assigned missions during the CST-7 test.

FUTURE PLANS

Since 1988, ODAAR II system has become APL's workhorse for airborne acquisition of ocean temperature data.

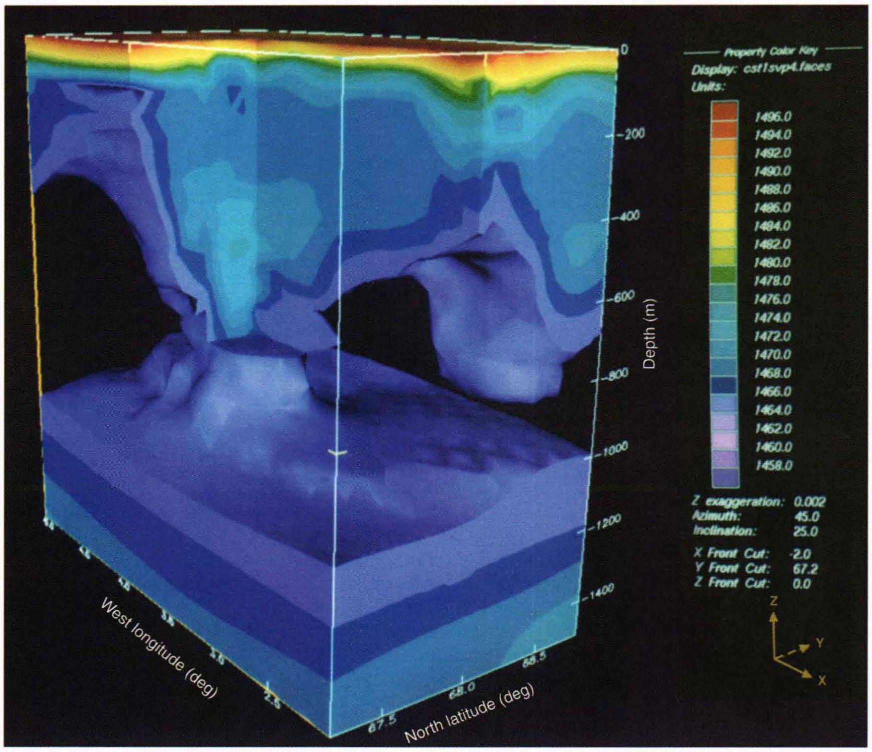

Figure 5. The three-dimensional field of two temperature eddies during Critical Sea Test 1 in the Norwegian Sea indicated a complex field of mesoscale oceanic turbulence. An intense warm-core eddy, situated in the center of the operation area and interacting with a second small eddy in the northeast corner of the area, caused further complications.

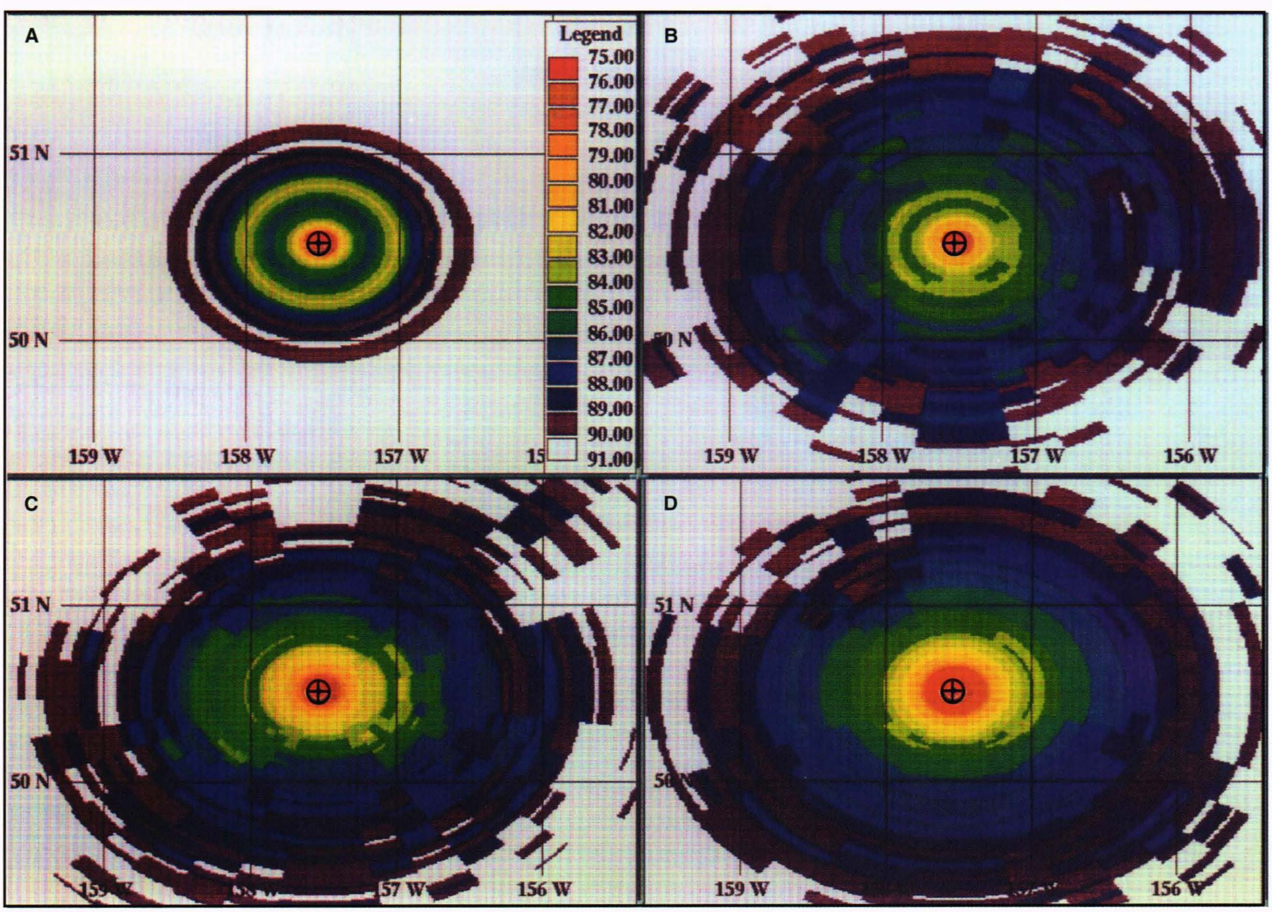

Figure 6. Range-dependent one-way acoustic transmission loss (legend in decibels relative to 1μPa at 1 m) from a fixed depth at the blue cross to a fixed depth at each point on the map. Panel **A** shows predictions using Navy standard range-dependent sound velocity profile data; panels **B**, **C**, and **D** show predictions using profile data from three different Ocean Data Acquisition and Analysis Recorder II flights during the Critical Sea Test 7 exercise. **A.** Historical database. **B.** 28 Jan P-3 AXBT Survey. **C.** 7 Feb P-3 AXBT Survey. **D.** 12 Feb P-3 AXBT Survey.

Other APL departments as well as other organizations utilize the ODAAR II system for their field exercises. Because of its ease of installation, its portability, and its ability to utilize many software packages, the outlook for the ODAAR II system is promising. Other system designs for performing measurements have used the ODAAR II system as a model in similar operating environments.

REFERENCES

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[3]Hanson, J. L., *Analysis of Environmental Conditions During Critical Sea Test (CST-1)*, JHU/APL STD-R-1839 (1989).

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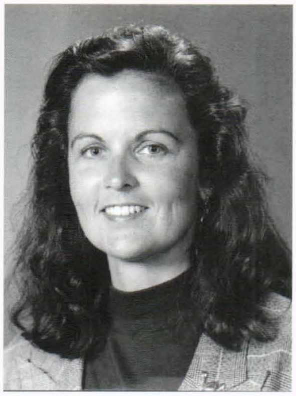
THE AUTHOR



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