Hydroacoustic Studies Using HydroCAM – Station-centric Integration of Models and Observations

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1. Summary of Activities

BBN's work from April through June of 2003 was focused on the testing and release of HydroCAM 4.0, development of HydroCAM 4.1 software, continued data collection and analysis, and initial preparations for the 2003 Seismic Research Review.

HydroCAM 4.0 was released and sent to DOE and AFTAC on June 9. This is the first release of new software on this contract. The code addresses the problems and issues that BBN and AFTAC had identified in the Fall of 2003. HydroCAM 4.1 is under development. A description of that development is shown in section 3.2.

We continued our efforts to collect ground truth hydroacoustic data from sub-sea earthquakes in the Indian Ocean. To date, we have collected over 130 events. These data are recorded on the International Monitoring System stations at Diego Garcia and Cape Leeuwin.

Finally, BBN submitted an abstract for the 2003 Seismic Research Review meeting. However, after discussions with Phil Harben at Lawrence Livermore Labs, we have decided to collaborate on one program-wide paper for the meeting.

2. Introduction

The current contract's period of performance began on September 4, 2002. BBN is now on its second increment of funding which is intended to cover BBN's work through fiscal year 2003.

This contract's research is intended to extend the capability of BBN's Hydroacoustic Coverage Assessment Model (HydroCAM). Specifically, the effort is designed to improve HydroCAM's database and modeling capabilities with respect to hydroacoustic blockage. In this phase BBN is undertaking three tasks. First, BBN is investigating blockage by analyzing events in the Indian Ocean that are recorded at the International Monitoring System (IMS) stations at Diego Garcia and Cape Leeuwin. Second, BBN will attempt to improve HydroCAM's blockage modeling capability by integrating high-resolution bathymetry into HydroCAM near IMS stations.

The third task in this contract is a support-oriented one. BBN is tasked to support the HydroCAM and modeling needs of DOE and AFTAC. Lawrence Livermore National Laboratory (LLNL) and AFTAC are the two primary users of HydroCAM. In the past BBN has also supported them by performing event-driven data analysis and modeling tasks. Therefore, BBN expends significant effort maintaining the HydroCAM software and addressing any issues/needs that our contacts at DOE and AFTAC might have.

What follows is a complete summary of BBN activities on these tasks from April 2003 – June 2003.

3. Software development/Support

3.1. HydroCAM 4.0

The bulk of the time/labor spent in the second quarter of 2003 was spent in final development, testing and release of HydroCAM Version 4.0. This version of HydroCAM, the first release of new software on this contract, was focused on addressing problems with the code and bringing the software up-to-date after a twelve-month hiatus. The issues that were addressed in the code have been documented in the past two technical reports. New technical challenges will be addressed in the forthcoming release of HydroCAM 4.1, which is described in section 3.2.

Due to the long hiatus in software maintenance, it was important to thoroughly test the software. Testing the entire application was prohibitively expensive, so the testing focused on answering two questions:

1. Was HydroCAM 4.0 compatible with recent releases of Matlab?
2. Did the new version address the problems that had been identified without breaking anything else?

A focused, iterative loop of regression testing was used to ensure that these questions were answered affirmatively. HydroCAM 4.0 was released on June 9, 2003.

3.2. HydroCAM 4.1

As stated in previous reports, HydroCAM 4.1 will include the ability to calculate paths using very high-resolution bathymetry near a receiving station while using lower resolution global bathymetry for the rest of the ocean. We hope that this will improve our ability to predict hydroacoustic blockage.

As of this writing, we have successfully modified HydroCAM's interface and path model code to handle two different bathymetric resolutions. We are testing this functionality using a 15-second local bathymetric database near Wake Island and a 2-minute resolution global database for the rest of the ocean basin. Unfortunately, a detailed analysis of these two databases shows that there is not a lot of bathymetry near Wake Island that will effect propagation at SOFAR channel depth. We will continue testing using this configuration to ensure that both databases are being accessed correctly and that the path results are indicative of those bathymetric databases.

We are still searching for high-resolution bathymetry near the Indian Ocean stations. However, the HydroCAM code was written in anticipation of these high-resolution databases, so their integration should be relatively simple.

4. Data Collection and Analysis

Data collection efforts continued in the second quarter. BBN monitors the Indian Ocean for earthquakes and other events of interest that might be recorded at the IMS stations at Diego Garcia and Cape Leeuwin. Figure 1 shows the recorded events collected Diego Garcia (H08*) from 2001-2003. Figure 2 shows the recorded events collected at Cape Leeuwin (H01*) from 2002-2003.

Figure 1 – Map of event events in the Hydroacoustic Reference Database recorded at HA08
-- Diego Garcia (111 events)

Figure 2 – Map of event events in the Hydroacoustic Reference Database recorded at HA01
 -- Cape Leeuwin (65 events)

This database is currently being tailored for submission to the DOE knowledge base. Event data are archived in CSS Version 3.0 format. For each event, the following files make up the event data:

- ?? A waveform file (.w extension) containing the time series array element data;
- ?? A waveform description file (.wfdisc extension) containing the information necessary for decoding and analyzing the waveform file. This information includes sample rate, start time of waveform (first sample time), number of samples, station identifiers, etc.;
- ?? A waveform tag file (.wftag extension) containing event ID and date information; and
- ?? An origin file (.origin extension) containing ground truth location, event magnitude, event time, event date, etc.

The waveform files and meta-data files are named according to their respective event ID. This event ID is created using the date of the event. Since there are some days when more than one event occurs and we are limited to an 8 digit ID, we have truncated the date string so that the last digit can be used as a daily event index. For example, if there were three events on January 22, 2002, the first event's ID would be 20201220; the second would be 20201221; and the third 20201222.

For the contemporary events, we have organized the data by year. In each year's directory, we have used the following organizational structure for the data:

5. 2003 Seismic Research Review

For the 2003 Seismic Research Review, BBN submitted the following abstract detailing our analysis efforts:

LONG-RANGE PROPAGATION IN THE INDIAN OCEAN: COMBINING MODELS WITH DATA TO UNDERSTAND BLOCKAGE AND REFLECTIONS

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Office of Defense Nuclear Nonproliferation

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ABSTRACT

The ocean acoustic environment (sound speed versus location, depth and time of year) is known to a degree of precision that allows models to accurately predict long-range ray paths, refraction, travel times, and attenuation (Farrell and LePage, 1996). Using these predictions,

estimates can be made of detection ranges, station coverage and localization areas of uncertainty, or AOU (Farrell et al., 1997). Two processes that also affect propagation and subsequent detection and AOU estimates are blockage and reflection from bathymetric features along the acoustic ray path. These processes are more complicated to model than long-range propagation in the sound channel axis. Last year we reported on an attempt to model the long-range reflection impulse response of the Indian Ocean and a subsequent matched-field technique for event localization (Upton and Pulli, 2002). Limited testing of this procedure has yielded promising results, but has also pointed out the need for further study of the blockage and reflection process.

To reconcile these issues, we have been compiling ground truth databases of hydroacoustic signals in the Indian Ocean as recorded by the new stations at Diego Garcia and Cape Leeuwin. Much like the seismic calibration efforts now under way, our studies seek to provide wide-area and azimuthal coverage of events recorded by these two stations. As of this writing, the database consists of recordings of 150 earthquakes and a limited amount of airgun data. For each event, the recordings span 1-3 hours of data in order to include most of the expected reflections.

We now have recordings from source locations that cover over 50% of the grid points used in the impulse response model calculations at Diego Garcia (Upton and Pulli, 2002). This data allows us to begin to validate the model with real data from across the ocean basin. Further, the acoustic power levels of the hydroacoustic arrivals can be scaled to account for event magnitudes and source-receiver distances. This provides for nearly 360-degrees of azimuthal blockage prediction coverage based on real data at the two Diego Garcia stations. Correction factors have been included to account for the fact that the earthquakes occur at depths that are below those included in the acoustic calculations.

In this paper, we report on the comparison of model predictions with the ground truth data for a number of specific events in the Indian Ocean. In many cases, model predictions of blockage and reflections agree with observed data. In other cases, predictions and models do not agree. These discrepancies have important implications when assessing detection coverage and AOU calculations in the Indian Ocean.

END ABSTRACT

In discussions with Phil Harben, we decided that there was a need to demonstrate a cohesive program between BBN and DOE. We agreed that though hydroacoustic funding is scant, our work is very focused on meeting AFTAC and DOE's goals. To that demonstrate that, Lawrence Livermore Labs and BBN, as its subcontractor, will present a collaborative paper and poster in Tucson at this year's seismic research review.

6. POA&M for Q3 2003

In the third quarter of this year, BBN plans to continue its research into improving blockage prediction via improved bathymetry and studies using real data. At the end of September,

Dr. Pulli and Mr. Upton will travel to Tucson, AZ to participate in the Seismic Research review meeting.

In this quarter, we intend to meet the following major milestones:

- ?? Delivery of our complete 2001 Hydroacoustic Ground Truth Event Database
- ?? Delivery of our complete 2002 Hydroacoustic Ground Truth Event Database
- ?? Delivery of our 2003 Hydroacoustic Ground Truth Event Database to date
- ?? Delivery of HydroCAM 4.1
- ?? Participation in the 2003 Seismic Research Review meeting in Tucson, AZ

6.1. Gantt Chart

6.2. Labor Budget

For the third quarter of 2003, we will continue at a modest rate of spending. We anticipate that Jay Pulli and Zach Upton will work at a rate of 30-40 hours/month for the quarter. Charging will in September as we prepare for and attend the Seismic Research Review meeting.

6.3. Risks

A research and support contract of this nature is relatively low risk. As stated in the introduction, our primary responsibilities are to support DOE and AFTAC with research and software support.

The only significant risks that could effect BBN making all of it's proposed improvements to HydroCAM are related to acquiring local high-resolution bathymetry near the current and proposed IMS stations. We anticipate that we will be able to find these data, but it may require the release of a classified version of HydroCAM.